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

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

Table 13.9 (continued)

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

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

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

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

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

Table 13.10 (continued)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

13.4 Conclusions

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

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

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

Notes

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Comment Jeffrey G. Williamson

Motivation and Findings

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

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

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

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

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

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

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

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

These are impressive findings. Can we believe them?

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

Three Problems

Aggregation

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

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

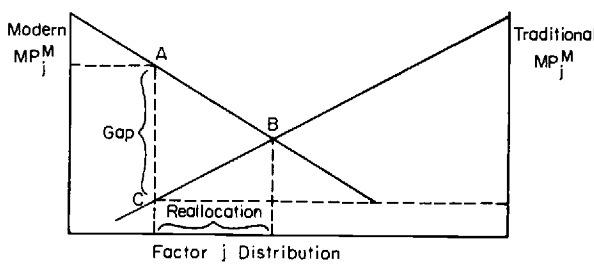

Fig. C13.1 Factor market imperfections and the Harberger Triangle.

The Effective Labor Stock

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

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

where

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

This labor aggregation scheme is used throughout.

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

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

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

The Flow of Labor Services

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

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

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

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

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