PRODUCTIVITY GROWTH IN MANUFACTURING
DURING EARLY INDUSTRIALIZATION:
EVIDENCE FROM THE AMERICAN
NORTHEAST, 1820 TO 1860

Kenneth L. Sokoloff

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ABSTRACT

This paper reports estimates of labor and total factor productivity, for thirteen 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.

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It has long been recognized that industrialization got under way in the U. S. 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 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 (Chandler, 1977; David, 1975; Landes, 1969, 1985; Lazonick and Brush, 1985; Marglin, 1974; Sokoloff, 1984b).

Despite the clear significance of the issues involved, there have been few studies of productivity growth during early U. S. 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 make them together an unequalled 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 four 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 thirteen 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 II 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 III. They reveal that if one treats firm valuations of their capital investments as relatively accurate assessments of the capital input, as it is contended here 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 suggest imply about the early stages of industrialization in the U. S. are offered in section IV.

II

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 1 and 2, respectively, for thirteen 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, $\underline{A}$, $\underline{B}$, and $\underline{C}$, 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 sub-samples 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 explicitly identify themselves, several methods of ordering the establishments by their probability of being part-time operators, so that selected proportions could be dropped from the sub-samples over which productivity was estimated, were applied to the

TABLE 1
Nominal Value Added per Equivalent Worker in
Selected Manufacturing Industries: 1820 to 1860

		1820	1832	1850 (firms)	1850 (agg.)	1860 (firms)	1860 (agg.)
Boots/Shoes	A	$276.0 (22)	–	$283.5 (254)		$430.7 (170)	
	B	323.3 (17)	–	290.1 (247)	$305.4 (8110)	434.2 (161)	$421.7 (7326)
	C	350.0 (15)	–	306.7 (207)		454.7 (133)	
Coaches/	A	473.7 (33)	$330.6 (36)	388.4 (96)		691.4 (122)	
Harnesses	B	490.5 (31)	359.6 (35)	461.5 (88)	435.4 (2635)	697.5 (118)	600.1 (5057)
	C	502.5 (28)	368.9 (32)	464.2 (77)		645.8 (98)	
Cotton	A	352.8 (64)	504.3 (76)	322.3 (24)		494.9 (23)	
Textiles	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)	
Furniture/	A	395.0 (25)	359.9 (26)	380.6 (48)		664.7 (42)	
Woodwork	B	434.2 (21)	364.6 (25)	421.7 (46)	517.3 (2299)	695.8 (38)	674.5 (1804)
	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 (1494)	613.6 (21)	648.1 (1288)
	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)	1469.4 (922)
	C	667.1 (107)	–	793.8 (4)		1514.3 (10)	
Flour/	A	442.8 (70)	–	530.0 (109)		846.1 (105)	
Grist Mills	B	566.1 (45)	–	549.3 (104)	689.7 (5128)	900.4 (97)	906.4 (4964)
	C	638.8 (34)	–	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)	1128.9 (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 (3256)	825.7 (69)	1033.5 (2670)
	C	499.9 (47)	543.2 (33)	562.1 (65)		896.0 (53)	
Tobacco	A	373.4 (8)	–	312.8 (15)		733.7 (12)	
	B	466.4 (7)	–	312.8 (15)	240.1 (628)	733.7 (12)	667.1 (918)
	C	517.9 (5)	–	360.7 (12)		744.8 (11)	
Wool	A	373.4 (53)	650.9 (59)	730.7 (42)		871.5 (23)	
Textiles	B	466.4 (35)	651.7 (58)	739.2 (40)	563.2 (1375)	871.5 (23)	849.7 (1041)
	C	571.9 (19)	652.0 (48)	738.8 (35)		840.7 (20)	

Table 1

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 (U. S. House of Representatives, 1832). The
aggregate estimates were computed from the industry-wide information
reported by state in U. S. 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
separately enumerate adult males and boys. Accordingly, the reported
numbers of male employees in those years were decomposed 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 percent of male employees
in 1820, it was further assumed that the shares had been reduced to 33

percent by 1850 and 1860.

The estimates based on firm data were computed over sub-samples 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 sub-sample of establishments over which the productivity estimates were computed.

Three sets of productivity estimates have been prepared from three corresponding sets of firm sub-samples. The sets of sub-samples 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 sub-samples 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 sub-samples included those with negative value added, a few other large outliers, and those who placed in the top 3 percent of enterprises in the respective years by both measures of total factor productivity. These criteria led to 4 percent being truncated from the 1820 sample, 3 percent from that in 1832, 5 percent in 1850, and 4 percent 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 sub-sample, establishments that ranked in the lowest 30 percent by both
measures of total factor productivity were dropped from sub-sample A
to get B. The corresponding percentages were 5 percent in 1832, 10
percent in 1850, and 10 percent 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 part-time, 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 percent in 1820, 5 percent in 1832, 9 percent in 1850, and 10
percent in 1860.

For set C, even larger fractions of the firms in the samples
were truncated. Firms that, by either measure of total factor
productivity, were in the bottom 40 percent of the 1820 sample were
left out of the sub-sample that was the basis for the C estimates of
that year. The corresponding threshold points for truncation from the
C sub-samples for the other years are 10 percent for 1832, 20 percent

for 1850, and 20 percent for 1860. In addition, those establishments that were in the top 3 percent of firms by either measure of total factor productivity in their respective years, and had not already been dropped from the A and B sub-samples, were also truncated to produce the C sub-samples. These criteria led to 48 percent being truncated from the 1820 sample, 17 percent from that of 1832, 28 percent from that of 1850, and 29 percent 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 sub-sample. 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 2
Nominal Gross Output per Equivalent Worker in
Selected Manufacturing Industries: 1820 to 1860

		1820	1832	1850 (firms)	1850 (agg.)	1860 (firms)	1860 (agg.)
Boots/	A	$517.6 (22)	–	$556.8 (254)		$904.2 (170)	
Shoes	B	581.2 (17)	–	564.1 (247)	$563.0 (8110)	910.1 (161)	$803.6 (7326)
	C	594.6 (15)	–	593.7 (207)		940.7 (133)	
Coaches/	A	873.8 (33)	$574.4 (36)	765.9 (96)		1175.8 (122)	
Harnesses	B	904.6 (31)	614.0 (35)	902.4 (88)	763.4 (2635)	1184.2 (118)	987.5 (5057)
	C	928.1 (28)	622.1 (32)	932.3 (77)		1136.4 (98)	
Cotton	A	668.4 (64)	927.7 (76)	1045.0 (24)		1053.2 (23)	
Textiles	B	721.6 (45)	928.6 (75)	1056.6 (23)	1073.7 (856)	1053.2 (23)	1497.0 (840)
	C	796.7 (25)	933.7 (69)	1046.3 (18)		1574.0 (20)	
Furniture/	A	629.2 (25)	677.3 (26)	724.4 (48)		1023.8 (42)	
Woodwork	B	665.1 (21)	685.8 (25)	742.3 (46)	830.9 (2299)	1064.0 (38)	1027.4 (1804)
	C	760.5 (15)	721.0 (22)	762.5 (39)		1096.5 (31)	
Glass	A	676.0 (3)	1300.4 (6)	–		–	
	B	676.0 (3)	1300.4 (6)	–	879.4 (77)	–	1030.5 (79)
	C	727.2 (2)	1299.6 (5)	–		–	
Hats	A	796.2 (27)	1027.5 (13)	1329.0 (17)		1866.6 (13)	
	B	899.3 (22)	1027.5 (13)	1338.7 (16)	1278.2 (814)	1866.6 (13)	1605.3 (281)
	C	816.7 (19)	1061.2 (10)	1377.2 (12)		1868.1 (11)	
Iron	A	762.2 (32)	–	745.2 (36)		1457.1 (23)	
	B	1251.4 (21)	–	872.2 (33)	1030.5 (1494)	1588.2 (21)	1422.2 (1288)
	C	1347.1 (15)	–	881.7 (28)		1788.9 (15)	
Liquors	A	1554.5 (177)	–	1454.0 (7)		4253.9 (13)	
	B	1882.1 (132)	–	1606.0 (6)	3341.0 (633)	4508.9 (12)	4252.1 (922)
	C	1954.0 (107)	–	1806.6 (4)		4898.0 (10)	
Flour/	A	1950.3 (70)	–	3895.9 (109)		5756.9 (105)	
Grist Mills	B	2540.3 (45)	–	4037.1 (104)	4900.8 (5128)	6117.0 (97)	6154.7 (4964)
	C	2650.4 (34)	–	4794.6 (64)		6599.5 (64)	
Paper	A	667.9 (23)	1418.2 (27)	2153.1 (20)		1619.1 (20)	
	B	673.3 (22)	1418.2 (27)	2153.1 (20)	2065.8 (361)	1648.4 (19)	2286.9 (472)
	C	690.2 (20)	1477.8 (23)	1953.5 (18)		1874.9 (14)	
Tanning	A	853.5 (120)	1535.7 (45)	1412.3 (98)		2750.5 (77)	
	B	1037.0 (76)	1550.2 (43)	1455.5 (92)	1909.3 (3256)	2825.1 (69)	3573.5 (2670)
	C	1218.7 (47)	1450.2 (33)	1581.8 (65)		3043.0 (53)	
Tobacco	A	669.0 (8)	–	727.2 (15)		1781.4 (12)	
	B	682.6 (7)	–	727.2 (15)	715.0 (628)	1781.4 (12)	1120.3 (918)
	C	703.6 (5)	–	838.2 (12)		1809.8 (11)	
Wool	A	677.3 (53)	1662.8 (59)	1756.1 (42)		2086.6 (23)	
Textiles	B	821.3 (35)	1664.8 (58)	1776.7 (40)	1530.8 (1375)	2086.6 (23)	2143.4 (1041)
	C	906.1 (19)	1681.3 (48)	1784.6 (35)		2120.5 (20)	

Table 2

Notes and Sources: See the note to Table 1. The estimates were calculated as the ratio of the value of gross output to the total number of equivalent adult male workers.

problem, and yielded roughly similar results. The method and procedures underlying the construction of the three sets of sub-samples employed in this paper are explained in the note to Table 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 1 and 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 thirteen selected industries registered significant advances in product per equivalent worker, by each of the measures. Ten of the thirteen managed a greater than 50 percent 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 73 and 102 percent respectively, whereas the weighted average increases are only slightly different, 72 and 112 percent.[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 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 $\underline{A}$ estimates imply much more
substantial productivity growth than the "best-guess" $\underline{B}$ figures, and
the $\underline{C}$ 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 $\underline{C}$
estimates for 1820, and the $\underline{B}$ estimates for 1860, 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 thirteen industries fall from 72 to 46 for value-
added labor productivity and from 112 to 97 percent 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 these is the irregular pattern of advance that a number of the industries exhibit. Nominal labor productivity does not always increase continuously across the sub-periods, 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 the sub-periods, 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 significantly bias the productivity estimates for those years 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 3. Measures of the changes in the prices of the outputs and of the raw materials for each of the thirteen 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 series for the period yielded industry-specific indexes for the outputs of all thirteen industries, and for the raw materials of nine.[11] The Warren and Pearson Price Index (henceforth referred to as the WPI) was employed as the index for

TABLE 3
Price Indexes, 1820 to 1860

		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/	Q	178	141	95	100
Harnesses	RM	137	119	106	102
	K	150	128	109	102
Cotton	Q	179	115	78	98
Textiles	RM	155	88	69	110
	K	160	130	112	103
Furniture/	Q	200	149	111	100
Woodwork	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/	Q	91	−	87	98
Grist Mills	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
Tobacco	Q	138	69	100	127
	RM	138	69	100	127
	K	140	81	103	122
Wool	Q	161	138	133	102
Textiles	RM	95	74	80	104
	K	144	124	114	102
Capital Component Price Indexes					
Machinery		183	159	138	107
Structures		136	118	107	100

Table 3

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 U. S 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 U. S. 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
U. S. 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 U. S. Bureau of the Census (1975, E-128 and E-126).

Furniture/Woodwork: The output index is that for "furniture"
from Brady (1966), and the raw materials index is from U. S. 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 U. S. Bureau of the Census (1975, E-62 and E-123).

Mills: Both indexes are from U. S. Bureau of the Census (1975, E-124 and E-123).

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

Tanning: The same price index serves here as the basis for both the output and raw materials indexes, U. S. 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).

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 patched into the original series.[12]

In addition to these price indexes for outputs and raw materials, Table 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 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 thirteen 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 ten of the thirteen. 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 thirteen 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 4 and 5 respectively, indicate that all
of 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 166 percent in value added
per equivalent worker and 198 percent by the alternative gauge. Only
very few failed to register gains of 100 percent. 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 sub-period 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

TABLE 4
Index of Real Value Added Per Equivalent Worker
in Selected Manufacturing Industries: 1820 to 1860

		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/	A	100	88	154	172	260	225
Harnesses	B	100	93	176	166	253	218
	C	100	93	173	162	229	213
Cotton	A	100	222	210	299	256	400
Textiles	B	100	201	192	270	231	361
	C	100	175	196	231	247	308
Furniture/	A	100	122	174	236	337	341
Woodwork	B	100	113	175	215	321	311
	C	100	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/	A	100	–	125	163	177	190
Grist Mills	B	100	–	101	127	148	149
	C	100	–	110	113	153	132
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
Tobacco	A	100	–	141	108	261	237
	B	100	–	135	104	250	227
	C	100	–	148	98	240	215
Wool	A	100	203	237	183	368	359
Textiles	B	100	163	192	146	295	288
	C	100	147	173	132	256	259
Average							
Weighted	B	100	[129]	[169]	194	[229]	266
Unweighted	B	100	[142]	[189]	209	[239]	284

Table 4

Notes and Sources: See the notes to Tables 1 and 3. The estimates of
value added per equivalent worker presented in Table 1 were converted
to constant dollars by employing the price indexes reported in Table 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 U. S. 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.

TABLE 5
Index of Real Gross Output per Equivalent Worker
in Selected Manufacturing Industries: 1820 to 1860

		1820	1832	1850 (firms)	1850 (agg.)	1860 (firms)	1860 (agg.)
Boots/Shoes	A	100	–	161	163	290	258
	B	100	–	145	145	260	230
	C	100	–	149	142	263	224
Coaches/	A	100	83	164	164	240	201
Harnesses	B	100	86	187	158	233	194
	C	100	85	189	155	218	190
Cotton	A	100	216	359	369	288	409
Textiles	B	100	200	336	341	267	379
	C	100	182	301	309	361	343
Furniture/	A	100	144	207	238	325	327
Woodwork	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	124	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/	A	100	–	209	263	274	293
Grist Mills	B	100	–	166	202	224	225
	C	100	–	189	193	231	216
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	233
Tobacco	A	100	–	150	147	289	182
	B	100	–	147	145	284	178
	C	100	–	164	140	280	173
Wool	A	100	286	314	274	486	500
Textiles	B	100	236	262	226	401	412
	C	100	216	238	205	369	373
Average							
Weighted	B	100	[151]	[215]	230	[275]	298
Unweighted	B	100	[164]	[236]	253	[298]	325

Table 5

Notes and Sources: See the notes to Tables 2 and 3. The estimates of gross output per equivalent worker in current dollars presented in Table 2 were converted to constant dollars by employing the price indexes reported in Table 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 U. S. 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.

years included, or cyclical effects, but their number is nevertheless
unsettling. It is, however, reassuring to note that the frequency and
magnitude of such 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 6 were computed from the B sets of indexes in Table 4 and 5.
Rates of advance are reported for the entire period from 1820 to 1860,
as well as for several sub-periods. The estimates indicate that labor
productivity increased rapidly in virtually all industries, ranging
from 1.0 and 2.1 percent per annum for VLP and GQLP respectively in
flour/grist mills to 4.3-5.5 and 5.3-6.2 percent in paper. Weighted
averages of the performance of the thirteen industries yield estimated
ranges of 2.0-2.4 percent and 2.5-2.7 percent for the rates of growth
of the two measures of labor productivity. These figures are

TABLE 6
Growth Rates of Labor Productivity
in Selected Manufacturing Industries: 1820 to 1860

		1820-1832 Z	1820-1850 Z	1850-1860 Z	1820-1860 Z
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/	VLP	-0.7	1.8-2.0	2.7-3.7	2.0-2.4
Harnesses	GQLP	-1.4	1.6-2.2	2.1-2.2	1.7-2.2
Cotton	VLP	6.6	2.3-3.5	1.9-2.9	2.2-3.3
Textiles	GQLP	6.5	4.3-4.3	-2.3-1.0	2.5-3.5
Furniture/	VLP	1.1	1.9-2.7	3.8-6.2	2.9-3.0
Woodwork	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/	VLP	-	0.1-0.8	1.6-3.8	1.0-1.0
Grist Mills	GQLP	-	1.8-2.5	1.1-3.0	2.1-2.1
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	VLP	4.5	1.3-2.3	4.4-7.0	2.7-2.8
Textiles	GQLP	8.1	2.8-3.4	4.4-6.2	3.6-3.7
Weighted	VLP	[1.6]	[1.6]-2.1	3.3-[3.3]	[2.0]-2.4
Average	GQLP	[2.9]	[2.3]-2.6	2.8-[3.2]	[2.5]-2.7

Table 6

Notes and Sources: These annual rates of growth were computed from the
constant-dollar estimates of labor productivity presented in set "B" of
Tables 4 and 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 4 and 5.

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 U. S. economy as a whole. (David, 1967, 1977; Gallman, 1972a,
1972b).

Not only do these estimates of productivity growth in
northeastern manufacturing during early industrialization exceed what
might have been expected from previous work, but they are quite high by
historical standards. For example, McCloskey (1981) has computed rates
of labor productivity growth for four major manufacturing industries in
Britain during that country's initial phase of industrial development,
1780 to 1860. His industry rates range from 0.9 to 2.6 percent per
annum, with an unweighted average of 1.6 percent. Moreover, the
figures presented here are greater than those estimated by Kendrick
(1961) for the U. S. manufacturing sector between 1869 and 1957.

The other major pattern that emerges from these estimated rates
of labor productivity growth is that, on average, there appears to have
been an acceleration in the pace of advance over the period. This
characterization is based primarily on a comparison of the record
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, yields weak, if any, evidence of acceleration.
Nevertheless, the thirteen industries considered together exhibit a

marked increase in the rate of labor productivity growth. The
acceleration is particularly striking with the VLP measure, where a
weighted average of the industries registered growth of 1.6-2.1 percent
per annum before 1850 and 3.3 percent following. On an individual
industry basis, nine of the thirteen realized faster growth during the
later sub-period than in the earlier one. Although, the pace of
advance may indeed have quickened, it is clear that rapid progress must
have been realized as early as the 1820s. While the evidence of
acceleration in productivity during the initial stages of
industrialization might seem to conform well with the work of scholars
who view the diffusion of mechanization across the manufacturing sector
during the 1840s and 1850s as the crucial development behind
productivity growth in manufacturing, this perspective 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 to have
generally 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 U. S. industry increased at rates of 4.1 percent per annum between 1820 and 1860, and of 3.4 percent 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 percent 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 percent 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 potentially be of sufficient import 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 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 to only one specific product or raw material of an
industry and were in several cases 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
were generally selected for use, so as to bias 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 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 prevalance 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 sub-samples over which the sets of estimates were computed. The $\underline{B}$ set of estimates was intended to represent conservative "best-guess" figures, and provides the basis for the rates of growth reported in Table 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 conceivably a possibility, but as an examination of the nominal figures in Table 1 and 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

of 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 were separately enumerated. 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 under-counting 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 ensure that there were a certain minimum number of observations from each state that had surviving data, and hence suffer from a disproportionate representation of manufacturing firms from states that had relatively limited industrial development or small populations (Atack, Bateman, and Weiss, 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 actually 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 thirteen industries seems

likely to have exceeded those of firms that were part-time enterprises.

Even if the adjustments underlying the $\underline{B}$ set of estimates, on which the

discussion focuses, are not quite sufficient, sensitivity analysis

employing set $\underline{C}$ 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 previously reckoned. 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 U. S. 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

pro-cyclical 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

percent 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 percent 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 these were major increases in labor productivity across a wide range of manufacturing industries during the antebellum period. Not so clear, however, is the relative importance of the various contributors, such as capital deepening or mechanization, to these developments. 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

TABLE 7
Indexes of Labor Productivity for
Classes of Manufacturing Industries: 1820 to 1860

	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)	[183]	[246]	[153]	[165]	[177]	[230]	[156]	[173]
1850 (aggregate)	207	256	179	187	207	249	170	174
1860 (firm)	[231]	[287]	[226]	[255]	[223]	[277]	[239]	[269]
1860 (aggregate)	298	330	228	247	280	317	240	244

Per Annum
Growth Rates:

1820-1850	[1.8]-2.2	[2.7]-3.0	[1.5]-1.9	[1.7]-2.1	[1.7]-2.2	[2.5]-2.9	[1.5]-1.8	1.8-[1.8]
1850-1860	[2.8]-3.9	[2.3]-2.7	2.6-[3.8]	2.9-[4.6]	[2.7]-3.1	2.5-[2.7]	3.7-[4.2]	3.6-[4.6]
1820-1860	[2.0]-2.6	[2.6]-2.9	[2.1]-2.1	2.3-[2.4]	[1.9]-2.4	[2.5]-2.8	[2.2]-2.2	2.3-[2.5]

Table 7

Notes and Sources: These estimates were computed as weighted averages
of the industry-specific figures underlying the indexes presented in
Tables 4, 5 and 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.

proportions employed and productivity growth through a discussion of the cases of individual industries, the thirteen 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 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 177 to 217 (depending on whether the firm or aggregate data is employed) percent between 1820 and 1860, whereas those less dependent on capital managed only 144 to 169 percent. 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 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 percent 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 formally evaluate 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 percent per annum for 1820 to 1860, to between 2.7-3.0 and 1.7-2.1 percent for 1820 to 1850. 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 to 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 that mechanized, and were highly capital intensive, early, such as cotton textiles, 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 judgement 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 were eventually 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.

III

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 will in turn 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 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 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

TABLE 8
Indexes of Real Partial Factor Productivity:
1820 to 1860

		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/	GQ/RM	100	121	136	154	148	155
Harnesses	GQ/K	100	85	206	181	126	137
	GQ/L	100	86	187	158	233	194
Cotton	GQ/RM	100	88	68	82	112	123
Textiles	GQ/K	100	124	222	269	301	219
	GQ/L	100	200	336	341	267	379
Furniture/	GQ/RM	100	91	158	181	177	178
Woodwork	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	124	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/	GQ/RM	100	—	137	138	143	143
Grist Mills	GQ/K	100	—	109	131	105	107
	GQ/L	100	—	166	202	224	225
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
Tobacco	GQ/RM	100	116	93	80	91	132
	GQ/K	100	75	114	98	80	150
	GQ/L	100	130	147	145	284	178
Wool	GQ/RM	100	65	75	70	128	124
Textiles	GQ/K	100	145	208	169	263	252
	GQ/L	100	236	262	226	401	412

Table 8

Notes and Sources: See the note to Table 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 3. These estimates were then normalized relative to a base of 100 representing the respective industry's levels in 1820.

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 were typically very large, the advances in raw materials productivity observed are quite modest. Capital productivity appears to have generally 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 8. These latter ratios indicate that northeastern manufacturing did shift somewhat toward more capital-intensive production processes, as judged by the capital to 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 118-127 percent range, the rise in capital per unit of labor amounted to only 67-72 percent. 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 directly account 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 thirteen in 1820, appear to have experienced the largest increases in the capital to labor ratio. Conversely, several

of the less capital-intensive industries, boots/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 57-91 percent over the period in the more capital-intensive industries (as indentified at either 1820 or 1850), and by 16-95 percent 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 is clear that the classes of industries were not converging in their degrees of capital intensity, and that many 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 of 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 to 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 in 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 thirteen industries in Tables 9 and 10. As with the labor productivity figures

TABLE 9
Index of Total Factor Productivity:
Computed with Value Added as the Measure of Output

		1820	1832	1850 (firms)	1850 (agg.)	1860 (firms)	1860 (agg.)
Boots/Shoes	A	100	-	157	179	195	240
	B	100	-	144	160	175	215
	C	100	-	145	154	175	206
Coaches/	A	100	94	175	191	231	216
Harnesses	B	100	93	181	173	210	196
	C	100	93	179	171	189	193
Cotton	A	100	195	188	264	269	344
Textiles	B	100	174	169	235	240	306
	C	100	149	186	200	224	261
Furniture/	A	100	134	191	248	298	303
Woodwork	B	100	127	198	229	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/	A	100	-	109	140	140	149
Grist Mills	B	100	-	89	112	118	119
	C	100	-	95	98	121	105
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	188
	B	100	114	141	201	130	153
	C	100	93	127	175	121	133
Tobacco	A	100	-	130	96	178	224
	B	100	-	126	92	171	216
	C	100	-	131	88	165	206
Wool	A	100	180	227	171	332	318
Textiles	B	100	141	179	134	260	248
	C	100	123	157	118	212	218
Average							
Weighted	B	100	[126]	[162]	182	[203]	231
Unweighted	B	100	[132]	[177]	191	[207]	241

Table 9

<u>Notes</u> <u>and</u> <u>Sources</u>: These estimates of total factor productivity were computed over the same sets of observations as the corresponding labor productivity estimates presented in Table 1 and 4 were. See the notes to Tables 1 and 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 estimate 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 3. These "real" estimates of total factor productivity were then normalized relative to an 1820 standard of 100.

TABLE 10
Index of Total Factor Productivity:
Computed with Gross Output as the Measure of Output

		1820	1832	1850 (firms)	1850 (agg.)	1860 (firms)	1860 (agg.)
Boots/Shoes	A	100	–	133	142	178	196
	B	100	–	127	134	168	185
	C	100	–	125	129	165	179
Coaches/	A	100	104	157	166	175	172
Harnesses	B	100	104	160	159	168	164
	C	100	104	158	158	159	163
Cotton	A	100	128	141	157	180	203
Textiles	B	100	121	134	149	170	192
	C	100	112	133	136	164	176
Furniture/	A	100	122	184	217	229	232
Woodwork	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/	A	100	–	156	173	173	178
Grist Mills	B	100	–	142	155	159	160
	C	100	–	148	150	160	154
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	107	120	139	143	154
	C	100	98	115	131	138	145
Tobacco	A	100	–	113	102	132	151
	B	100	–	111	100	130	148
	C	100	–	114	98	128	145
Wool	A	100	124	146	130	231	227
Textiles	B	100	110	130	115	205	202
	C	100	103	122	108	187	190
Average							
Weighted	B	100	[109]	[136]	144	[170]	178
Unweighted	B	100	[113]	[148]	152	[171]	184

Table 10

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 Table 2 and 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 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 3, before the calculations were performed. These "real" estimates of total factor productivity were then normalized relative to a 1820 standard of 100.

reported above, the estimates were computed for each of three sets of sub-samples 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 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 103 to 131 percent with output is defined as value added (NFP) and from 70 to 78 percent by the alternative gauge (TFP). Each industry performed well by at least one measure. Flour/grist mills registered the smallest advance in NFP, only 18 to 19 percent, but the estimated gain in TFP approached 60 percent; and although tobacco ranked at the bottom in terms of progress in TFP, its increases of 30-48 percent in that measure, and of 71-116 percent 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 directly accounted for 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 can not be attributed to 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 $\underline{C}$ and $\underline{B}$ sets of estimates suggest, the basic picture that emerges is not sensitive to any reasonable adjustments of the sub-samples 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 in at least 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

TABLE 11
Growth Rates of Total Factor Productivity
in Selected Manufacturing Industries: 1820 to 1860

		1820-1832 X	1820-1850 X	1850-1860 X	1820-1860 X
Boots/Shoes	NFP	-	1.3-1.6	1.9-2.9	1.4-2.0
	TFP	-	0.8-1.0	2.9-3.3	1.3-1.6
Coaches/	NFP	-0.7	1.9-2.1	1.2-1.5	1.7-1.9
Harnesses	TFP	0.3	1.6-1.6	0.3-0.5	1.3-1.3
Cotton	NFP	5.2	1.8-3.0	2.7-3.6	2.3-2.9
Textiles	TFP	1.8	1.0-1.4	2.4-2.6	1.4-1.7
Furniture/	NFP	2.2	2.4-2.9	2.1-3.8	2.7-2.8
Woodwork	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	1.2-1.3
	TFP	-	0.9-1.6	0.2-2.3	1.2
Flour/	NFP	-	-0.4-0.4	0.6-2.8	0.4-0.4
Grist Mills	TFP	-	1.2-1.5	0.3-1.2	1.2-1.2
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	NFP	3.2	1.0-2.0	3.8-6.4	2.4-2.5
Textiles	TFP	0.9	0.5-0.9	4.7-5.8	1.8-1.9
Weighted	NFP	[1.8]	[1.5]-1.9	[2.3]-2.4	[1.7]-2.0
Average	TFP	[0.8]	[1.0]-1.2	[2.2]-2.2	[1.3]-1.8

Table 11

Notes and Sources: These per annum rates of total factor productivity

growth were computed from the set B estimates reported in Tables 9

and 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.

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 9 and 10 for the entire period between 1820 and 1860, as well as for several sub-periods. They are presented in Table 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 thirteen industries match, if not exceed, the performance of the U. S. economy during other periods. Between 1820 and 1860, northeastern manufacturing appears to have achieved per annum rates of increase of 1.7-2.0 percent in NFP and 1.3-1.8 in TFP. These figures might be compared to the 1.8 percent 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 percent 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 U. S. 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, as 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 1.5-1.9 percent per annum over the first thirty years to 2.3-2.4 percent during the later ten. The pattern of acceleration is, admittedly, somewhat weaker if one focuses on the contrast between 1820-1832 and 1832-1860, 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 inputs 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 rapid diffusion of machinery is certainly consistent with this interpretation, but alternative explorations of this feature of the economic record are also available.[29]

Although some of 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

TABLE 12
Indexes of Total Factor Productivity for
Classes of Manufacturing Industries: 1820 to 1860

	Mechanized Industries		Other Industries		Capital-intensive Industries		Other Industries	
	NFP	TFP	NFP	TFP	NFP	TFP	NFP	TFP
1820	100	100	100	100	100	100	100	100
1850 (firm)	[168]	[137]	[155]	[134]	[160]	[134]	[164]	[143]
1850 (aggregate)	182	142	181	147	181	142	182	151
1860 (firm)	[217]	[172]	[186]	[166]	[205]	[169]	[200]	[173]
1860 (aggregate)	250	180	209	176	232	176	229	186

Per Annum
Growth Rates:

1820-1850	[1.6]-1.8	[1.1]-1.2	[1.5]-2.0	[1.0]-1.3	[1.4]-1.9	[1.0]-1.2	[1.7]-2.0	[1.2]-1.4
1850-1860	[2.8]-3.3	[2.3]-2.4	1.4-[1.7]	1.8-[2.1]	2.3-[2.5]	2.2-[2.3]	[1.8]-2.4	[2.0]-2.2
1820-1860	[1.9]-2.2	[1.4]-1.5	[1.5]-1.9	[1.3]-1.4	[1.7]-2.0	[1.3]-1.4	[1.7]-2.1	[1.4]-1.6

Table 12

Notes and Sources: These estimates were computed as weighted averages
of the industry-specific figures presented underlying the indexes
presented in Tables 9, 10, and 11. The weighted averages were
constructed with the system of weighting employed in Table 7. See the
notes to those tables.

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 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 at least as much capital deepening as their less capital-intensive and mechanized counterparts did. One would, accordingly, expect them to exhibit more total factor productivity growth.

When one examines the indexes of total factor productivity presented in Table 12 for classes of manufacturing industries, however, only minor differences in performance emerge.[32] The discrepancies in the amount of productivity growth realized between the more and less capital-intensive industries are trivial in magnitude and vary in sign with the choice between measures. As for the other system of

TABLE 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 to 1860

		% 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/	F	9	29	61
Harnesses	A	7	19	74
Cotton	F	-2	48	54
Textiles	A	5	46	49
Furniture/	F	4	27	68
Woodwork	A	4	26	70
Glass	F	-	-	-
	A	5	37	57
Hats	F	5	49	46
	A	0	40	60
Iron	F	3	42	55
	A	6	30	63
Liquors	F	11	28	61
	A	14	21	65
Flour/	F	12	30	57
Grist Mills	A	12	30	58
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	F	4	44	51
Textiles	A	5	46	49

Table 13

Notes and Sources: The decomposition of the growth in gross output per

equivalent worker was based on the accounting information:

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

where * signifies a derivative of the log. The decomposition applies

to the firms included in the B sub-samples. See the notes to Tables 5

and 8.

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, particularly when TFP serves 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 sub-periods 1820-1850 and 1850-1860. As already alluded to, the rates of increase of both capital intensity and labor productivity accelerated sharply between the two sub-periods among the former classes of industries relative to the latter.[33] If the capital investments involved considerable embodied technical change, then one would expect a relative increase in the pace of total factor productivity in 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, 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
percent of the growth in labor productivity as measured by GQLP.
Indeed, in no case does the share exceed 16 percent. 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 below 25 percent.[34] These
findings dramatize how remarkably limited the importance of capital
deepening was in generating labor productivity growth 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 would appear to deserve more attention.

IV

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 U. S.. 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 (Lazonick and Brush, 1985;
Goldin and Sokoloff, 1982; Sokoloff, 1984b). Although many questions
remain, the results also appear to be consistent with, if not to
actually 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 U. S., 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.

FOOTNOTES

* This paper was substantially revised during the year following the
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acknowledged.

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

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, Bateman, and Weiss (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
   industries 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 over
   time in labor productivity within industries 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 sub-samples 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 (full-time). A general sense of the orders of magnitude
has, however, been obtained 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 $\underline{C}$
figures for 1820 with respect to the $\underline{B}$ 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 U. S. Census Bureau
(1858). The two point estimates available for twelve 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 percent).

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_ sub-sample 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 percent.

9. Of greatest concern in this regard are the glass, liquors, 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 over-sampling 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 re-weighting 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 to only 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.

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 that 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 0.25-0.35 range in 1820 to roughly the 0.45-0.55 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 were 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 percent of the male labor force. Such a constraint, probably serves to bias upward the estimates of the labor input for several industries. This 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 $\underline{C}$ estimates for 1820 and the $\underline{B}$ estimates for 1860, ranges between 2.3 and 2.5 percent per annum. These figures are only slightly lower than the 2.5 to 2.7 range derived from the employment of the $\underline{B}$ 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 to labor ratios in the Northeast obtained from U. S. 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 U. S. 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 accordingly be due to the less-developed states, which were over-represented in the samples, being characterized by a much different system or type of cotton 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. Just as was 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 87 to 113 percent over the period, while TFP increases by 63 to 71 percent.

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 intra-regional 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; U. S. 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 to labor ratios were low and hadn't 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 were 0.9-1.2 percent and -0.1-+0.1 percent 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 percent per

annum, as compared to the 0.7-2.3 percent 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 to 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.

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