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13 Productivity Growth in Manufacturing during Early Industrialization: Evidence from the American Northeast, 1820–1860

Kenneth L. Sokoloff

13.1 Introduction

It has long been recognized that industrialization got under way in the United States early in the nineteenth century and was largely concentrated in the Northeast throughout the antebellum period. The dramatic sectoral reallocation of resources that accompanied this process is generally acknowledged to have yielded a significant gain in measured per capita income, if only because resources in that region were more productive in industries other than agriculture. The extent of productivity growth within sectors, however, remains unclear. This gap in our knowledge has been a serious obstacle to improving our understanding of this initial phase of industrialization, because the record of productivity is so closely related to issues of the sources, location, timing, and nature of this episode in American economic growth.

Evidence on the progress realized in manufacturing, in particular, would have a direct bearing on whether the surge of rapid industrial

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expansion in the Northeast was driven by dynamic manufacturing industries that were generating sustained increases in productivity and income or by a declining agricultural sector that was finding it increasingly difficult to compete with producers outside the region. Moreover, industry- specific estimates would help determine to what degree early productivity growth in manufacturing was linked to capital- deepening or capital-augmenting innovations. Some scholars have suggested that these factors were virtual prerequisites for major gains in productivity, while others have emphasized that changes in the organization of labor, increases in the intensity of work, and other alterations in production processes that were not dependent on additional capital equipment per unit of labor may have been important sources of measured advances (Landes 1969, 1985; Marglin 1974; David 1975; Chandler 1977; Sokoloff 1984b; Lazonick and Brush 1985).

Despite the clear significance of the issues involved, there have been few studies of productivity growth during early United States industrialization due to the relative inaccessibility of evidence.[1] Recently collected samples of firm data from the schedules of the 1820 Census of Manufactures and the *McLane Report* of 1832 provide valuable new sources of information, however (Sokoloff 1982). Employing these bodies of evidence in conjunction with the Bateman-Weiss samples of firms from the schedules of both the 1850 and the 1860 Census of Manufactures, and the aggregate data from those censuses, this paper seeks to establish the record of productivity growth in northeastern manufacturing during this critical period of industrial development.

These sources are not without flaws, but the richness of the information they contain makes them together an unequaled collection of material for research on the subject. All of them provide reports of the value of outputs produced and the quantity or value of inputs utilized, and thus indexes of productivity can be estimated for many industries in each of the 4 years. Perhaps the primary concern involving the quality of the data is that the firms included in the four cross-sectional samples from the manufacturing survey and censuses may not be representative of the population of northeastern manufacturing firms during the respective years.[2] Problems of the representativeness of data are always a serious matter and require special care in conducting the analysis. Nevertheless, as will be discussed below, the sample selection biases that afflict these bodies of evidence seem unlikely to be responsible for the qualitative results uncovered.

This paper reports estimates of labor and total factor productivity for 13 manufacturing industries in the Northeast over the period from 1820 to 1860. It finds that although the highly mechanized and capital-intensive industries, such as cotton and wool textiles, realized somewhat more rapid progress than the others did, even the latter managed major advances. The evidence appears to support the conclusion that the manufacturing sector in the Northeast was quite dynamic during this stage of industrialization, and that much of its early productivity growth can be explained by changes in production processes that did not require mechanization or substantial increases in capital intensity. This suggests, as has been argued by a number of recent studies building on an old tradition, that developments such as increases in the division and intensity of labor within firms and other relatively subtle alterations in technique, perhaps stimulated by the expansion of markets, may have played important roles in accounting for the progress achieved.

Estimates of labor productivity over the period are presented in section 13.2 of the paper. The procedures employed in constructing them are discussed in some detail, and although they were consciously designed to yield conservative estimates of the increase in productivity, weighted averages indicate rates of labor productivity growth that are quite high by nineteenth- or twentieth-century standards. There is evidence of an acceleration in the pace of advance, particularly in the less mechanized and capital-intensive industries. Estimates of total factor productivity are presented in section 13.3. They reveal that if one treats firm valuations of their capital investments as relatively accurate assessments of the capital input, as I contend that one should, the data imply that most manufacturing industries realized large gains in total factor productivity over the period. As all classes of industries appear to have manifested similar rates of progress, doubts about the primacy of capital deepening or capital intensity in generating productivity growth are reinforced. Moreover, the estimated advances are of such a magnitude that they appear to account, together with increases in the ratio of raw materials to labor, for nearly all of the rise in labor productivity. Some general remarks on what these findings imply about the early stages of industrialization in the United States are offered in section 13.4.

13.2 Estimates of Labor Productivity

There are at least several reasons why the record of labor productivity deserves separate treatment from that of total factor productivity. Perhaps the major one is that movements in labor productivity convey information about the evolution of production methods that is not generally contained in the more comprehensive measure. Since several of the most important issues relating to the development of manufacturing technology during early industrialization concern the direction and extent of changes in factor proportions, it would seem desirable to examine both labor and total factor productivity. The availability of the two series is also useful in that investigation of apparent inconsistencies between them can help to identify problems with the data or of interpretation. Finally, it might be argued that, because movements in output per unit of labor are more closely related to those in per capita income, establishing the record of labor productivity, even in only this single sector of the economy, would by itself directly contribute to our understanding of economic growth during this critical period. The accounting exercise of decomposing the responsibility for increases in labor productivity between changes in factor proportions and total factor productivity, for example, may yield results suggestive of what similar calculations for per capita income would indicate.

Two measures of labor productivity are employed here, value added per equivalent worker and gross output per equivalent worker. Estimates expressed in current dollars are presented in tables 13.1 and 13.2, respectively, for 13 industries at the years 1820, 1832, 1850, and 1860. The industries examined were selected so as to cover both the major ones of the period and a broad cross-section of the manufacturing sector, subject to the limitations imposed by the need for each industry to be reasonably well represented in the samples of manufacturing firm data and a desire to maintain conventional industrial classifications.[3] Some industries do not have estimates of productivity reported for certain years, because of an inadequate number of observations, but the threshold for inclusion was set to keep the number of omissions low.

Three sets of estimates, A, B, and C, are reported for each industry. They are computed over different subsets of firms, with the variation in composition attributable to the progressive application of increasingly stringent standards for separating establishments likely to be operating part-time from those in full-time production. Part-time enterprises should be excluded from the subsamples over which the estimates are prepared, because the measured productivity levels of such firms are biased downward due to the general practice of reporting the average labor input over the period in operation, rather than over the entire year.[4] Since these firms generally failed to identify themselves explicitly, several methods of ordering the establishments by their probability of being part-time operators, so that selected proportions could be dropped from the subsamples over which productivity was estimated, were applied to the problem and yielded roughly similar results. The method and procedures underlying the construction of the three sets of subsamples employed in this paper are explained in the note to table 13.1. The logic behind reporting three sets of estimates is to provide evidence on the sensitivity of the results to the assumptions made about the prevalence of part-time operators in different years.[5] Although intended to yield somewhat conservative estimates of the rates of productivity growth over time, the B set represents the "best-guess'' figures and will be the basis, unless otherwise indicated, for the results discussed below.

The major implication of the estimates reported in tables 13.1 and 13.2 is that nominal labor productivity, whether evaluated in terms of value added or gross output, increased substantially between 1820 and 1860. All of the 13 selected industries registered significant advances in product per equivalent worker, by each of the measures. Ten of the 13 managed a greater than 50% increase in gross output per unit of labor (GQLP) between 1820 and 1860, and eight did by the value-added gauge of labor productivity (VLP).[6] The unweighted averages of the growth over the period in the value-added and gross-output measures of labor productivity are 76% and 98%, respectively, whereas the weighted average increases are only slightly different, 68% and 99%.[7] This record of advance might not seem remarkable taken by itself, but, considered together with the evidence of sharp decreases in output prices (see table 13.3), the implied gains in real labor productivity are dramatic indeed.

It is fortunate that the principal qualitative finding seems to be insensitive to reasonable variation in the proportions of firms truncated from the samples to deal with the problem of the inclusion of part-time firms in the data. The A estimates imply much more substantial productivity growth than the ''best-guess'' B figures, and the C set suggests somewhat less progress, but all three provide evidence of an era of major increases in manufacturing productivity. This general robustness can be demonstrated by computing the implied growth in labor productivity that results from an especially extreme adjustment for the problem.[8] If, for example, one accepts the C estimates for 1820, thus assuming that an unrealistically high proportion of firms in the earlier year operated part-time and that an extraordinary decline in their prevalence occurred, weighted averages of the estimated growth in labor productivity over the 13 industries fall from 68 to 51 for value-added labor productivity and from 99% to 85% for gross-output labor productivity. These are not trivial alterations to the quantitative results, but the picture of labor productivity growth in manufacturing that emerges from the data remains essentially unchanged. Such sensitivity analysis suggests that although the initial truncation of establishments for likely part-time operations has major effects on estimated productivity levels and growth, the influence of successive truncations declines, to the point that no plausible revision of the proportion of firms assumed to be operating part time in 1820 could reverse the basic finding of major advances over the period.

There are several troubling features of the estimates that should be considered in interpreting them, but they do not seem to warrant a general rejection of the reliability of the figures. Perhaps foremost among

Table 13.1 Nominal Value Added per Equivalent Worker in Selected Manufacturing Industries, 1820–60

			1850		1860	
Industry	1820	1832	Firms	Agg.	Firms	Agg.
Boots/shoes						
A	$276.0 (22)	—	$283.5 (254)		$430.7 (170)	
B	323.3 (17)	—	290.1 (247)	$305.4 (8,110)	434.2 (161)	$421.7 (7,326)
C	350.0 (15)	—	306.7 (207)		454.7 (133)	
		—				
Coaches/ harnesses						
A	473.7 (33)	$330.6 (36)	388.4 (96)		691.4 (122)	
B	490.5 (31)	359.6 (35)	461.5 (88)	435.4 (2,635)	697.5 (118)	600.1 (5,057)
C	502.5 (28)	368.9 (32)	464.2 (77)		645.8 (98)	
Cotton textiles						
A	352.8 (64)	504.3 (76)	322.3 (24)		494.9 (23)	
B	391.0 (45)	505.5 (75)	326.5 (23)	460.0 (856)	494.9 (23)	772.7 (840)
C	457.8 (25)	513.6 (69)	390.2 (18)		618.6 (20)	
Furntiure/ woodwork						
A	395.0 (25)	359.9 (26)	380.6 (48)		664.7 (42)	
B	434.2 (21)	364.6 (25)	421.7 (46)	517.3 (2,299)	695.8 (38)	674.5 (1,804)
C	496.5 (15)	384.3 (22)	426.7 (39)		722.2 (31)	
Glass						
A	488.3 (3)	767.2 (6)	—		—	
B	488.3 (3)	767.2 (6)	—	593.5 (77)	—	682.1 (79)
C	519.6 (2)	753.8 (5)	—		—	
Hats						
A	417.6 (27)	541.3 (13)	591.1 (17)		788.9 (13)	
B	485.5 (22)	541.3 (13)	595.7 (16)	633.3 (814)	788.9 (13)	808.2 (281)
C	413.8 (19)	558.5 (10)	631.9 (12)		776.6 (11)	

Iron						
A	350.4 (32)	—	328.9 (36)		564.1 (23)	
B	585.4 (21)	—	443.8 (33)	470.5 (1,494)	613.6 (21)	648.1 (1,288)
C	593.6 (15)	—	479.3 (28)		702.5 (15)	
Liquors						
A	530.0 (177)	—	635.8 (7)		1262.6 (13)	
B	640.7 (132)	—	699.7 (6)	1052.5 (633)	1339.7 (12)	1,469.4 (922)
C	667.1 (107)	—	793.8 (4)		1514.3 (10)	
Flour/ grist mills						
A	563.0 (43)	—	530.0 (109)		846.1 (105)	
B	651.6 (32)	—	549.3 (104)	689.7 (5,128)	900.4 (97)	906.4 (4,964)
C	735.9 (24)	—	672.7 (64)		1051.3 (64)	
Paper						
A	426.0 (23)	582.6 (27)	982.0 (20)		706.4 (20)	
B	432.1 (22)	582.6 (27)	982.0 (20)	913.2 (361)	720.3 (19)	1,128.9 (472)
C	445.7 (20)	618.4 (23)	909.8 (18)		817.0 (14)	
Tanning						
A	331.8 (120)	582.2 (45)	511.7 (98)		803.3 (77)	
B	419.0 (76)	588.0 (43)	531.0 (92)	761.3 (3,256)	825.7 (69)	1033.5 (2,670)
C	499.9 (47)	543.2 (33)	562.1 (65)		896.0 (53)	
Tobacco						
A	305.6 (8)	—	312.8 (15)		733.7 (12)	
B	319.0 (7)	—	312.8 (15)	240.1 (628)	733.7 (12)	667.1 (918)
C	337.1 (5)	—	360.7 (12)		744.8 (11)	
Wool textiles						
A	373.4 (53)	650.9 (59)	730.7 (42)		871.5 (23)	
B	466.4 (35)	651.7 (58)	739.2 (40)	563.2 (1,375)	871.5 (23)	849.7 (1,041)
C	571.9 (19)	652.0 (48)	738.8 (35)		840.7 (20)	

(continued)

Table 13.1 (continued)

Notes and sources: The firm-level estimates were computed from the samples of northeastern manufacturing firm data drawn from the schedules of the 1820, 1850, and 1860 Federal Censuses of Manufactures and the *McLane Report* (United States House of Representatives 1832). The aggregate estimates were computed from the industry-wide information reported by state in United States Census Office (1858, 1865). The figures reported for 1832, 1850, and 1860 are based on information that probably pertains primarily to the operations of firms in 1831, 1849, and 1859, respectively. The estimates were calculated as the ratio of the industry value added (or the value of output minus the cost of the raw materials) to the total number of equivalent adult male workers in the industry. The number of equivalent workers was computed according to the formulation: $TE = M + 0.5\ (F + B) + E$, where TE is the number of equivalent adult male workers, M is the number of adult male employees, F and B are the numbers of female and boy employees, respectively, and E is set equal to one per firm as the measure of the entrepreneurial input. In 1850 and 1860, firms generally did not enumerate adult males and boys separately. Accordingly, I decomposed the reported numbers of male employees in those years into adults and boys by assuming that boys accounted for the same proportions, by industry, of male employees as they had in 1820. In those industries in which boys had accounted for more than 33% of male employees in 1820, I assumed further that the shares had been reduced to 33% by 1850 and 1860.

The estimates based on firm data were computed over subsamples from the various years that have observations deleted from them in order to control for the effects of establishments that operated only part-time and other outliers. The method adopted to identify potential part-time firms utilized two distributions of firms for each year by total factor productivity, one computed with gross output as the measure of output (TFP) and the other treating value added as that measure (NFP). The guiding principle was that the lower the total factor productivity of a firm in a given year, the more likely the firm was a part-time operation and should be truncated from the subsample of establishments over which the productivity estimates were computed.

Three sets of productivity estimates have been prepared from three corresponding sets of firm subsamples. The sets of subsamples vary in composition by the successive truncations made primarily to exclude part-time firms from the calculations. The A set of estimates were computed over subsamples of firms with no adjustments for part-time operators. The establishments dropped from the samples of firms that reported all of the necessary information and did not explicitly identify themselves as part-time enterprises to obtain the A subsamples included those with negative value added, a few other large outliers, and those who placed in the top 3% of enterprises in the respective years by *both* measures of total factor productivity. These criteria led to 4% being truncated from the 1820 sample, 3% from that in 1832, 5% in 1850, and 4% from the sample in 1860.

Set B is based on more severe truncations of the left tails of the distributions of firms by total factor productivity. For the 1820 subsample, establishments that ranked in the lowest 30% by both measures of total factor productivity were dropped from subsample A to get B. The corresponding percentages were 5% in 1832, 10% in 1850, and 10% in 1860. The smaller proportions truncated from the samples of later years reflect the presumed decline over time in the fraction of firms operating part time, as well as the desire to bias the estimated productivity growth rate downward. In order to achieve this latter goal, one would seek to overestimate the proportion of establishments in 1820 that operated parttime, and underestimate the proportion in 1860. A particularly small proportion was dropped from the 1832 sample because enumerators from the *McLane Report* indicated that nearly all of the establishments covered from the states considered here were operating throughout the year. The total proportions of firms excluded from the entire samples to obtain set B were 29% in 1820, 5% in 1832, 9% in 1850, and 10% in 1860.

For set C, even larger fractions of the firms in the samples were truncated. Firms that were in the bottom 40% of the 1820 sample, by either measure of total factor productivity, were left out of the subsample that was the basis for the C estimates of that year. The corresponding threshold points for truncations from the C subsamples for the other years are 10% for 1832, 20% for 1850, and 20% for 1860. In addition, those establishments that were in the top 3% of firms by *either* measure of total factor productivity in their respective years, and had not already been dropped from the A and B subsamples, were also truncated to produce the C subsamples. These criteria led to 48% being truncated from the 1820 sample, 17% from that of 1832, 28% from that of 1850, and 29% from that of 1860.

The numbers appearing within parentheses signify the number of observations on which the respective estimate is based. No estimates are reported for years in which there were less than three observations in the A subsample. The only industry whose estimates are based on such a limited number of firms is glass, but in this case the several firms appearing in the 1820 sample account for a substantial proportion of the regional output. No estimates are reported for the boots/shoes industry in 1832, because a large proportion of the firms in the sample from that year were putting-out establishments.

Table 13.2 Nominal Gross Output per Equivalent Worker in Selected Manufacturing Industries, 1820–60

			1850		1860	
Industry	1820	1832	Firms	Agg.	Firms	Agg.
Boots/ shoes						
A	$517.6 (22)	—	$556.8 (254)		$904.2 (170)	
B	581.2 (17)	—	564.1 (247)	$563.0 (8,110)	910.1 (161)	$803.6 (7,326)
C	594.6 (15)	—	593.7 (207)		940.7 (133)	
Coaches/ harnesses						
A	873.8 (33)	$574.4 (36)	765.9 (96)		1,175.8 (122)	
B	904.6 (31)	614.0 (35)	902.4 (88)	763.4 (2,635)	1,184.2 (118)	987.5 (5,057)
C	928.1 (28)	622.1 (32)	932.3 (77)		1,136.4 (98)	
Cotton textiles						
A	668.4 (64)	927.7 (76)	1,045.0 (24)		1,053.2 (23)	
B	721.6 (45)	928.6 (75)	1,056.6 (23)	1,073.7 (856)	1,053.2 (23)	1,497.0 (840)
C	796.7 (25)	933.7 (69)	1,046.3 (18)		1,574.0 (20)	
Furniture/ woodwork						
A	629.2 (25)	677.3 (26)	724.4 (48)		1,023.8 (42)	
B	665.1 (21)	685.8 (25)	742.3 (46)	830.9 (2,299)	1,064.0 (38)	1,027.4 (1,804)
C	760.5 (15)	721.0 (22)	762.5 (39)		1,096.5 (31)	
Glass						
A	676.0 (3)	1,300.4 (6)	—		—	
B	676.0 (3)	1,300.4 (6)	—	879.4 (77)	—	1,030.5 (79)
C	727.2 (2)	1,299.6 (5)	—		—	
Hats						
A	796.2 (27)	1,027.5 (13)	1,329.0 (17)		1,866.6 (13)	
B	899.3 (22)	1,027.5 (13)	1,338.7 (16)	1,278.2 (814)	1,866.6 (13)	1,605.3 (281)
C	816.7 (19)	1,061.2 (10)	1,377.2 (12)		1,868.1 (11)	

Iron						
A	762.2 (32)	—	745.2 (36)		1,457.1 (13)	
B	1,251.4 (21)	—	872.2 (33)	1,030.5 (1,494)	1,588.2 (21)	1,422.2 (1,288)
C	1,347.1 (15)	—	881.7 (28)		1,788.9 (15)	
Liquors						
A	1,554.5 (177)	—	1,454.0 (7)		4,253.9 (13)	
B	1,882.1 (132)	—	1,606.0 (6)	3,341.0 (633)	4,508.9 (12)	4,252.1 (922)
C	1,954.0 (107)	—	1,806.6 (4)		4,898.0 (10)	
Flour/ grist mills						
A	2,923.3 (43)	—	3,895.9 (109)		5,756.9 (105)	
B	3,419.8 (32)	—	4,037.1 (104)	4,900.8 (5,128)	6,117.0 (97)	6,154.7 (4,964)
C	3,560.7 (24)	—	4,794.6 (64)		6,599.5 (64)	
Paper						
A	667.9 (23)	1,418.2 (27)	2,153.1 (20)		1,619.1 (20)	
B	673.3 (22)	1,418.2 (27)	2,153.1 (20)	2,065.8 (361)	1,648.4 (19)	2,286.9 (472)
C	690.2 (20)	1,477.8 (23)	1,953.5 (18)		1,874.9 (14)	
Tanning						
A	853.5 (120)	1,535.7 (45)	1,412.3 (98)		2,750.5 (77)	
B	1,037.0 (76)	1,550.2 (43)	1,455.5 (92)	1,909.3 (3,256)	2,825.1 (69)	3,573.5 (2,670)
C	1,218.7 (47)	1,450.2 (33)	1,581.8 (65)		3,043.0 (53)	
Tobacco						
A	669.0 (8)	—	727.2 (15)		1,781.4 (12)	
B	682.6 (7)	—	727.2 (15)	715.0 (628)	1,781.4 (12)	1,120.3 (918)
C	703.6 (5)	—	838.2 (12)		1,809.8 (11)	
Wool textiles						
A	677.3 (53)	1,662.8 (59)	1,756.1 (42)		2,086.6(23)	
B	821.3 (35)	1,664.8 (58)	1,776.7 (40)	1,530.8 (1,375)	2,086.6 (23)	2,143.4 (1,041)
C	906.1 (19)	1,681.3 (48)	1,784.6 (35)		2,120.5 (20)	

Notes and sources: See the note to table 13.1 The estimates were calculated as the ratio of the value of gross output to the total number of equivalent adult male workers.

these is the irregular pattern of advance that a number of the industries exhibit. Nominal labor productivity does not always increase continuously across the subperiods, and even in those industries where it does, the apparent rates of growth fluctuate widely over time. Some variability should be expected, however, since the nominal estimates are not adjusted for the substantial and erratic changes in the prices of many commodities, including outputs and raw materials, that occurred during the period. Moreover, a great deal of random variation in the estimates of productivity would also be generated by the limited numbers of observations.[9] This latter problem is quite serious for estimating the growth in productivity over individual subperiods, but would be expected to decline in significance for the study of long-term changes, because the proportion of the variation in estimated productivity due to substantive or actual movements in productivity should increase with the length of the period under examination.

Also puzzling are the sometimes large discrepancies between the estimates computed from the firm-level information and those from aggregate data in 1850 and 1860. The industry estimates drawn from these two sources are frequently similar but diverge substantially in some cases, particularly in 1850. One might have expected the figures based on aggregate data to be generally lower, because of the presumed inclusion of part- time establishments in those totals. However, where there are large disparities, it is typically these estimates which exceed those from the firm data. This might seem to imply that the prevalence, or the production, of part-time operators was rather modest in those years. In addition, the pattern is consistent with the view that the design of the 1850 and 1860 samples served to bias the productivity estimates for those years significantly downward.[10] Accordingly, one might suppose that the aggregate- based estimates would be more representative of the actual productivity levels in the respective industries than those computed from firm data. Whatever the reasons for the discrepancies, the close correspondence between the estimates in 1860 means that the qualitative results on productivity growth over the entire period are not sensitive to the choice between the firm- and aggregate-based figures for that year.

Although the series of current-dollar estimates are useful in roughly gauging the long- term trends in labor productivity, they are not nearly as informative as would be series expressed in constant dollars. Accordingly, a variety of price indexes have been assembled to construct estimates of real productivity from current-dollar values, and are reported in table 13.3. Measures of the changes in the prices of the outputs and of the raw materials for each of the 13 industries would of course be preferred for the calculation of the constant-dollar estimates. This goal could not be achieved, but a wide-ranging survey of available price

Table 13.3 Price Indexes, 1820–60

Indexes	1820	1832	1850	1860
General output price indexes				
Consumer price index	156	119	93	100
Wholesale price index	114	99	88	102
Industry price indexes:				
Boots/shoes				
Q	166	155	111	100
RM	113	124	88	113
K	140	135	103	105
Coaches/harnesses				
Q	178	141	95	100
RM	137	119	106	102
K	150	128	109	102
Cotton textiles				
Q	179	115	78	98
RM	155	88	69	110
K	160	130	112	103
Furniture/woodwork				
Q	200	149	111	100
RM	111	102	121	98
K	151	126	115	100
Glass				
Q	190	109	81	100
RM	114	99	88	102
K	149	115	99	101
Hats				
Q	166	155	111	105
RM	114	99	88	102
K	142	127	105	103
Iron				
Q	171	145	113	100
RM	128	111	99	102
K	159	137	118	103
Liquors				
Q	96	—	91	104
RM	57	—	83	96
K	124	—	106	102
Flour/grist mills				
Q	91	—	87	98
RM	57	—	83	96
K	142	—	115	102
Paper				
Q	319	244	125	104
RM	179	115	78	98
K	164	136	111	101
Tanning				
Q	90	99	70	113
RM	65	72	51	113
K	104	101	81	108

(*continued*)

Table 13.3 (continued)

Indexes	1820	1832	1850	1860
Tobacco				
Q	138	69	100	127
RM	138	69	100	127
K	140	81	103	122
Wool textiles				
Q	161	138	133	102
RM	95	74	80	104
K	144	124	114	102
Capital component price indexes				
Machinery	183	159	138	107
Structures	136	118	107	100

Notes and sources: Corresponding to the productivity estimates, the price indexes reported for 1832, 1850, and 1860 actually refer to the price levels in 1831, 1849, and 1859. The price indexes, however, are expressed relative to an 1860 standard of 100. The industry-specific capital price indexes were constructed as a weighted average of the price indexes for "structures" and "machinery," as well as of the industry-specific indexes for output and raw materials. The weights were obtained from firm-level data on the composition of the total capital investment contained in the *McLane Report* or, when there were insufficient observations from 1832, from aggregate information contained in the report of the 1890 Census of Manufactures. See Sokoloff (1984a) and United States Census Office (1895). The "structures" and "machinery" indexes were weighted by the shares of the total capital investment that they accounted for in the respective industries. The remaining proportion of the capital investment was assumed to consist entirely of inventories, which were divided equally between output and raw materials. Hence, the latter two indexes received half of the weight for inventories in constructing each industry's capital price series.

General Output: Consumer and wholesale price indexes (CPI and WPI henceforth) from United States Bureau of the Census (1975, E-135 and E-52).

Boots/shoes: Output price index for "shoes" from Brady (1966). Interpolation was based on the WPI (as were all interpolations of price indexes drawn from Brady). The index for raw materials was constructed from the 1850 and 1860 firm data, and from United States Bureau of the Census (1975, E-55).

Coaches/harnesses: Output index constructed from that for "carriages, buggies, and wagons" in Brady (1966) and from the 1850 and 1860 firm data. The index for raw materials also consists of a segment obtained from these data, spliced into the WPI.

Cotton textiles: Both the output and raw materials indexes are from United States Bureau of the Census (1975, E-128, E-126).

Furniture/woodwork: The output index is that for "furniture" from Brady (1966), and the raw materials index is from United States Bureau of the Census (1975, E-59) and the 1850 and 1860 firm data.

Glass: The output index is that for "window glass" from Brady (1964). The WPI serves as the index for raw materials.

Hats: The output index is that for "men's hats" from Brady (1964). The WPI serves as the index for raw materials.

Iron: The output index was constructed from several price series contained in Cole (1938). The raw materials index is the WPI, with a segment estimated from the 1850 and 1860 firm data spliced in.

Liquors: Both indexes are from United States Bureau of the Census (1975, E-62, E-123).

Mills: Both indexes are from United States Bureau of the Census (1975, E-124, E-123).

Paper: The output price index is that for "writing paper" from Brady (1966). The index for raw materials is from United States Bureau of the Census (1975, E-128).

Table 13.3 (continued)

Tanning: The same price index serves here as the basis for both the output and raw materials indexes, United States Bureau of the Census (1975, E-55). The two indexes differ slightly, however, in that the segments between 1850 and 1860 were obtained from the firm data for those years.
Tobacco: A price index for "tobacco" was constructed from several series appearing in Cole (1938). This index was utilized for both outputs and raw materials.
Wool textiles: The output index is for "woolen worsted goods" from Brady (1966). The index for raw materials was constructed from information in Cole (1938).
Capital component price indexes: The indexes for structures and machinery are for "factories, office buildings" and "machine-shop products," respectively. Both are drawn from Brady (1966).

series for the period yielded industry-specific indexes for the outputs of all 13 industries, and for the raw materials of nine.[11] The Warren and Pearson wholesale price index (henceforth referred to as the WPI) was employed as the index for the prices of raw materials in the remaining four industries. In cases where there was reason to doubt the representativeness of an index, and where the procedure was feasible, the change in price between 1850 and 1860 was estimated from the information in the samples from those years, and spliced into the original series.[12]

In addition to these price indexes for outputs and raw materials, table 13.3 also presents industry-specific estimates of the price of capital. These indexes of the price of capital will be utilized in the calculations of total factor productivity treated below, and were computed as weighted averages of the indexes for structures, machinery, outputs, and raw materials. The weights vary across industries, and were obtained from industry-specific proportions of capital invested in structures and land, machinery and tools, and inventories. Inventories were assumed to have been composed of equal amounts of outputs and of raw materials.

Perhaps the most striking general pattern that emerges from an examination of table 13.3 is that the prices of outputs declined significantly relative to those of raw materials and capital between 1820 and 1860. In all of the 13 industries but tobacco, where the same series was adopted for both outputs and raw materials, the index for output prices fell relative to that for raw materials; the index declined relative to that for capital in 10 of the 13. Since it is also clear that real wages rose substantially over the period, one can infer, by duality, that total factor productivity must have increased (Sokoloff 1983).

Indexes of real value added and real gross output per equivalent worker have been constructed for the 13 industries by applying the output price series to the conversion of the current-dollar labor productivity estimates to units of constant dollars. These indexes, which are presented in tables 13.4 and 13.5, respectively, indicate that all of

Table 13.4 **Index of Real Value Added per Equivalent Worker in Selected Manufacturing Industries, 1820–60**

Industry	1820	1832	1850 Firms	1850 Agg.	1860 Firms	1860 Agg.
Boots/shoes						
A	100	—	154	165	259	254
B	100	—	135	142	224	217
C	100	—	131	130	216	200
Coaches/harnesses						
A	100	88	154	172	260	225
B	100	93	176	166	253	218
C	100	93	173	162	229	213
Cotton textiles						
A	100	222	210	299	256	400
B	100	201	192	270	231	361
C	100	175	196	231	247	308
Furniture/woodwork	100					
A	100	122	174	236	337	341
B	100	113	175	215	321	311
C		104	155	188	291	272
Glass						
A	100	274	—	285	—	265
B	100	274	—	285	—	265
C	100	253	—	268	—	249
Hats						
A	100	139	212	227	299	306
B	100	119	184	195	257	263
C	100	145	228	229	297	309
Iron						
A	100	—	142	203	277	318
B	100	—	115	122	180	190
C	100	—	122	120	203	188
Liquors						
A	100	—	127	209	220	256
B	100	—	115	173	193	212
C	100	—	126	166	210	203
Flour/grist mills						
A	100	—	98	128	140	149
B	100	—	88	111	128	129
C	100	—	96	98	133	114
Paper						
A	100	179	588	547	509	813
B	100	176	580	539	511	801
C	100	181	521	523	562	777
Tanning						
A	100	160	198	295	193	248
B	100	128	163	234	157	196
C	100	99	145	196	143	165

Table 13.4 (continued)

Industry	1820	1832	1850 Firms	1850 Agg.	1860 Firms	1860 Agg.
Tobacco						
A	100	—	141	108	261	237
B	100	—	135	104	250	227
C	100	—	148	98	240	215
Wool textiles						
A	100	203	237	183	368	359
B	100	163	192	146	295	288
C	100	147	173	132	256	259
Average						
Weighted (B)	100	[159]	[168]	192	[230]	264
Unweighted (B)	100	[158]	[187]	208	[250]	283

Notes and sources: See the notes to tables 13.1 and 13.3. The estimates of value added per equivalent worker presented in table 13.1 were converted to constant dollars by employing the price indexes reported in table 13.3, and then normalized relative to a base of 100 representing the respective industry's level in 1820. The weights employed in computing the weighted averages are equivalent to the industry shares of the value added produced in the northeastern states in 1850, and were calculated from information contained in United States Census Office (1858). The weights were normalized so that their sum was equal to one whenever there were missing values. Averages based on fewer than 13 industries (affected by missing values) are reported within brackets.

the industries realized major advances in real labor productivity, by either measure, between 1820 and 1860. Weighted averages of the records of the industries yield, taking the estimates based on aggregate data as the standard for 1860, increases of 164% in value added per equivalent worker and 187% by the alternative gauge. Only very few failed to register gains of 100%. It is interesting to note that in most industries the progress in gross output per equivalent worker significantly exceeded that in value added per equivalent worker. This feature of the results presumably reflects a rapid growth in the amounts of raw materials processed per unit of labor during the period.

As for the reliability of these labor productivity estimates, it must be admitted that even after their conversion to constant dollars, there remain many anomalies where the productivity growth indicated for an industry over a subperiod is either implausibly high or low. These cases generally involve rather short spans of time, but not always. Many of them might be attributed to noise in the point estimates generated by a paucity of observations, inappropriate or inaccurate price indexes, rapid changes in the factor proportions utilized, varying degrees or types of sample selection bias over the years included, or cyclical effects, but their number is nevertheless unsettling. It is, however, reassuring to note that the frequency and magnitude of such

Table 13.5 Index of Real Gross Output per Equivalent Worker in Selected Manufacturing Industries, 1820–60

			1850		1860	
Industry	1820	1832	Firms	Agg.	Firms	Agg.
Boots/shoes						
A	100	—	161	163	290	258
B	100	—	145	145	260	230
C	100	—	149	142	263	224
Coaches/harnesses						
A	100	83	164	164	240	201
B	100	86	188	154	233	194
C	100	85	189	155	218	190
Cotton textiles						
A	100	216	359	369	288	409
B	100	200	336	341	267	379
C	100	182	301	309	361	343
Furniture/Woodwork						
A	100	144	207	238	325	327
B	100	138	201	225	320	309
C	100	127	181	197	288	270
Glass						
A	100	335	—	305	—	290
B	100	335	—	305	—	290
C	100	312	—	284	—	269
Hats						
A	100	138	250	240	371	319
B	100	122	223	213	328	282
C	100	139	252	234	362	311
Iron						
A	100	—	148	205	329	321
B	100	—	105	125	218	195
C	100	—	99	116	228	181
Liquors						
A	100	—	99	227	253	252
B	100	—	90	187	221	209
C	100	—	98	180	231	201
Flour/grist mills						
A	100	—	139	175	183	196
B	100	—	123	150	166	167
C	100	—	141	144	172	160
Paper						
A	100	278	823	789	744	1050
B	100	275	816	783	751	1042
C	100	280	722	764	833	1016
Tanning						
A	100	164	213	288	257	333
B	100	136	180	237	217	274
C	100	108	167	201	198	234

Table 13.5 (continued)

			1850		1860	
Industry	1820	1832	Firms	Agg.	Firms	Agg.
Tobacco						
A	100	—	150	147	289	182
B	100	—	147	145	284	178
C	100	—	164	140	280	173
Wool textiles						
A	100	286	314	274	486	500
B	100	236	262	226	401	412
C	100	216	238	205	369	373
Average						
Weighted (B)	100	[186]	[207]	220	[265]	287
Unweighted (B)	100	[191]	[235]	249	[305]	320

Notes and sources: See the notes to tables 13.2 and 13.3. The estimates of gross output per equivalent worker in current dollars presented in table 13.2 were converted to constant dollars by employing the price indexes reported in table 13.3 and then normalized relative to a base of 100 representing the respective industry's level in 1820. The weights employed in computing the weighted averages are equivalent to the industry shares of gross output produced in the northeastern states in 1850, and were calculated from information contained in United States Census Office (1858). The weights were normalized so that their sum was equal to one whenever there were missing values. Averages based on fewer than thirteen industries (affected by missing values) are reported within brackets.

strange results are greatly reduced in the series of total factor productivity estimates discussed below.[13] The industry with the most puzzling record is paper, which appears, by both measures of labor productivity, to have realized astonishingly high rates of advance, particularly after 1832. Although substantial progress would be expected, because of the dramatic increases in the utilization of raw materials and capital per unit of labor over the period, the estimated gains are probably too large to be believed. Given that this qualitative result is not sensitive to the choice between the firm-level and aggregate estimates, the problem may stem from the output price index employed.[14] Anomalies in the productivity series for boots/shoes, tanning, and tobacco are also associated with suspicious movements in the relevant price indexes.[15].

The per annum growth rates of labor productivity presented in table 13.6 were computed from the B sets of indexes in table 13.4 and 13.5. Rates of advance are reported for the entire period from 1820 to 1860, as well as for several subperiods. The estimates indicate that labor productivity increased rapidly in virtually all industries, ranging from 0.6%–0.7% and 1.3% per annum for VLP and GQLP, respectively, in flour/grist mills to 4.3%–5.5% and 5.3%–6.2% in paper. Weighted averages of the performance of the 13 industries yield estimated ranges

Table 13.6 Growth Rates of Labor Productivity in Selected Manufacturing Industries, 1820–60 (%)

Industry	1820–32	1820–50	1850–60	1820–60
Boots/shoes				
VLP	—	1.0–1.2	4.4–5.2	2.0–2.1
GQLP	—	1.3–1.3	4.7–6.0	2.2–2.5
Coaches/harnesses				
VLP	−0.7	1.8–2.0	2.7–3.7	2.0–2.4
GQLP	−1.4	1.6–2.2	2.1–2.2	1.7–2.2
Cotton textiles				
VLP	6.6	2.3–3.5	1.9–2.9	2.2–3.3
GQLP	6.5	4.3–4.3	−2.3–1.0	2.5–3.5
Furniture/woodwork				
VLP	1.1	1.9–2.7	3.8–6.2	2.9–3.0
GQLP	3.0	2.4–2.8	3.2–4.8	2.9–3.0
Glass				
VLP	9.6	3.7	−0.7	2.5
GQLP	11.6	3.9	−0.5	2.8
Hats				
VLP	1.6	2.1–2.3	3.0–3.4	2.4–2.5
GQLP	1.9	2.6–2.8	2.9–4.0	2.7–3.1
Iron				
VLP	—	0.5–0.7	4.6–4.6	1.5–1.7
GQLP	—	0.2–0.8	4.6–7.5	1.7–2.0
Liquors				
VLP	—	0.5–1.9	2.0–5.3	1.7–1.9
GQLP	—	−0.4–2.2	1.1–9.4	1.9–2.1
Flour/grist mills				
VLP	—	−0.4–0.4	1.6–3.8	0.6–0.7
GQLP	—	0.7–1.4	1.1–3.0	1.3–1.3
Paper				
VLP	5.3	6.0–6.2	−1.2–4.0	4.3–5.5
GQLP	9.7	7.4–7.5	−0.8–2.9	5.3–6.2
Tanning				
VLP	2.2	1.7–3.0	−1.7–0.4	1.2–1.7
GQLP	2.8	2.1–3.0	1.5–1.8	2.0–2.6
Tobacco				
VLP	—	0.1–1.0	6.3–8.1	2.1–2.4
GQLP	—	1.3–1.3	2.1–6.8	1.5–2.7
Wool textiles				
VLP	4.5	1.3–2.3	4.4–7.0	2.7–2.8
GQLP	8.1	2.8–3.4	4.4–6.2	3.6–3.7
Weighted average				
VLP	[4.3]	[1.8]–2.3	3.2–[3.2]	[2.2]–2.5
GQLP	[5.8]	[2.5]–2.7	2.5–[2.7]	[2.5]–2.7

Notes and sources: These annual rates of growth were computed from the constant-dollar estimates of labor productivity presented in set B of tables 13.4 and 13.5. The VLP estimates refer to the growth of value added per equivalent worker, and the GQLP refer to the growth of gross output per equivalent worker. Ranges of estimates are often presented, reflecting the differences between the figures derived from firm data and those based on aggregate data. See the notes to tables 13.4 and 13.5.

of 2.2%–2.5% and 2.5%–2.7% for the rates of growth of the two measures of labor productivity. These figures are remarkable in that they are drawn from the experience of industries that together accounted for a large share of the entire manufacturing sector in the Northeast and yet are substantially higher than those that other scholars concerned with antebellum growth have calculated for the United States economy as a whole (David 1967, 1977; Gallman 1972a, 1972b).

These estimates of productivity growth in northeastern manufacturing during early industrialization may exceed what might have been expected from previous work on the era, but they seem quite reasonable by other historical standards. For example, McCloskey (1981) has computed rates of productivity growth for four manufacturing industries in Britain during that country's initial phase of industrial development, 1780 to 1860. His calculations suggest that the British record of advance was similar to that observed here in the American Northeast. Of perhaps even greater interest, our estimates of labor productivity growth during early industrialization are slightly larger than those computed by Kendrick (1961) for the United States manufacturing sector between 1869 and 1957.

Another finding that emerges from these estimates is that, on average, there is weak evidence for acceleration in the rate of labor productivity growth over the period. This claim is based primarily on a comparison of the experience between 1820 and 1850 with that between 1850 and 1860 and thus must be offered tentatively. An analysis focusing on the performance before and after 1832, of the eight industries for which we have estimates in that year, reinforces the grounds for skepticism about the occurrence of acceleration. When the thirteen industries are considered together, they exhibit a marked increase in the rate of labor productivity growth by the VLP measure, from 1.8%–2.3% per annum before 1850 to 3.2% following, but no change by the GQLP measure. According to the latter, labor productivity rose at a roughly constant 2.5%–2.7% per annum between 1820 and 1850, as well as between 1850 and 1860. On an individual industry basis, nine of the thirteen enjoyed faster growth during the latter subperiod, by either measure, than in the former. Whether or not the pace quickened over time, it is clear that rapid progress must have been realized as early as the 1820s. While evidence of acceleration would conform with the work of scholars who view the diffusion of mechanization across manufacturing industries during the 1840s and 1850s as the crucial development behind productivity growth in that sector, this perspective, even if it were more strongly supported by the data, contributes little to understanding how and why the impressive advances between 1820 and 1850 were achieved (Chandler 1977).

Given that the utilization of sophisticated machinery and highly capital-intensive production processes were essentially confined to but a few industries until late in the period, the finding that a broad range of manufacturing industries enjoyed substantial gains in productivity throughout the early nineteenth century might tend to enhance appreciation of the importance of the changes in labor organization and other relatively modest alterations in technique that seem generally to have been adopted sooner and more widely. Another reaction, however, would be to question the accuracy of the estimates of productivity growth. Comparisons between the rates reported here and those computed for other places or eras do provide some check on the plausibility of the results, but those drawn with alternative industry-specific figures for the same period would be even more informative. Unfortunately, such estimates are quite scarce, and the only prominent industry for which they are readily available is cotton textiles. As for that industry, the rates of labor productivity growth presented here are generally lower than what other scholars have found. Davis and Stettler (1966) calculated that gross output per worker in the entire United States industry increased at rates of 4.1% per annum between 1820 and 1860 and of 3.4% between 1832 and 1860, as compared to the 2.5%–3.5% and 1.9%–2.3% rates for the respective periods reported here. Their estimates for cotton textiles in Massachusetts indicate somewhat slower rates of advance in that state; but their figure of 2.2% per annum growth between 1832 and 1860, resembling the 2.0% and 2.5% rates of McGouldrick (1968) and Layer (1955) for mills in Lowell during roughly the same years, is near the upper end of our range. Nickless's (1979) analysis of Layer's data on three Lowell establishments yields an even higher estimate, 3.3% per annum, for the period from 1836 to 1860. Hence, the evidence from the only other industry for which independent estimates are easily obtained suggests that our figures on labor productivity growth are on the low side, as they were constructed to be.

A skeptic might not accept the number or relevance of the standards of comparison utilized, and continue to dispute the estimates of the rates of advances as too high, claiming that the results were an artifact due to some defect in the data or in the way they were derived. There are, indeed, several aspects of the estimation procedure that could be of sufficient importance to account for the findings of rapid productivity growth across a wide spectrum of manufacturing industries and, on average, in the sector at large. Perhaps the most obvious of these is the selection of price indexes. As is clear from the indexes listed in table 13.3, there were substantial fluctuations in both absolute and relative prices over the period from 1820 to 1860. In this context, it is conceivable that some of the price indexes utilized might diverge significantly from the actual movement of the relevant prices, particularly since the indexes frequently pertain only to one specific product or raw material of an industry and in several cases were drawn from the WPI. Nevertheless, in order for there to be a qualitatively important upward bias in the estimates of productivity growth, the respective price indexes would have to seriously overstate the decline in output prices relative to input prices. Given the absence of any evidence or argument that such a systematic pattern in the errors of the price indexes across industries exists, there would seem to be no basis for accepting the argument that inaccurate price indexes account for the general finding of rapid labor productivity growth.

There are several other reasons to doubt the severity of the problems with the price indexes. The first is that when multiple price indexes were available for an industry, the most conservative of them generally were selected for use, biasing the estimated rates of productivity growth downward. Another factor that mitigates the significance of possible errors in the indexes is that the value-added figures were deflated to constant dollars with only output price indexes, instead of converting the values of gross outputs and raw materials separately. In manufacturing industries in which the prices of the raw materials consumed fell relative to the output prices, this procedure would lead the advance over time in real labor productivity to be overestimated. The evidence, however, suggests that it was the relative price of the outputs that typically declined during the period. Of the eight industries included in table 13.3 that have separate and industry-specific indexes for outputs and inputs, all experienced a decrease in the former relative to the latter. To the extent that this pattern was characteristic of the manufacturing sector, the employment of output price series to deflate the nominal value-added figures should tend to bias estimates of productivity growth downward, not upward. Hence, the likelihood that the result of substantial advances was due to inaccurate price indexes seems even more remote. Given that there are undoubtedly some errors in the price indexes utilized, however, and that the magnitude and perhaps the direction of the biases referred to must vary across industries, one should be cautious about comparing the relative performances reported for individual industries. Although the rates of productivity growth should be biased downward in most industries, the variability in the extent of the biases at the industry level implies that the record of any particular industry relative to another might be quite fragile.[16]

The other feature of the construction of the estimates that the qualitative results might plausibly be sensitive to is the method of adjustment for the inclusion of establishments operating part-time in the samples. This is a potentially important problem, because such enterprises did not generally explicitly identify themselves as such, became less prevalent in manufacturing over time, and had their measures of productivity biased downward from the actual levels.[17] As discussed above, the logic of the procedure adopted to deal with the dilemma was based on the assumption that the lower the total factor productivity of an establishment, the greater the likelihood it operated only a fraction of the year. Generous assessments of the prevalence of part-time operations in the various years were made, and corresponding percentages of the least productive enterprises were dropped from the respective samples to obtain the subsamples over which the sets of estimates were computed. The B set of estimates was intended to represent conservative "best-guess" figures, and provides the basis for the rates of growth reported in table 13.6. If the adjustments to the samples underestimated the extent of part-time operations in 1820, or especially the decrease in their prevalence over time, then the rates of productivity growth would likely be biased upward. This is a possibility, but as an examination of the nominal figures in tables 13.1 and 13.2 indicates, the qualitative result of rapid productivity growth, on average, in manufacturing is not sensitive to reasonable variation in the proportions of firms presumed to have been operating part-time and truncated from the samples. Estimates of the advances in several of the industries, such as iron and tanning, might be substantially affected, however, as could the relative rates of progress in some industries versus others.

There are other aspects of the estimation procedures that might be expected to yield biased results, but they are more likely to lead to understatements of the advances in productivity than overstatements. The first concerns the manner in which value added was computed. Each of the bodies of data employed contains reports of the value of outputs produced and the value of raw materials consumed by the particular firm or industry. Value added was calculated in a straightforward fashion by deducting the value of the raw materials from the total value of output. The potential bias arises from the additional category of expenses specified by firms in the 1820 Census of Manufactures. This class of production costs was defined as "contingent expenses" and included the costs of items such as fuel, insurance, and repairs to equipment. Since none of the other surveys collected information on a similar category of expenses, "contingent expenses" were ignored in the calculation of the value-added figures for 1820. If, however, some of the expenditures on inputs counted among "contingent expenses" in that year were included as raw materials later, then the value added per firm would be overestimated in 1820 relative to that in other years, and the growth in the value-added measures of productivity underestimated.

Another possible source of systematic error in the preparation of the productivity estimates is the method of aggregating different classes of workers into units of adult male equivalents. Females and boys have been treated as equal, in terms of their labor input, to one-half of an adult male employee, with these weights having been drawn from evidence on the relative wages of the groups prevailing near the end of the period.[18] In both the 1820 Census of Manufactures and the *McLane Report* of 1832, each of the three types of workers was enumerated separately. There were only two classifications of employees utilized in the 1850 and 1860 censuses, however, males and females. For those years, the reported number of male workers in each industry was decomposed into adults and boys by assuming that the industry-specific proportions of males that were boys were the same in 1850 and 1860 as they had been in 1820.[19] Since the shares of male employees that were boys probably rose somewhat over the period, a small upward bias might be imparted by this procedure to the estimation of the labor inputs in the later, relative to the earlier, years (Goldin and Sokoloff 1982). As a consequence, estimates of productivity in those years, and thus of its growth over time, would tend to be biased downward.

One might also expect the estimates of productivity growth during the period to understate the actual record because of the problems in the sample selection that afflict the various bodies of data. First, the systematic undercounting of smaller establishments in the 1820 and 1832 samples should probably generate overestimates of the productivity levels in those years.[20] In addition, the unrepresentative character of the samples from 1850 and 1860 would be expected to yield underestimates. These two samples were designed to incorporate a certain minimum number of observations from each state that had surviving data, and hence they suffer from a disproportionate representation of manufacturing firms from states that had relatively limited industrial development or small populations (Atack et al. 1979). As the firms from such states tended to be less productive than those from other areas, at least partially because of their smaller scales of operation, the levels of productivity estimated from the samples should be lower than those actually prevailing in the Northeast at the respective years. Moreover, the inclusion of part-time establishments in the aggregate data from the 1850 and 1860 censuses means that the estimates obtained from these sources are downward biased as well. Hence, with productivity levels overestimated for 1820 and underestimated for 1850 and 1860, the rates of advance derived should be lower than those that were realized.

The above discussion has reviewed, in considerable detail, many of the features of the data sources and the estimation procedures that might have contributed to inaccurate or biased assessments of the productivity growth between 1820 and 1860. It has been argued that most of them would be expected to have led to estimates that were biased downward. The chief exception to this generalization about the impacts of the potential biases is the effect of a decline over time in the relative amount of manufacturing production carried out by firms operating seasonally. The disproportionate truncation of the least productive manufacturing establishments from the 1820 sample, however, should probably more than compensate for this problem, because the percentages dropped from the analysis for the 13 industries seem likely to have exceeded those of firms that were part-time enterprises. Even if the adjustments underlying the B set of estimates, on which the discussion focuses, are not quite sufficient, sensitivity analysis employing set C for 1820 indicates that the qualitative results would not be altered by any reasonable relaxation of the assumptions concerning the prevalence of seasonal operations in that year.[21] Particularly when one considers the net effect of all the biases, it appears likely that the estimates of productivity growth in manufacturing understates, on average, the actual record.

The evidence seems to support the conclusion that labor productivity growth in manufacturing during this initial phase of industrialization was remarkably rapid and significantly higher than scholars may have reckoned previously. What is one to make of this performance? One possibility is to attribute the progress to the combined effects of a variety of related developments marking the period that include the introduction and diffusion of machinery, increases in capital and raw materials intensity, changes in the organization of labor, the realization of scale economies, learning by doing, and the impact of expanding markets through the selecting out of inefficient producers and the stimulation of technical innovation. One might also explain the remarkably high rates of labor productivity growth as being at least partially accounted for by the severe contraction that occurred in the United States between 1816 and 1821, and might have dragged productivity in 1820 well below its trend level. From this perspective, the estimates could accurately reflect the actual amount of labor productivity growth between 1820 and 1860 but convey a misleading impression about the long-term record.

Although cyclical effects might, in principle, have been large, the qualitative findings with respect to productivity growth over the entire period from 1820 to 1860 are not fundamentally altered when one makes adjustments for them. In order to gauge the potential magnitudes of the cyclical effects on manufacturing productivity, estimates of the trend over time in gross output per worker were computed through regression analysis from the annual series on cotton textiles assembled by Davis and Stettler (1966) and by Layer (1955), and then the residuals were compared with the NBER classifications of cyclical behavior by year (Thorp 1926). Both sets of residuals indicate some procyclical variation, with the greatest deviations below trend in labor productivity being achieved, on average, one year before the trough of the business cycle. The Davis and Stettler series implies much greater cyclical variation than the Layer series, but even here the effect seems somewhat modest. In the average business cycle, labor productivity, as measured by gross output per worker, fell to only 4.2% below trend during the year before the trough.[22] Moreover,, over the limited period of time spanned by their data, the magnitude of the deviation from trend does not appear to have been systematically related to the duration of the cycle. It is not clear whether cyclical variation in labor productivity should be more or less in cotton textiles than in other industries. Nevertheless, even if the 4.2% figure is doubled and applied to all manufacturing industries, the adjustment for the business cycle in 1820 would not change the qualitative results concerning the pace of labor productivity growth over the period under study. Such refinements would be even less significant for the other years covered by the data, because none of them seem to have been associated with extreme cyclical activity.[23]

It is apparent that taking cyclical factors into consideration does not appreciably alter the interpretation of the finding that there were major increases in labor productivity across a wide range of manufacturing industries during the antebellum period. The relative importance of the various contributors, such as capital deepening or mechanization, to these developments, however, is less clear. That virtually all of the industries investigated realized impressive gains in labor productivity despite the rather modest degrees of mechanization and capital intensity in most of them suggests that other factors must have played a significant role. An indirect method of roughly gauging whether capital deepening or mechanization were the principal determinants of the rate of progress is to examine whether the records of productivity growth of the capital- and machinery-intensive industries compared favorably with those of their counterparts.

Instead of treating the relationship between the factor proportions employed and productivity growth through a discussion of the cases of individual industries, the 13 industries were ranked by both capital intensity and machine intensity, on the basis of information pertaining to 1850 and 1832, respectively, and divided into two groups for each dimension.[24] Weighted averages of the alternative measures of labor productivity were computed for the various classes of industries, and indexes and per annum rates of growth derived from them are presented in table 13.7.

Several findings of interest emerge from these estimates. Perhaps most important is that, over the entire period from 1820 to 1860, all categories of industries registered major increases in labor productivity. It does appear, however, that the more capital-intensive and machinery-intensive industries generally realized somewhat larger advances, particularly in terms of GQLP. For example, in the more capital-intensive industries this measure of labor productivity rose by 161%–202% (de-

Table 13.7 Indexes of Labor Productivity for Classes of Manufacturing Industries, 1820–60

Year	Mechanized Industries		Other Industries		Capital-Intensive Industries		Other Industries	
	VLP	GQLP	VLP	GQLP	VLP	GQLP	VLP	GQLP
1820	100	100	100	100	100	100	100	100
1850 (firm)	[181]	[232]	[153]	[165]	[175]	[219]	[154]	[171]
1850 (aggregate)	204	239	179	187	205	235	170	174
1860 (firm)	[234]	[271]	[226]	[255]	[220]	[261]	[248]	[275]
1860 (aggregate)	296	311	228	247	278	302	240	244
Per annum growth rates:								
1820–50	[2.1]–2.5	[3.0]–3.0	[1.5]–2.0	[1.7]–2.2	[1.9]–2.5	[2.7]–3.0	[1.5]–1.9	1.9–[1.9]
1850–60	[2.6]–3.8	[1.5]–2.7	2.5–[3.9]	2.8–[4.5]	[2.3]–3.1	1.8–[2.5]	3.5–[4.9]	3.4–[4.9]
1820–60	[2.2]–2.8	[2.6]–3.0	[2.1]–2.1	2.3–[2.4]	[2.0]–2.7	[2.5]–2.9	[2.3]–2.4	2.3–[2.6]

Notes and sources: These estimates were computed as weighted averages of the industry-specific figures underlying the indexes presented in table 13.4, 13.5, and 13.6. They were calculated with the same weights employed in those tables to construct the weighted averages. However, the weights of the industries in each class were normalized so that their sum was always equal to one. The mechanized industries include cotton textiles, wool textiles, paper, glass, mills, and iron. The capital-intensive industries include cotton textiles, wool textiles, paper, mills, iron, liquors, and tanning.

pending on whether the firm or aggregate data are employed) between 1820 and 1860, whereas those less dependent on capital managed an increase of 144%–175%. This differential is consistent with the view that the utilization of machinery or capital equipment may have facilitated changes in production processes that increased the rate at which raw materials could be processed into final products with a given amount of labor.

What is rather puzzling about these comparisons between the various classes of industries is that the qualitative results appear sensitive to whether the productivity estimates are derived from the samples of firm information or from the aggregate data. Especially in 1860, the aggregate figures suggest much greater productivity growth in the capital-intensive and machinery-intensive industries, relative to their counterparts, than do the estimates obtained from the firm reports. Since both sets of estimates would be expected to be biased downward, as discussed above, the substantial disparity might be thought to shed light on which sources of biases are most serious and accordingly to convey information about the structure of the manufacturing sector. In particular, it might seem to suggest that the disproportionate sampling of firms in 1860 from less developed states biases the firm-level productivity estimates downward by more than the aggregate productivity figures are affected by the inclusion of part-time operations in the census totals. Such an explanation does not hold up well, however, to the observation that no industries other than tanning and perhaps cotton textiles have large discrepancies of the same sign between the firm- and aggregate-level productivity estimates in both 1850 and 1860. Instead, the sensitivity of the finding of higher productivity growth in the capital-intensive and machinery-intensive industries to the choice between the two sets of estimates is primarily attributable to the enormous differences in 1860 for cotton textiles and paper that have not yet been satisfactorily accounted for.[25]

Regardless of the appropriate interpretation of the significantly more rapid progress of labor productivity implied by the aggregate data, one must be impressed with the extent of the advances realized by those industries with low levels of capital or machinery intensity. By either measure of labor productivity, these industries managed growth rates of over 2.0% per annum. Despite the evidence that industries with a greater reliance on capital and machinery did slightly better, this strong record would seem to bear against the view that the increasing utilization of these factors of production per unit of labor were the dominant forces in accounting for, or encouraging, growth in manufacturing productivity during this early phase of industrialization.

One might legitimately challenge the persuasiveness of this argument, on the grounds that a comparison of the rates of productivity growth between classes of industries defined by their factor intensities at one moment in time does not bear directly on the issue of how changes in the ratio of capital to labor over time contributed to advances in labor productivity. Such a procedure does, however, establish whether there was an association between the capital intensity of an industry at a point in time and the future capacity for, or history of, its productivity growth (depending on whether capital intensity is measured at the beginning or end of the period in question), but that is a somewhat different, if related, question. In this regard, the finding that the rates of advance achieved were nearly equal across classes of industries tends to suggest that any relationship between capital intensity and productivity growth was weak during this phase of industrial development. An alternative approach to the problem of how important capital accumulation was in promoting productivity increase would be to evaluate formally how much of the growth in labor productivity over some specified span of time can be directly attributed, in an accounting sense, to the accumulation of capital per unit of labor that occurred. Such an analysis entails the measurement of total factor productivity and will be carried out in the next section of the paper.

Another caveat to the interpretation of the comparisons between the rates of labor productivity growth in machinery- or capital-intensive industries and their counterparts is that the disparities are significantly smaller for the entire period from 1820 to 1860 than they are when attention is restricted to developments before 1850. For example, the gap in the rate of increase of GQLP between the mechanized industries and the less mechanized widens from between 2.6%–2.9% and 2.3%–2.4% per annum for 1820–60 to between 3.0%–3.0% and 1.7%–2.2% for 1820–50. This pattern reflects both impressive rates of advance throughout the period for all industries and an acceleration from 1850 to 1860 that is especially pronounced among, and perhaps exclusive to, the less mechanized and capital-intensive industries. The record of change in the capital-labor ratio is similar, in that the less mechanized and the less capital- intensive industries experienced an extraordinary rise between 1850 and 1860, while their counterparts failed to manifest any robust acceleration.

This perspective on the evidence tends to place somewhat greater emphasis on the roles played by mechanization and capital accumulation in promoting labor productivity growth. The estimates can be viewed as consistent with the notion that the advances were initially most rapid among industries such as cotton textiles that mechanized and were highly capital intensive early, and that the pace of progress in the rest of the manufacturing sector was boosted as sophisticated capital equipment began to be diffused more broadly during the 1840s and 1850s. Nevertheless, it is also clear that many industries, such as hats and furniture/woodwork, realized substantial increases in productivity while they were still utilizing small amounts of capital per unit of labor and little or no machinery.

The findings thus support the judgment that there may have been two general sources, or perhaps "stages," of productivity growth in manufacturing during early industrialization. The first wave of advances seems to have been associated, in many industries, with changes in the organization of labor and other alterations in production processes that did not involve large adjustments in the capital-to-labor ratio (Goldin and Sokoloff 1982; Sokoloff 1984b). The gains from these sorts of improvements eventually were to be exhausted, but a second class of innovations related to the introduction of sophisticated capital equipment followed, leading perhaps to an acceleration of labor productivity growth (Chandler 1977; Atack 1985). These stylized "stages" undoubtedly fail to describe the experience of all manufacturing industries; indeed, it is apparent that industries passed through them at different rates and periods, and that the timing of the diffusion of the new production methods may have varied across firms within industries with location and other characteristics. Moreover, changes in production techniques that encompassed aspects of both "stages" at once were implemented in some industries. It is difficult to determine precisely how important each development was in explaining labor productivity growth, particularly with only the bodies of evidence examined here. An exploration of more comprehensive measures of productivity should, however, help to improve our assessment of at least the relative significance of the various contributors.

13.3 Estimates of Total Factor Productivity

Although the estimates of labor productivity growth presented above are quite informative about the record of industrial development in the Northeast, broadening the investigation of productivity to include other factors as inputs can extend our knowledge further. It makes possible, in particular, the decomposition of the growth in labor productivity between the amounts attributable to increases in capital and raw materials utilized per unit of labor and that due to advances in total factor productivity. Such information in turn will contribute to our understanding of the evolution of production methods and help to determine how important physical capital accumulation was during the early stages of industrialization.

It is useful to begin the treatment of total factor productivity by examining the indexes of real partial factor productivity reported in table 13.8. These figures indicate the industry-specific movements over the period in the ratios of gross output to raw materials, capital, and labor. Several features of these estimates deserve comment. The first

Table 13.8 Indexes of Real Partial Factor Productivity, 1820–60

Industry	1820	1832	1850 Firms	1850 Agg.	1860 Firms	1860 Agg.
Boots/shoes						
GQ/RM	100	—	107	113	141	156
GQ/K	100	—	181	217	115	220
GQ/L	100	—	145	145	260	230
Coaches/harnesses						
GQ/RM	100	121	136	154	148	155
GQ/K	100	85	206	181	126	137
GQ/L	100	86	187	158	233	194
Cotton textiles						
GQ/RM	100	89	68	82	112	123
GQ/K	100	124	222	215	301	219
GQ/L	100	200	336	341	267	379
Furniture/woodwork						
GQ/RM	100	91	158	181	177	178
GQ/K	100	204	304	283	225	222
GQ/L	100	138	201	225	320	309
Glass						
GQ/RM	100	103	—	155	—	140
GQ/K	100	179	—	218	—	188
GQ/L	100	335	—	305	—	290
Hats						
GQ/RM	100	90	96	105	113	131
GQ/K	100	163	205	242	209	284
GQ/L	100	122	223	213	328	282
Iron						
GQ/RM	100	—	127	115	119	134
GQ/K	100	—	150	125	180	142
GQ/L	100	—	105	125	218	195
Liquors						
GQ/RM	100	—	180	148	146	157
GQ/K	100	—	83	143	114	97
GQ/L	100	—	90	187	221	209
Flour/grist mills						
GQ/RM	100	—	143	144	148	148
GQ/K	100	—	103	124	100	102
GQ/L	100	—	123	150	166	167
Paper						
GQ/RM	100	51	72	71	107	119
GQ/K	100	150	372	310	455	321
GQ/L	100	275	816	783	751	1042
Tanning						
GQ/RM	100	97	95	100	117	116
GQ/K	100	93	112	143	114	117
GQ/L	100	136	180	237	217	274

Table 13.8 (continued)

			1850		1860	
Industry	1820	1832	Firms	Agg.	Firms	Agg.
Tobacco						
GQ/RM	100	—	93	80	91	132
GQ/K	100	—	114	98	80	150
GQ/L	100	—	147	145	284	178
Wool textiles						
GQ/RM	100	65	75	70	128	124
GQ/K	100	145	208	169	263	252
GQ/L	100	236	262	226	401	412

Notes and sources: See the note to table 13.1. The nominal values of the respective measures of partial factor productivity were converted to constant dollars with the industry-specific price indexes presented in table 13.3. These estimates were then normalized relative to a base of 100 representing the respective industry's levels in 1820.

is that in nearly all industries, each of these ratios of partial factor productivity increases between 1820 and 1860. Although the liquors and tobacco industries do diverge slightly from this pattern, neither case appears to contradict significantly the general result as the decreases they manifest are small and sensitive to the choice between firm- and aggregate-level estimates. Since the index of total factor productivity is equivalent to a weighted average of these individual ratios, it is accordingly obvious that any reasonable measure of the former would rise over the period in all industries.

Another pattern in the data that merits emphasis is that, in all industries, labor productivity increased much more over the period than either raw materials or capital productivity. While the gains in labor productivity between 1820 and 1860 typically were very large, the advances in raw materials productivity observed are quite modest. Capital productivity appears generally to have increased less than labor and more than raw materials productivity, although there are a few prominent deviations from this pattern where it also failed to keep up with the rise in the latter (i.e., liquors and flour/grist mills). This evidence suggests that, in general, manufacturing production methods evolved over time in such ways as to reduce the amounts of labor and, to a lesser extent, capital required to process a unit of raw materials into final product. It conforms well with the work of scholars who have argued that many of the innovations introduced by manufacturers during this period were intended to substitute relatively cheap raw materials for other inputs (Habakkuk 1962).

By dividing *GQ/L* by *GQ*/K or *GQ/RM*, one can calculate the change over time in the ratios of capital or raw materials to labor from the information provided in table 13.8. These latter ratios indicate that northeastern manufacturing did shift somewhat toward more capital-intensive production processes, as judged by the capital-labor ratio, between 1820 and 1860. However, the extent of this adjustment in factor proportions pales by comparison with the dramatic surge in raw materials intensity that occurred contemporaneously. Whereas the weighted-average growth in the ratio of raw materials to labor was in the 110%–118% range, the rise in capital per unit of labor amounted to only 59%–63%. It is striking that both of these increases in the utilization of other inputs per unit of labor are proportionally much lower than the estimated growth in GQLP during the period. This finding casts additional doubt on whether either raw materials accumulation or capital accumulation, but especially the latter, could play the dominant role in explaining the advance in labor productivity.

There is, of course, substantial variation across the industries in the extent of the movement toward greater capital intensity, and some of them experienced significantly larger shifts than the average did. Nevertheless, as will be shown below, the increase in the ratio of capital to labor was not sufficiently massive in any industry to account directly for a major share of the progress realized in labor productivity. Moreover, it is interesting that the industries that underwent the most extensive capital deepening during the period may have been those that were most capital intensive to begin with. Industries such as liquors, flour/grist mills, paper, tanning, and wool textiles, which were among the seven most capital intensive of the 13 in 1820, appear to have experienced the largest increases in the capital-labor ratio. Conversely, several of the less capital-intensive industries, boot/shoes, furniture/woodwork, and hats, were among those with the smallest percentage gains. Weighted averages of the two classes of industries reveal that the capital-to-labor ratio rose by 45%–79% over the period in the more capital-intensive industries (as identified at either 1820 or 1850), and by 16%–95% in their counterparts. Since the estimated range of increase for the former class of industries does not unambiguously dominate that for the latter, one cannot make an unqualified claim that those industries that were initially most capital intensive carried out more capital deepening. Nevertheless, it seems that the classes of industries were not converging in their degrees of capital intensity and that many industries remained highly labor intensive throughout the period.[26]

A final point to make about the indexes of partial factor productivity is that they imply that the doubts some scholars have raised concerning the accuracy of the census valuations of the capital invested in manufacturing firms are unwarranted. The chief question about the usefulness of the reported capital input has been whether establishments included working capital in their statements to census enumerators.[27]

If, as some have argued, they did not, then estimates of both the growth of capital intensity and total factor productivity over time would likely be confounded. The possible seriousness of the problem can be evaluated with the more detailed information on the composition of capital investments contained in the 1832 sample drawn from the *McLane Report*. These data include separate assessments of the value of capital invested in land and structures, tools and machinery, and inventories (Sokoloff 1984a).

Since the bulk of the capital investment was in working capital, and the 1832 estimates of total factor productivity and the capital-labor ratio were based on valuations of the capital input that included inventories, one would expect to observe some stark contrasts between the estimates from that year and those from 1820 or 1850 if working capital had not been incorporated as part of the reported capital investments into the censuses of the other years. More specifically, there would be large decreases in total factor productivity and substantial increases in capital intensity between 1820 and 1832, especially in those industries in which investment in working capital was relatively important. No such patterns emerge, nor do the differentials in total factor productivity across industries, varying with the relative investments in fixed and working capital, that would be evident in the 1820, 1850, and 1860 data if their information on capital investments did not include at least a major component of the working capital. It thus seems unlikely that undervaluation of working capital in manufacturing censuses was a serious defect, and correspondingly that the estimates of the growth in total factor productivity and capital intensity are significantly distorted as a consequence.

Indexes of real total factor productivity, based on the two alternative definitions of output, are presented for the 13 industries in tables 13.9 and 13.10. As with the labor productivity figures reported above, the estimates were computed for each of three sets of subsamples of firms so as to demonstrate the insensitivity of the results to the extent of adjustment for part-time firms, and the price indexes appearing in table 13.3 were employed to convert the nominal measures of gross output, value added, raw materials, and capital to constant dollars before productivity was calculated.

The results indicate that by either of the two measures, nearly all industries realized substantial growth in total factor productivity between 1820 and 1860. Weighted averages of the records of the individual industries yield estimated increases ranging from 104% to 130%, with output defined as value added (NFP), and from 68% to 76% by the alternative gauge (TFP). Each industry performed well by at least one measure. Flour/grist mills registered the smallest advance in NFP, only 10%–11%, but the estimated gain in TFP approached 50%; and although

Table 13.9 Indexes of Total Factor Productivity: Computed with Value Added as the Measure of Output

			1850		1860	
Industry	1820	1832	Firms	Agg.	Firms	Agg.
Boots/shoes						
A	100	—	158	179	195	240
B	100	—	144	160	175	215
C	100	—	145	154	175	206
Coaches/harnesses						
A	100	94	175	191	231	216
B	100	93	181	173	210	196
C	100	93	179	171	189	193
Cotton textiles						
A	100	195	188	264	269	344
B	100	174	169	235	240	306
C	100	149	186	200	224	261
Furniture/woodwork						
A	100	134	191	248	298	303
B	100	127	198	230	288	281
C	100	121	183	210	274	257
Glass						
A	100	227	—	258	—	233
B	100	227	—	258	—	233
C	100	216	—	249	—	225
Hats						
A	100	147	201	229	253	298
B	100	130	179	203	224	264
C	100	156	213	234	254	304
Iron						
A	100	—	165	203	262	289
B	100	—	128	122	170	173
C	100	—	128	112	180	159
Liquors						
A	100	—	121	184	173	193
B	100	—	113	160	158	168
C	100	—	122	156	174	164
Flour/grist mills						
A	100	—	95	123	122	130
B	100	—	84	105	110	111
C	100	—	88	91	113	97
Paper						
A	100	149	466	415	440	572
B	100	147	458	408	440	563
C	100	150	422	399	487	550
Tanning						
A	100	139	168	247	157	187
B	100	114	141	201	129	152
C	100	93	127	175	120	132

Table 13.9 (continued)

			1850		1860	
Industry	1820	1832	Firms	Agg.	Firms	Agg.
Tobacco						
A	100	—	130	96	178	224
B	100	—	126	92	171	216
C	100	—	131	88	165	206
Wool textiles						
A	100	180	227	171	332	318
B	100	141	179	134	260	248
C	100	123	157	118	212	218
Average						
Weighted B	100	[143]	[160]	181	[204]	230
Unweighted B	100	[144]	[175]	191	[207]	240

Notes and sources: These estimates of total factor productivity were computed over the same sets of observations as the corresponding labor productivity estimates presented in tables 13.1 and 13.4 were. See the notes to tables 13.1 and 13.4. The index of total factor productivity for the weighted average of the industries was computed with the same weights, and in the same manner, as the index of labor productivity reported in the latter table. The output elasticities employed in the computation were selected from a range derived by estimating Cobb-Douglas production functions over each cross-sectional sample. These regressions yielded estimates of the capital coefficient between 0.25 and 0.30. The latter value was employed here so as to increase the estimates of the inputs in the later years relative to the earlier. The formulation of total factor productivity employed here is NFP = $(VA/K^{0.30}L^{0.70})$, where NFP is a measure of total factor productivity utilizing value added as the measure of output, VA is value added, K is the value of the capital invested, and L is the labor input. The calculations of NFP were performed after the values of gross output, raw materials, and capital had been deflated to constant dollars, utilizing the price indexes reported in table 13.3. These "real" estimates of total factor productivity were then normalized relative to an 1820 standard of 100.

tobacco ranked at the bottom in terms of progress in TFP, its increases of 30%–48% in that measure, and of 71%–116% in NFP, are not unimpressive. The cotton textiles, wool textiles, and paper industries are among those attaining the largest estimated increases in total factor productivity, but major gains were also achieved by industries such as furniture/woodwork and hats, which were among the least capital intensive and mechanized throughout the period. These figures provide dramatic testimony to how dynamic the manufacturing sector was during the early stages of industrialization. Moreover, they serve to undercut the hypothesis that capital accumulation was the driving force behind productivity growth during this era. The substantial increases in total factor productivity demonstrate clearly that the bulk of the gains in labor productivity cannot be accounted for directly by capital or raw materials deepening within manufacturing firms. In addition, the wide range of industries that shared in this general advance of productivity suggests that the phenomenon cannot be attributed to

Table 13.10 Indexes of Total Factor Productivity: Computed with Gross Output as the Measure of Output

			1850		1860	
Industry	1820	1832	Firms	Agg.	Firms	Agg.
Boots/shoes						
A	100	—	133	142	178	197
B	100	—	127	134	168	185
C	100	—	125	129	165	179
Coaches/harnesses						
A	100	104	156	166	175	171
B	100	104	159	159	168	164
C	100	104	158	158	159	163
Cotton textiles						
A	100	128	141	157	180	203
B	100	121	134	149	170	192
C	100	112	133	136	164	176
Furniture/woodwork						
A	100	122	184	217	229	232
B	100	116	186	206	222	220
C	100	114	179	197	218	211
Glass						
A	100	163	—	202	—	185
B	100	163	—	202	—	185
C	100	160	—	201	—	183
Hats						
A	100	115	148	157	185	199
B	100	108	140	148	174	187
C	100	118	153	159	186	201
Iron						
A	100	—	137	151	187	193
B	100	—	122	119	153	153
C	100	—	124	115	157	147
Liquors						
A	100	—	134	170	169	173
B	100	—	129	159	162	162
C	100	—	134	157	168	160
Flour/grist mills						
A	100	—	139	154	154	159
B	100	—	130	143	146	147
C	100	—	136	138	148	142
Paper						
A	100	103	203	192	246	280
B	100	102	200	190	245	277
C	100	103	192	188	256	273
Tanning						
A	100	118	129	153	155	169
B	100	108	120	139	143	154
C	100	98	115	131	138	145

Table 13.10 (continued)

Industry	1820	1832	1850 Firms	1850 Agg.	1860 Firms	1860 Agg.
Tobacco						
A	100	—	113	102	132	151
B	100	—	111	100	130	148
C	100	—	114	98	128	145
Wool textiles						
A	100	124	146	130	231	227
B	100	110	130	115	205	202
C	100	103	122	108	187	190
Average						
Weighted (B)	100	[114]	[133]	142	[168]	176
Unweighted (B)	100	[117]	[141]	152	[174]	183

Notes and sources: These estimates of total factor productivity were computed over the same sets of observations as the corresponding labor productivity estimates preserved in tables 13.2 and 13.5 were. See the notes to those tables. The index of total factor productivity for the weighted average of the industries was computed with the same weights, and in the same manner, as the index of labor productivity reported in table 13.5. The output elasticities were selected from a range provided by Cobb-Douglas production functions estimated cross-sectionally. The choice was influenced by the desire to have the coefficients for capital and raw materials to be on the high side so as to depress the estimated rates of productivity growth. The formulation of total factor productivity employed here is TFP = $(GQ/RM^{0.54}L^{0.33}K^{0.13})$, where TFP is a measure of total factor productivity utilizing the gross value of output as the measure of output, *RM* is the value of raw materials, *L* is the labor input, and *K* is the value of capital invested. All of the relevant variables were deflated to constant dollars, by the indexes in table 13.3, before the calculations were performed. These "real" estimates of total factor productivity were then normalized relative to a 1820 standard of 100.

developments such as the diffusion of new and more sophisticated capital equipment, which touched only a relatively limited number of industries until late in the period.

The consistency of the finding of large gains in total factor productivity, across industries and measures, bolsters confidence in the robustness of the qualitative result. Moreover, as the minor differences between the C and B sets of estimates suggest, the basic picture that emerges is not sensitive to any reasonable adjustments of the subsamples to account for the existence of part-time establishments.[28] It is also encouraging to note that there are fewer implausible fluctuations in these estimates than in the indexes of labor productivity, particularly with the TFP measure. Several industries do continue to manifest strange records of progress, but at least in the most troubling cases, paper, tanning, and tobacco, the price indexes relied on are suspect and likely the primary source of the problems. The other questionable features may also be attributable to the inappropriate or defective nature of the price series utilized, or an inadequate number of observations in some years. Whatever the explanation for these anomalies, however, the fundamental results do not depend upon their inclusion in the manufacturing averages.

Estimates of the per annum growth rates of total factor productivity have been computed from the indexes reported in tables 13.9 and 13.10 for the entire period between 1820 and 1860, as well as for several subperiods. They are presented in table 13.11, and confirm that a wide spectrum of manufacturing industries in the Northeast enjoyed rapid progress in total factor productivity during this initial phase of industrialization. Indeed, the weighted average per annum growth rates for these 13 industries match, if not exceed, the performance of the United States economy during other periods. Between 1820 and 1860, northeastern manufacturing appears to have achieved per annum rates of increase of 1.8%–2.2% in NFP and 1.3%–1.5% in TFP. These figures might be compared to the 1.8% rate for NFP estimated by Kendrick (1961) for the national manufacturing sector between 1869 and 1953, or to the 0.8%–0.9% and 1.4% rates computed by Gallman (1986) for the annual increase in TFP for the economy at large during the respective periods 1840–1900 and 1900–1960. Although some might react to the application of these standards by rejecting the early manufacturing rates of advance as implausibly high, it should be remembered that one would expect the pace of productivity growth in the most dynamic sector of the most burgeoning region during the period to have surpassed that for the national economy or for United States manufacturing in total. Hence, the finding that northeastern manufacturing might have realized faster rates of total factor productivity increase during its initial burst of expansion than economy-wide averages, pertaining to the same or other periods, should perhaps not be too surprising.

These estimates further suggest, more strongly than did those for labor productivity growth, that productivity rose, on average, more slowly between 1820 and 1850 than during the 1850s. The average rate of advance in TFP, for example, increased from 1.0%–1.2% per annum over the first 30 years to 2.2%–2.3% during the later 10. The pattern of acceleration is, admittedly, somewhat weaker if one focuses on the contrast between 1820–32 and 1832–60, and only on those industries for which 1832 figures are available. Nevertheless, even here, the weight of the evidence seems to favor a mild increase in the pace of total factor productivity growth. Many researchers have contended that such an acceleration may have resulted from a spurt in the accumulation of more and better capital equipment, during the 1840s and 1850s (Chandler 1977; David 1977; Williamson and Lindert 1980). They might tend to argue that the process of capital deepening only seems unimportant, because the conventional measures of input fail to fully detect the technical change that is embodied in newer vintages of capital. The acceleration of total factor productivity growth during a decade of more

Table 13.11 Growth Rates of Total Factor Productivity in Selected Manufacturing Industries, 1820–60 (%)

Industry	1820–32	1820–50	1850–60	1820–60
Boots/shoes				
NFP	—	1.3–1.6	2.0–3.0	1.4–2.0
TFP	—	0.8–1.0	2.9–3.3	1.3–1.6
Coaches/harnesses				
NFP	−0.7	1.9–2.1	1.3–1.5	1.7–1.9
TFP	0.3	1.6–1.6	0.3–0.5	1.3–1.3
Cotton textiles				
NFP	5.2	1.8–3.0	2.7–3.6	2.3–2.9
TFP	1.8	1.0–1.4	2.4–2.6	1.4–1.7
Furniture/woodwork				
NFP	2.2	2.4–2.9	2.0–3.8	2.7–2.8
TFP	1.4	2.2–2.5	0.7–1.8	2.0–2.1
Glass				
NFP	7.7	3.3	−1.0	2.2
TFP	4.5	2.5	−0.9	1.6
Hats				
NFP	2.4	2.0–2.5	2.3–2.7	2.1–2.5
TFP	0.7	1.2–1.4	2.2–2.4	1.4–1.6
Iron				
NFP	—	0.7–0.8	2.9–3.6	1.4–1.4
TFP	—	0.6–0.7	2.3–2.5	1.1–1.1
Liquors				
NFP	—	0.4–1.6	0.5–3.5	1.2–1.2
TFP	—	0.9–1.6	0.2–2.3	1.2
Flour/grist mills				
NFP	—	−0.6–0.2	0.6–2.8	0.2–0.3
TFP	—	0.9–1.2	0.3–1.2	1.0–1.0
Paper				
NFP	3.6	5.0–5.4	−0.4–3.3	3.9–4.5
TFP	0.2	2.2–2.4	2.0–3.8	2.3–2.6
Tanning				
NFP	1.2	1.2–2.4	−2.7– −0.8	0.7–1.1
TFP	0.7	0.6–1.1	1.1–1.8	0.9–1.1
Tobacco				
NFP	—	−0.3–0.8	3.1–8.9	1.4–2.0
TFP	—	0.0–0.4	1.5–4.0	0.7–1.0
Wool textiles				
NFP	3.2	1.0–2.0	3.8–6.4	2.4–2.5
TFP	0.9	0.5–0.9	4.7–5.8	1.8–1.9
Weighted average				
NFP	[3.3]	[1.6]–2.1	[2.4]–2.4	[1.8]–2.2
TFP	[1.2]	[1.0]–1.2	[2.2]–2.3	[1.3]–1.5

Notes and sources: These per annum rates of total factor productivity growth were computed from the set B estimates reported in tables 13.9 and 13.10. See the notes to those tables. The NFP estimates are of the growth of total factor productivity measured with value added as output. The TFP estimates are based on the measure of total factor productivity that employs gross output as the measure of output and explicitly treats the value of raw materials as an input.

rapid diffusion of machinery is certainly consistent with this interpretation, but alternative explanations of this feature of the economic record are also available.[29]

Although some of the technical change realized between 1820 and 1860 was undoubtedly embodied in capital goods, there are several reasons to doubt whether a proper accounting for this phenomenon would be capable of reversing the qualitative conclusion concerning the significance of capital accumulation for productivity growth in early manufacturing. First, even if one were to ascribe as much as half of the acceleration in total factor productivity increase to improvements of manufacturing capital not reflected in its price, the amount of productivity growth so generated would be quite small relative to the total realized over the entire period. One might claim that more of the estimated advance in total factor productivity should be credited to embodied technical change unincorporated in price, but the rationale for this appears weak. Not only did the less capital-intensive and less mechanized industries do quite well before the purported consequential developments of the 1840s and 1850s, but their investments in machinery and tools per unit of labor remained quite small in absolute terms, as well as in relation to their total investment in capital, at the end of the period. Even most of the counterpart industries, classified as more mechanized and capital intensive, had rather modest absolute and relative amounts invested in capital equipment that was directly involved in production (Sokoloff 1984a). Given that manufacturing industries had the bulk of their investments in structures and inventories, there would seem to be severe limits on the amount of embodied technical change that the capital input could plausibly be endowed with.[30]

One approach to evaluating the importance of embodied technical change is to compare the records of total factor productivity growth between the more capital-intensive and the less capital-intensive industries, or between the more mechanized and less mechanized ones. The logic underlying this procedure is that where new vintages of capital are endowed with embodied technical change, the measured increase over time in the inputs utilized by firms will be lower, relative to the outputs produced, and hence measured total factor productivity will be higher. Given that one would expect the realization of technical change embodied in capital and not incorporated in its price to be associated with either the size of the capital input relative to other inputs or the change in that relative size of the capital input over the period in question, the more capital-intensive and mechanized industries might seem likely to have enjoyed greater total factor productivity growth than the others if this component of embodied technical change was of much quantitative significance.[31] Although, as discussed above, the evidence of significantly more capital deepening over the period by these classes of industries is not entirely robust, it is clear that they did employ larger amounts of capital and machinery per unit of labor throughout the period, and carried out approximately as much capital deepening as their less capital-intensive and mechanized counterparts did. One might, accordingly, expect them to exhibit more total factor productivity growth.

When one examines the indexes of total factor productivity presented in table 13.12 for classes of manufacturing industries, however, only minor differences in performances emerge.[32] The discrepancies in the amount of productivity growth realized between the more and less capital-intensive industries are rather trivial in magnitude. As for the other system of classification, the more mechanized industries do seem to have experienced higher rates of advance than the less mechanized did. However, these disparities are small relative to the rates of increase, and are dependent on NFP serving as the gauge for total factor productivity. Another feature of these estimates that bears against the hypothesis that much of the technical change realized was embodied in physical capital and not reflected in its price is the relative decline in the rate of total factor productivity growth of the less mechanized and capital-intensive industries, as compared to their counterpart classes, between the subperiods 1820–50 and 1850–60. As already alluded to, the rates of increase of both capital intensity and labor productivity accelerated sharply between the two subperiods among the former classes of industries relative to the latter.[33] If the capital investments involved considerable embodied technical change, then one might have expected a relative increase in the pace of total factor productivity in the less mechanized and capital-intensive industries to have accompanied the relative surge in capital deepening and labor productivity.

Regardless of how persuasive these arguments for questioning the extent of embodied technical change are, it is informative to decompose the growth over the period in gross output per equivalent worker between the amounts directly attributable, in an accounting sense, to increases in capital intensity (*K/L*), in raw materials intensity (*RM/L*), and in total factor productivity (TFP). The results of such a procedure are reported in table 13.13, with separate estimates presented for the estimates obtained from the firm data and those from the aggregate data. They indicate that in most industries the increase between 1820 and 1860 in capital intensity explains less than 10% of the growth in labor productivity as measured by GQLP. Indeed, in no case does the share exceed 16%. Advances in total factor productivity, on the other hand, appear to be the principal force behind labor productivity growth, generally accounting for over half of the increase in GQLP and never

Table 13.12 Indexes of Total Factor Productivity for Classes of Manufacturing Industries, 1820–60

	Mechanized Industries		Other Industries		Capital-Intensive Industries		Other Industries	
Year	NFP	TFP	NFP	TFP	NFP	TFP	NFP	TFP
1820	100	100	100	100	100	100	100	100
1850 (firm)	[166]	[133]	[155]	[134]	[159]	[131]	[162]	[141]
1850 (aggregate)	181	138	181	147	181	138	182	151
1860 (firm)	[221]	[169]	[186]	[166]	[204]	[165]	[205]	[175]
1860 (aggregate)	249	176	209	176	231	172	229	186
Per annum growth rates:								
1820–50	[1.8]–2.1	[1.0]–1.1	[1.5]–2.1	[1.0]–1.3	[1.6]–2.1	[0.9]–1.1	[1.7]–2.1	[1.2]–1.4
1850–60	[2.9]–3.2	[2.4]–2.4	1.4–[1.9]	1.8–[2.1]	2.5–[2.5]	2.2–[2.4]	2.3–[2.4]	2.1–[2.2]
1820–60	[2.0]–2.4	[1.4]–1.5	[1.6]–1.9	[1.3]–1.5	[1.8]–2.2	[1.3]–1.4	[1.9]–2.2	[1.4]–1.6

Notes and sources: These estimates were computed as weighted averages of the industry-specific figures underlying the indexes presented in tables 13.9, 13.10, and 13.11. The weighted averages were constructed with the system of weighting employed in table 13.7. See the notes to those tables.

Table 13.13 Decomposition of the Growth in Gross Output per Equivalent Worker between Proportions Accounted for by Increases in Capital Intensity, Raw Materials Intensity, and Total Factor Productivity, 1820–60 (%)

Industry	% Due to Δ (*K/L*)	% Due to Δ (*RM/L*)	% Due to Δ TFP
Boots/shoes			
F	11	34	54
A	1	25	74
Coaches/harnesses			
F	9	29	61
A	7	19	74
Cotton textiles			
F	−2	48	54
A	5	46	49
Furniture/woodwork			
F	4	27	68
A	4	26	70
Glass			
F	—	—	—
A	5	37	57
Hats			
F	5	48	46
A	0	40	60
Iron			
F	3	42	55
A	6	30	63
Liquors			
F	11	28	61
A	14	21	65
Flour/grist mills			
F	13	12	75
A	13	12	75
Paper			
F	3	52	44
A	6	50	43
Tanning			
F	11	43	46
A	11	46	43
Tobacco			
F	16	59	25
A	4	28	68
Wool textiles			
F	4	44	51
A	5	46	49

Notes and sources: The decomposition of the growth in gross output per equivalent worker was based on the accounting equation:

$$\dot{GQLP} = \dot{TFP} + 0.13\,(\dot{K/L}) + 0.54\,(\dot{RM/L}),$$

where ˙ signifies a derivative of the log. Separate decompositions were computed for the firm-level (F) and aggregate (A) data from 1860. See the notes to tables 13.5 and 13.8.

less than 25%.[34] These findings dramatize how remarkably limited the importance of capital deepening was in generating labor productivity growth in manufacturing during early industrialization. They imply that if capital accumulation played a substantial role at all, it was due to improvements in capital that were not reflected in price. Given the basis for skepticism about the extent to which technical progress was embodied in capital outlined above, other sources of total factor productivity, and thus of labor productivity, growth appear to deserve more attention.

13.4 Conclusions

This paper has relied on four cross-sections of manufacturing firm data to study the growth of labor and total factor productivity during early industrialization in the United States. Although the bodies of evidence analyzed suffer from some defects, the procedures employed in constructing the estimates were designed to deal with the problems and yield growth rates that would be biased downward. Despite this concern for producing conservative estimates, the results indicate that a wide range of manufacturing industries realized major increases in both labor and total factor productivity as early as the 1820s, and continued to do so at an accelerated pace through 1860. The breadth, magnitude, and timing of the advances observed suggest that the northeastern manufacturing sector was a dynamic one, whose productivity growth, perhaps coupled with similar gains in agriculture, fueled the process of industrialization in that region. The evidence would seem to make it increasingly difficult to sustain the view that the onset of industrial expansion in the Northeast was primarily due to the release of labor and other resources from a stagnant and declining agricultural sector.

Of perhaps even greater interest, the estimates imply that increases in total factor productivity, sometimes referred to as the residual, accounted for most of the advance in labor productivity between 1820 and 1860. The deepening of capital, in contrast, appears to have made only a modest contribution. Although it is possible that a major share of the growth in the residual over the period consisted of technical change embodied in capital equipment, which would enhance the significance of capital in explaining the gains in productivity, the shreds of evidence that can be gleaned from these data do not support this notion. Capital accumulation may indeed have had important influences on the course of early industrial development, such as through allowing for the extension of the transportation network and other social overhead capital, but the introduction of sophisticated capital equipment and capital deepening in general were evidently not as central to the initial phase of industrialization as they have sometimes been depicted.

On the contrary, the material examined here seems to suggest that other sources of measured productivity growth in manufacturing, including the changes in labor organization and the intensification of work that have been emphasized in recent studies, played the leading roles (Goldin and Sokoloff 1982; Sokoloff 1984b; Lazonick and Brush 1985). Although many questions remain, the results also appear to be consistent with, if not actually to support, the view that the expansion of markets that accompanied the onset of industrialization unleashed powerful forces that acted to raise productivity. At least in the United States, pre-industrial manufacturing seems to have had the potential, which it was ultimately to realize, for substantial gains in efficiency without major additions to the stock of capital equipment utilized per unit of labor.

Notes

1. Nearly all studies of productivity growth during this period have been based on information that was either highly aggregated or drawn only from a small number of cotton textile firms (Layer 1955; Davis and Stettler 1966; David 1967, 1975, 1977; McGouldrick 1968; Williamson 1972; 1972a, 2b, 1986; Nickless 1979).

2. Each of the data sets suffers from problems of sample selection bias. The coverage of the 1820 Census of Manufactures and the *McLane Report* differed substantially by geographic region and size of establishment, with an apparent net result of an undersampling of smaller, and accordingly less productive, firms. The design of the samples from 1850 and 1860 led to a disproportionate representation of firms from states with limited industrial development. See Sokoloff (1982) and Atack et al. (1979) for details on the characteristics of these samples. Since the sample selection biases are likely to raise the estimated productivity levels for 1820 and 1832, and reduce them in 1850 and 1860, the rates of productivity growth computed from these sources should understate the actual record.

3. The industrial classification system employed in the 1850 census was in general adopted, but several of the industry definitions used here include two or more of the 1850 categories. The reluctance to combine data from different industries stemmed from a concern about the possibility of confusing increases in labor productivity within industries over time with variation in the estimates due to changes in industrial composition.

4. This generalization about the reporting practices of part-time establishments is based primarily on an examination of the schedules for roughly 200 firms in the 1820 and 1832 samples that specified the fractions of the year they were in operation. Rather than expunging observations of seasonal enterprises from the calculations, one would of course prefer to have accurate assessments of their inputs and outputs to work with so that their levels of performance would be reflected in the estimates. It is likely that part-time firms, whose relative importance declined over time, were indeed less efficient producers than their full-time counterparts. Accordingly, to the extent that the adjustments in the composition of the subsamples do succeed in excluding all part-time establishments from consideration, the estimates of productivity growth might tend to understate the advances realized over the period by failing to pick up the perhaps important gains to the economy of displacing seasonal operators with full-time producers.

5. It is admittedly unclear what fractions of manufacturing firms in the various years were operating significantly fewer than 50 weeks per year (fulltime). A general sense of the orders of magnitude has been obtained, however, from the reports by many firms in 1832 of the fraction of the year they were in operation, from an examination

of the cross-sectional distributions of establishments by industry, size, wage rates, and location, as well as from inspections of the distributions of firms by measures of total factor productivity. The approach adopted in preparing the three sets of estimates was not to attempt a precise delineation of the proportion of firms operating part time in the individual years, but rather to demonstrate that no plausible assumptions about the changes in their relative numbers would reverse the qualitative findings. Although ad hoc in nature, this manner of displaying the patterns in the data appears effective. One can check the sensitivity of the industry-specific results by comparing the figures from the three sets of estimates, or by evaluating the C figures for 1820 with respect to the B figures for the later years. The extent of the allowance for the decreasing prevalence of part-time firms implied by this latter comparison appears to be extremely generous.

6. In this paper, such summaries of the quantitative results are based on the choice of the 1860 estimates computed from the aggregate data as the standard for that year.

7. The weights employed to construct the averages consist of the industry shares of total northeastern value added and gross output, respectively, in 1850, and were calculated from United States Census Bureau (1858). The two point estimates available for 12 of the industries in 1850 and 1860, as well as the growth rates they enter into, will henceforth be expressed as a range of estimates (i.e., 72%–112%).

8. The general robustness of the results is apparent from the observation that the estimates of labor productivity in 1820 are greatly affected by the shift from the B subsample to the C in only a few industries. The value-added figures are considerably more sensitive to the subset of establishments employed in the calculations, but even by this measure, only three of the industries have their levels of labor productivity raised by as much as 15%.

9. Of greatest concern in this regard are the glass, liquor, and tobacco industries. All of these industries are characterized by having estimates based on very few observations in at least one of the years. Random variation in the estimates due to this source may magnify the impact of sample selection bias in some cases. For example, the extremely high levels of productivity estimated for the glass industry in 1832 is probably related to their being computed from information on a rather small number of glass-making enterprises in Massachusetts. The most advanced plants in that industry were located in Massachusetts (Davis 1949), and that state accounted for a disproportionate share of the firms included in the *McLane Report*.

10. The 1850 and 1860 samples were designed to ensure that each state accounted for a certain minimum number of observations. This feature of their collection led to an oversampling of manufacturing firms from smaller and less-developed states such as Maine, Vermont, and New Hampshire. The establishments located in such states operated, on average, at lower levels of productivity. Accordingly, one would expect that this source of sample selection bias would lead to underestimates of productivity. In principle, one should be able to correct for this sample selection problem by reweighting the observations. In practice, however, inconsistent evidence from the aggregate census reports and the firm samples on the industrial composition of state manufacturing sectors suggests that there are other defects in the samples that confound the identification of the appropriate set of weights.

11. It is, of course, important to recognize that the great majority of the price series pertain only to a single output or raw material of the respective industries. Hence, they undoubtedly introduce errors and must be applied with caution. The four industries for which raw materials indexes could not be retrieved are coaches/harnesses, glass, hats, and iron. The Wholesale Price Index constructed by Warren and Pearson was employed as a reasonable substitute in these cases, because it behaves more like the average of the other raw materials series than the alternative general indexes. Another deficiency is that in two industries, tobacco and tanning, the author was compelled to rely on basically the same price index for both outputs and raw materials. It is especially unfortunate that separate indexes could not be obtained for these industries, because the indexes, which pertain primarily to the price of raw materials, move quite erratically. Additional information on whether the prices of outputs and raw materials in each of these industries actually followed such peculiar paths would be quite helpful. It seems

likely that the extraordinary variability in these price indexes accounts for at least some of the irregular movements in the productivity growth estimates for these industries.

12. In cases where there were several alternative price indexes available, the most conservative, with respect to the estimation of the increase in productivity over time, were generally selected.

13. This suggests that a significant portion of the variability in the labor productivity estimates is due to sharp changes in the factor proportions utilized by the firms sampled.

14. The extreme decline in the price index for paper output invites skepticism. However, it should be noted that the general stability between 1820 and 1860 in the ratio of gross output to raw materials in that industry would seem to suggest that the output price index might not be far off in terms of the extent of the decrease over the entire period.

15. As was mentioned above, the price indexes for tanning and tobacco fluctuate wildly, particularly between 1859 and 1860. The erratic behavior of the index for "hides and leather" may also affect estimates for boots/shoes, because this series serves as the index for raw materials in that industry, as well as for both outputs and raw materials in tanning.

16. The argument presented in this paragraph applies to estimates of productivity growth that employ value added as the measure of output. Hence, it supplies a rationale for why the value-added figures might indicate less advance over the period than those relying on gross output as the appropriate measure of product. Given the uncertainty about the accuracy of the individual price indexes, however, any conclusions about the relative performance of two industries, regardless of the measure of productivity referred to, should be offered tentatively.

17. There are, admittedly, some scholars who judge part-time operations to be the rule during the early stages of industrialization, rather than the exception. Moreover, few would expect there to be many firms in industries such as flour/grist mills that were in production all year. Nevertheless, the enumerators for the *McLane Report* indicated that the overwhelming majority of the establishments included in that survey claimed to be in operation for at least 50 weeks a year. Although the level of production in any individual firm may have been characterized by enormous seasonal variation, there might have been tasks that required at least some workers to be employed throughout the year. As long as enterprises in such circumstances reported their average labor and capital inputs, they should, for our purposes, have been classified as full-time operators and included in the subsets of firms over which the estimates were prepared.

18. As is apparent from the evidence presented in Goldin and Sokoloff (1982), the ratio of female to adult male wages increased from roughly the 0.30–0.37 range in 1820 to roughly the 0.44–0.52 range in 1850 and beyond. Hence, to the extent that the wage ratio reflects the average relative productivity of the two groups, it might be argued that employing the same weights in all years leads to overestimates of the amount of productivity growth. The issue turns, however, on whether the change in the relative productivity of females is due to variation over time in the age or skill composition of workers, or to some other factors. In any case, a wide range of weights for females and boys was tested, and the general qualitative results were found to be insensitive to reasonable variation in them.

19. It was further assumed that in no industry at 1850 or 1860 did boys account for more than 33% of the male labor force. Such a constraint, probably serves to bias upward the estimates of the labor input for several industries. The ceiling on the proportion of males who were boys was introduced as another way of ensuring that the estimates of the labor input in the later years would err on the high side, if at all.

20. This would be expected, because of the scale economies present in most manufacturing industries (Sokoloff 1984b). The bias is likely to have been greater in the 1832 sample, because Massachusetts firms accounted for a highly disproportionate share of the enterprises covered by that survey, and generally were larger and had higher-than-average levels of measured productivity.

21. For example, the weighted average of the industry rate of growth in gross output per equivalent worker, as computed from the C estimates for 1820 and the B estimates for 1860, ranges between 2.4% and 2.6% per annum. These figures are only slightly

lower than the 2.5%–2.7% range derived from the employment of the B estimates for both years.

22. The Davis and Stettler series might be expected to yield estimates of the variation in output per worker over the business cycle that were downward biased, because their figures pertain to output per man-hour. See Davis and Stettler (1966).

23. One caveat to this generalization is that the iron and steel industry appears to have been quite depressed during the late 1840s and early 1850s. See Temin (1964).

24. The industries were ordered in terms of capital intensity by the information on their aggregate capital-labor ratios in the Northeast obtained from United States Census Bureau (1858), and then divided into groups. The same classification of industries is derived from the 1820 firm data. The ranking by machinery intensity was computed from information contained in the 1820 and 1832 samples of firm data, particularly the latter, as well as in United States Census Office (1895). Industries were placed in categories on the basis of estimates of the investment in machinery per unit of labor computed for 1832.

25. The cotton textile establishments in the firm samples were, on average, also smaller and substantially less capital intensive than their counterparts in the aggregate data. Their levels of total factor productivity were, however, not much lower. The massive disparity in measured labor productivity may be due to the less developed states', which were overrepresented in the samples, being characterized by a much different system or type of cotton textile manufacture.

26. It must also be admitted that these indexes of partial factor productivity not infrequently exhibit irregular, if not implausible, movements from one point in time to another, as well as discrepancies between the firm- and aggregate-level estimates for 1850 and 1860. As I contended above in discussing the labor productivity figures, many of the former type of problems may be due to inaccurate price indexes, excessive variability in point estimates because of a small number of observations, or sample selection biases. The disparities between the independent estimates for 1850 and 1860 are disturbing, but they might again be partially explained by many of the firm-level estimates being based on the characteristics of relatively few firms located in unrepresentative areas. These anomalies in the data indicate that much caution should be exercised in drawing conclusions, particularly with respect to changes over short periods, but they do not justify a blanket dismissal of the results.

27. The other principal issue has concerned whether firms reported the gross value of their capital investment or the net value. Recent work has tended to agree that some net measure of the capital stock was being reflected in the figures. See Gallman (1986) and Sokoloff (1984a).

28. If one computes the weighted-average growth in total factor productivity from the C figures for 1820 and the B figures for 1860, the estimates decline only slightly. NFP rises by 88%–112% over the period, while TFP increases by 61%–69%.

29. One could, for example, explain the acceleration in total factor productivity as arising from the expansion of product markets, which stimulated changes in the organization of production within the firm, technical change, and intraregional specialization between the more urbanized counties and the outlying areas within the Northeast (Lindstrom 1978; Sokoloff 1984b).

30. Although it is difficult to imagine that variation in the relatively small amount of tools and machinery per worker could account for much of the large changes observed in productivity, it would be helpful to know, by industry, how the former ratio moved over time. Unfortunately, of all the data sets being examined here, only the 1832 sample contains the detailed information on the composition of capital necessary to estimate the ratio. It seems likely, however, that the percentage changes in machinery and tools per equivalent worker would resemble the course of the capital-to-labor ratio, because the shares of capital invested in tools and machinery had not been altered much by 1890 (Sokoloff 1984a; United States Census Office 1895).

31. This conjecture does not necessarily hold, but if all else was constant, one would expect it to. The chief obstacles or objections to its applicability probably concern the variation across industries in the rates at which capital goods depreciated, old vintages were replaced by new, and output increased over the period. The complication arising from this latter situation is that the industries that grew most rapidly would tend to benefit relatively more from technical change embodied in capital even if their capital-

labor ratios were low and had not changed much, because a greater proportion of their capital stock would consist of new-vintage items.

32. A series of pooled cross-section production functions were estimated with various measures of output serving as the dependent variable and measures of the inputs, year dummies, industry dummies, class dummies, and interactions appearing as independent variables. When variables for the interaction between dummies for the more mechanized or capital- intensive industries and the year 1860 were included in the specifications, the coefficients on them generally failed to indicate that these classes of industries realized significantly more productivity growth between 1820 and 1860.

33. For example, the per annum rates of growth of capital per equivalent worker between 1820 and 1850 ranged from 0.8%–1.1% and −0.1% to +0.1% for the more and less mechanized industries, respectively. During the next decade, the less mechanized industries experienced a sharp acceleration in their absolute and relative rates of increase of this variable to 4.0%–6.8% per annum, as compared with the 0.8%–2.1% pace registered by their counterparts.

34. If one decomposes the growth in value added per equivalent worker, the qualitative result is the same. Increases in the capital-labor ratio directly account for only a small fraction of the progress realized, leaving most of the rise in labor productivity to be explained by advances in total factor productivity.

Comment Jeffrey G. Williamson

Motivation and Findings

Although most economic historians and development economists seem to share the view that technological change is the driving force behind all Industrial Revolutions, it is surprising what little we know about its quantitative dimensions. True, since Abramovitz and Solow pointed the way 25 years ago, we have learned something about aggregate rates of total factor productivity growth economy-wide. But we still know very little about sectoral rates of total factor productivity growth, and it is at the sectoral level that the issue is of most importance.

Why do we care about sectoral measures of total factor productivity growth? Because we think that many of the stylized facts of the Industrial Revolution that matter reflect unbalanced total factor productivity advance. For open economies with relatively price-elastic output demands, unbalanced rates of total factor productivity growth are likely to do most of the work fostering the shift in output mix toward the dynamic modern sectors. The shift in output mix has, in turn, important implications for other endogenous variables of critical interest to us. Since the dynamic sectors tend to be urban based, city job creation and urbanization are assured. To the extent that the dynamic sectors tend to be skill intensive, wage inequality is fostered. And to the extent that the dynamic sectors tend to be capital intensive (especially when the indirect requirements for urban dwellings and social overhead are considered), investment requirements are augmented, saving rates tend

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to rise, and the rate of accumulation tends to accelerate. Apart from these important macro issues, information on productivity growth by industry clearly increases the opportunity to isolate the correlates of growth and thus to better understand the carriers of growth.

So it is that unbalanced total factor productivity advance during early industrialization must be better understood. Strangely enough, only a handful of Third World economies offer such evidence, and for Britain's First Industrial Revolution we still can only guess by reference to average labor productivities (Floud and McCloskey 1981).

There is an obvious reason for our quantitative ignorance: the data base is poor. This fact of life insures that the intrepid researcher is bound to stir critical debate. And so it is that Professor Sokoloff's "Productivity Growth in Manufacturing during Early Industrialization" is likely to stir critical debate here today.[1]

First, the database. Sokoloff has collected establishment production data for 1820, 1832, 1850, and 1860 in the American Northeast. The 1850 and 1860 data are taken from the Bateman-Weiss samples drawn from the *Census of Manufactures*, while Sokoloff (1982) himself has sampled the 1820 *Census of Manufactures* and the 1832 *McLane Report*.

Second, the findings. Using estimation procedures pioneered by Abramovitz, Kendrick, Denison, and others, Sokoloff emerges with the following impressive findings:

1. Antebellum labor productivity growth in manufacturing was much more rapid than has been appreciated (table 13.6);
2. Labor productivity growth was impressive enough in the 1820s and early 1830s so that there appears to be only weak evidence of trend acceleration over the antebellum period as a whole, especially in the gross output figures and especially over the first three decades of the antebellum period (table 13.6);
3. The estimated rates of total factor productivity growth are very rapid (table 13.11). They are highest in textiles, glass, paper, hats, furniture, and woodwork, but other sectors reveal impressive rates too;
4. Total factor productivity advance underwent modest acceleration up to 1850 before rising sharply in the decade following (table 13.11);
5. Total factor productivity growth typically "accounts for" more than 50% of labor productivity growth over the four decades as a whole, and capital deepening rarely "accounts for" more than 10% (table 13.13).

These are impressive findings. Can we believe them?

1. Professor Sokoloff has revised his paper extensively since the Williamsburg Conference. As a result, some of the remarks I made as a discussant no longer have relevance. This comment has been rewritten accordingly, although I have tried to retain the flavor of the debate.

Three Problems

Aggregation

What was manufacturing's overall performance? While Sokoloff supplies both weighted and unweighted averages, most of us would prefer the former. Otherwise it is difficult to assess exactly how important any given sector's performance was to manufacturing as a whole. Unfortunately, the weights employed are fixed at 1850 levels so that relatively dynamic sectors are not allowed to have their full impact on aggregate productivity performance as they increased their industrial output shares over time. But even if the aggregation was flawless, there is nothing to guarantee that those aggregates would coincide with the true rates of total factor productivity growth in manufacturing. After all, total factor productivity growth in manufacturing is composed of two parts, intra-industry total factor productivity growth, which Sokoloff reports in table 13.11, and *inter*industry total factor productivity growth, which he ignores. Much has been made of interindustry total factor productivity growth in the development and historical literature, the result stemming from improved resource allocation. For example, McCloskey (Floud and McCloskey 1981, p. 118–19) estimates a "Harberger Triangle" due to capital market imperfections in Britain—the area *ABC* in figure C13.1—and infers that its elimination between 1780 and 1850 would have added 0.1% per annum to economy-wide total factor productivity growth rates. If the same was true of labor markets, then the interindustry source might have been 0.2% per annum. The figures are likely to have been even larger for a faster growing economy with a larger boundary like America.

In short, the very modest acceleration in total factor productivity growth up to 1850 may or may not have been an attribute of American antebellum manufacturing—it depends on the importance of each of the sectors for which Sokoloff supplies productivity estimates, *and* it depends on the interindustry component which he ignores.

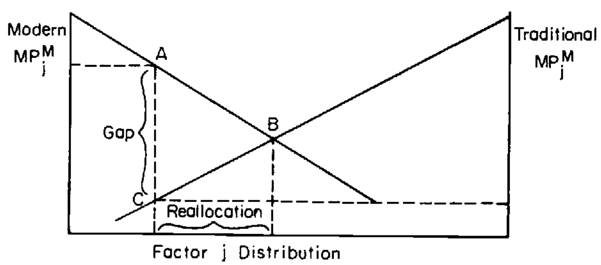

Fig. C13.1 Factor market imperfections and the Harberger Triangle.

The Effective Labor Stock

How shall we aggregate heterogeneous labor inputs? American manufacturing employed adult males, females, and children during the antebellum period, and the labor input mix varied over time and across industries. Sokoloff uses a constant weight rule of thumb ("notes and sources" to table 13.1), namely,

$$TE = M + 0.5(F + B) + E$$

where

TE = "equivalent" adult male workers = "effective" labor stock
M = adult males
F = females
B = boys
E = the entrepreneur.

This labor aggregation scheme is used throughout.

The first problem Sokoloff must confront is that the 1850 and 1860 censuses do not report adult males and boys separately. His solution is to assume that the 1820 distribution applies to 1850 and 1860 as well. Sokoloff thinks that this assumption is likely to impart a "small upward bias" to the measured growth of the effective stock of labor. I suspect that the bias may be larger than he admits, and that labor productivity and total factor productivity growth rates may be significantly understated, and further that the relative stability in productivity growth up to 1850 may be in part a spurious fabrication. I encourage Sokoloff to prove me wrong by sensitivity analysis.

The second problem which Sokoloff's procedure introduces is the constant weight applied to females and boys. The weight is guided by an average of the age/sex wage ratios prevailing in the 1850s (ranging between 0.34 and 0.55), when in fact it rose *sharply* over the antebellum period (from a range between 0.25 and 0.35 in the 1820s). While Sokoloff believes the constant-weight procedure tends to understate labor force growth, thus overstating labor productivity and total factor productivity growth, I would like to know more about which industries and which periods were most affected by the constant-weight assumption. In any case, it is not clear to me why *variable* weights cannot be used to construct the effective labor stock.

Certainly Paul David worried about both of these problems when looking at antebellum cotton textiles (David 1970), and Pamela Nickless (1979) did as well. Indeed, Nickless (1979, p. 902) estimated total factor productivity for cotton textiles 1836–60 to have grown far slower than Sokoloff's estimates for 1832–60 imply. Why? Sokoloff does not supply his effective labor stock estimates in the paper, but I suggest the answer may lie with his labor aggregation scheme.

The Flow of Labor Services

The 1820 census recorded "part-time" establishments which were of small size and seasonal. The share of establishments which were part-time varied over time and across industries: they appear to have been a far smaller share of all firms in the 1832 *McLane Report* as well as in the 1850 and 1860 censuses. To the extent that scale economies mattered during this era of the rise of large scale factories, and given that the smaller, part-time firms were less efficient, then the demise of the part-time firms was an important ingredient of industry total factor productivity growth. Indeed, Sokoloff himself supports this view in this paper and elsewhere (Sokoloff 1984). If I understand Sokoloff correctly, this important source of productivity growth has been purged from his samples B and C. Since it appears he has used B from table 13.6 onward, he understates total factor productivity growth, particularly for those industries in which the decline of part-time establishments was especially dramatic, and especially early in the antebellum epoch.

Sokoloff is faced with the following problem. The part-time firms record total employment stocks, rather than seasonally adjusted labor service flows. Rather than attempt to convert the part-time labor force to full-time estimates, Sokoloff chooses instead to truncate his samples. That is, those firms with "low" total factor productivity are purged from the sample on the grounds that they are the part-time firms in which labor inputs are overstated. Those purged from sample B amount to 29% in 1820, 5% in 1832, 9% in 1850, and 10% in 1860. Sokoloff also truncates his samples from the top, but the magnitudes are far smaller.

I have trouble with this treatment of part-time firms. Their demise was an important part of the technological process that Sokoloff is out to measure, and I believe the underlying total factor productivity growth rates are seriously biased as a result. Would the stability in productivity growth up to 1850 still be apparent if part-time firms were properly treated? I wonder.

How else might Sokoloff proceed? Here's one suggestion. Compute the average annual wage payment (by age and sex if possible) per worker by sector in the 1820 full-time firms (already identified by their "high" total factor productivity). Convert those annual wage rates to monthly wage rates. Assume that the monthly wage rates apply to the part-time firms, infer the number of months that the part-time firms were in operation, and scale down the labor input to the part-time firms accordingly.

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