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Economies of Scale in Nineteenth-Century American Manufacturing Revisited
A Resolution of the Entrepreneurial Labor Input Problem

Robert A. Margo

6.1 Introduction

At the start of the nineteenth century the United States economy was overwhelmingly agricultural, well behind England in the development of a manufacturing sector. By the mid-nineteenth century the American industrial revolution was solidly underway, chiefly in the Northeast but spreading elsewhere in the country. By century's end labor productivity in US manufacturing substantially exceeded levels in Great Britain or continental Europe and the United States was rapidly becoming the leading industrial economy in the world (Wright 1990; Broadberry and Irwin 2006).

The conventional narrative of American manufacturing ascendancy emphasizes the "rise of big business" (Chandler 1977). At the start of the century American manufacturing was overwhelmingly the province of the "artisan shop" in which a craftsman, perhaps assisted by an apprentice or two, fashioned a custom product from start to finish using hand tools and no inanimate power source. The artisan shop was replaced by the factory, which employed more workers utilizing division of labor and, with increasing frequency over the century, powered machinery. By the end of the century the

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factory had already morphed into establishments that were both larger in terms of employment and more capital intensive.[1]

Central to the conventional narrative is a belief that large-scale production contributed substantially to productivity growth in manufacturing through the exploitation of economies of scale. For the very end of the century the existence of scale economies in manufacturing is not in question; as Chandler documents, there are abundant examples of scale economies in industries like steel production and meat packing. However, can the same be said for earlier in the century when industrialization was getting underway?

For many economic historians, convincing evidence that economies of scale were present early in the American industrial revolution is contained in a famous paper by Kenneth Sokoloff (1984). Using samples from the 1820 and 1850 manuscript censuses of manufacturing, Sokoloff estimated Cobb-Douglas production functions showing economies of scale. Very importantly he was able to demonstrate this for nonmechanized establishments, suggesting that pure division of labor, as hypothesized by Adam Smith, was a source of productivity gains.

A crucial piece of Sokoloff's analysis was an adjustment that he made to the census data for what has come to be known as the "entrepreneurial labor input problem."[2] Although the issue was first raised (and resolved in a particular way) by Atack (1976, chs. 3, 7; 1977), economic historians were made more broadly aware of the implications of the problem by Sokoloff's paper. Like the other nineteenth-century manufacturing censuses, those for 1820 and 1850 collected information on the number of individuals working in the establishment, classified by age or gender.[3] According to Sokoloff (1984), the reported count of workers in 1820 and 1850 generally excluded the labor input of the owner if he was a sole proprietor (or owners, if there was more than one); however, based on supplementary information for 1820,

1. "Continuous processing" techniques are an example in which raw materials are constantly in motion and being processed, with plants operating on multiple shifts; see Chandler (1977) and Goldin and Katz (1998).

2. In this chapter I treat the "entrepreneurial labor input problem" as a problem of measurement of the entrepreneurial labor input *per se* rather than a topic with its own economic history—that is, tracing over time, for example, long-term changes in the labor input provided by entrepreneurs. See Fishbein (1973) and Atack and Bateman (1999a) for a comprehensive discussion of the history of the nineteenth-century manufacturing censuses, the information collected, and available modern samples from the surviving manuscript schedules. There is a long history of doubts and disputes about the accuracy of the census manufacturing data, particularly for the earlier census years. Indeed, the census takers themselves expressed serious doubts about the data they collected. Francis A. Walker, the superintendent at both the 1870 and 1880 census, for example, described the data reported by the manufacturing censuses on capital invested as "entirely untrustworthy and delusive" and "wholly worthless." Nevertheless, such jaundiced views did not prevent others at the time or modern scholars from making extensive use of the data and drawing inferences from them.

3. The 1820 census collected information on the average number of boys, young women, and adult males working at the establishment separately. The 1850 census reports separately the average number of male and female workers.

Sokoloff believed that hired managers were generally counted. In effect, Sokoloff believed that the census collected information on the labor input of employees but not the employer(s) (see Atack [1976] for a similar argument).

Because the employer or "entrepreneurial" portion of the labor input was allegedly overlooked, the common census measure of labor productivity, value added per worker, is overstated because the denominator, the labor input, is too small. Critically, the degree of overstatement is not uniform across establishments with different numbers of workers. To the contrary, the upward bias in labor productivity is systematically greater for establishments with few workers because in such establishments the ratio of the entrepreneurial labor input to that of the other workers is greater than in larger establishments. According to Sokoloff, failure to correct for this bias systematically overstates labor productivity in smaller relative to larger establishments, thereby causing the usual measure of scale economies—for example, the sum of the labor and capital coefficients in a value-added Cobb-Douglas production function—to be biased downward. Sokoloff proposed specific and somewhat different solutions for this problem in 1820 and 1850. Once these were implemented, he was able to establish econometrically the existence of economies of scale.

The early response to Sokoloff's paper was favorable, as evidenced by Atack (1987), who adopted Sokoloff's proposed solution in his estimation of production functions using establishment-level data from the 1850–1870 manufacturing censuses.[4] In later work, however, Atack changed his mind, arguing that, in general, the census *did* include the labor input of the entrepreneur if it was economically relevant to do so.[5] As far as anyone knows Sokoloff never accepted Atack's criticisms, nor has there been a satisfactory resolution of the dispute, leaving economic historians in the lurch as to which point of view has more merit.[6] Unlike some debates over measurement in economic history this is far from a trivial dispute because, as mentioned in the original paper and as shown here, Sokoloff's proposed adjustment has a marked effect on measured productivity in small establishments relative to larger and therefore on the extent of measured economies of scale. It is thus fundamental to our understanding of the "treatment effect" of changes in establishment size and organizational form on labor productivity during early industrialization, as measured from census data of the era.

In this chapter I revisit the entrepreneurial labor input problem in a systematic way using data from the Atack-Bateman (1999a) samples from the

4. In this regard, Atack's (1987) analysis of the 1850 data differs from his 1977 analysis (see the discussion later in the chapter).

5. See Atack and Bateman (1999b), a revised version of which was later published as Atack and Bateman (2008).

6. The issue has also been considered for the case of the 1871 Canadian census of manufactures; in particular, Inwood and Keay (2012) conclude that the entrepreneurial labor input was properly counted and that no Sokoloff-like adjustment is necessary.

1850–1880 censuses of manufacturing along with textual material from the instructions to census enumerators. The conclusion I reach has two parts. First, Atack's revised position that the census did generally include the labor input of the entrepreneur when economically relevant has much to recommend it with regard to sole proprietorships; in particular, his claim is consistent with the textual evidence from the enumerator instructions as well as statistical evidence on the distribution of establishment sizes.[7] However, this is not to say that the census enumerators always included sole proprietors in the count of workers when they were supposed to, as I also uncover several examples that suggest a failure to do so, but such failures appear to be relatively uncommon.

Second, I extend Sokoloff's (1984) analysis of the effects of partnerships (versus sole proprietors) by using data on organizational form that Atack subsequently added to the original 1850–1870 Atack-Bateman samples. Consistent with Sokoloff's findings, I show in a regression analysis that partnerships had higher output than sole proprietorships after controlling for the reported number of employees. However, the effects are not statistically significant (and are relatively small), especially after controlling for industry, location, and capital invested. I conclude that Sokoloff's recommended blanket correction for any possible undercount in 1850 and, by inference, for the 1860–1880 censuses is not defensible.

That said, while it may be inappropriate to apply a correction in the particular manner that Sokoloff recommended, he was correct that the labor input was underenumerated in small establishments relative to large—but for an entirely different reason. The relative underenumeration occurs because the census data on the labor input refer not to the total quantity of labor used in the establishment over the course of the census year or even a literal average of the number of workers, as is often assumed (see, for example, Laurie and Schmitz 1981, 73). Rather, my analysis leads me to conclude that the data generally refer to the typical number of individuals at work at the establishment during the census year, where "typical" refers to the number usually present on a normal day of operation. This typical number does not take into account occasional periods of time when more labor might be at work as well as periods when fewer than typical were present. The failure to incorporate above or below typical numbers of workers would not necessarily introduce bias but, as it happens, there is a bias that is asymmetric with respect to establishment size. In effect, the census data on the labor input are more accurate for larger establishments and less accurate from smaller establishments, with the error being one-sided (too low) for smaller relative

7. In this regard, my argument is similar to that sketched in Atack and Bateman (1999b), who also argue on the basis of the distribution of establishment sizes that sole proprietors were generally counted correctly. Atack and Bateman's focus in their paper is on profitability in manufacturing; in particular, they argue that a Sokoloff adjustment leads to estimates of returns for small establishments that are systematically too low.

to larger establishments. This is the same type of bias that Sokoloff identified, albeit for a very different reason.

In support of this claim, I make use of novel data from the 1880 census that were included in the manuscripts but never tabulated and published. In 1880, as in 1870, the census ascertained the average numbers of adult males, adult females, and child workers separately. However, the census also included a new question on the maximum number of workers at the establishment at any point in time during the census year. I create a subsample of establishments in 1880 for which, if the census data on average numbers were literally correct, no establishment should have reported a maximum number of workers that exceed the sum of adult male, adult female, and child workers. However, as I show, almost half of the establishments in the particular subsample did so report. I argue that the most likely explanation is that these establishments gave the *typical* number at work in response to the enumerator, rather than a true average—a type of answer that the census instructions to enumerators permitted. I go on to show that the likelihood of this happening was decreasing in establishment size, which is the same pattern of bias alleged by Sokoloff.

The 1880 data also allow me to estimate whether the difference between the maximum and typical number of workers had a material effect on labor productivity. I show that it did. Under a set of reasonable assumptions it is possible to back out an adjustment factor to correct the reported average number of workers. This adjustment factor reduces labor productivity in small establishments relative to large establishments but to a much smaller extent than Sokoloff's adjustment and to an insufficient degree to generate a robust finding of increasing returns to scale.

6.2 The Emergence of Large-Scale Manufacturing in Nineteenth-Century America

In the early nineteenth century the overwhelming share of the labor force, approximately 76 percent in 1800, was engaged in agricultural production. Over the course of the century, a shift of labor out of agriculture occurred such that, by 1900, the share in agriculture had fallen by slightly more than half, to 36 percent (Weiss 1986, 1993). Although much of the reallocated labor went to the service sector, a significant portion went to manufacturing where labor productivity was substantially higher than on the farm. The growth of manufacturing employment in the nineteenth century was not neutral with respect to establishment size. In particular, the average number of workers per establishment increased (Atack 1987). Smaller establishments, especially sole proprietorships, decreased their share of the total number of establishments and of total employment in manufacturing—a process referred to by labor historians as the "displacement" of the artisan shop by the factory.

Table 6.1 documents the evolution of this process over the period from 1850 to 1880 by presenting employment size distributions in manufacturing, using the Atack-Bateman (1999a) manuscript census samples. In computing the distributions I have made some novel adjustments for the possible underreporting of very small establishments prior to the Civil War. The details of these adjustments are described in the appendix.[8]

Panel A of table 6.1 shows the mean and median establishment size and proportion of establishments in five size categories: one to two workers, three to five workers, six to fifteen workers, sixteen to one hundred workers, and more than one hundred workers. These size categories are shown because within them the change over time in the proportions was monotonically decreasing (one to two workers), stable (three to five), or increasing (six or more). In the discussion below, I will refer to establishments with sixteen or more workers as "factories." While any specific cutoff, of course, is arbitrary, the substantive patterns evident in the table do not change for reasonable variations in this cutoff.

The basic finding of panel A is that the distribution of establishments shifted over time toward larger firm sizes—that is, the share of establishments in the smallest category (one to two workers) decreased over time while the shares of establishments with six or more workers increased. For establishments in the factory bin (sixteen or more workers) the increasing share reflects an upward trend in place before 1850 (Sokoloff 1984), but for the middle category (six to fifteen) the increase appears to have started after the Civil War.

The overriding impression from panel A is that change in the size distribution of establishments measured by employment was fairly slow. To be sure the estimated mean size grew by 73 percent between 1850 and 1880 but the average sizes—from 7.2 to 12.5 workers—were still small. Clearly, even as late as 1880 tiny establishments remained dominant in terms of numbers—approximately a quarter were sole proprietorships with the proprietor reported as the sole employee, while another 44 percent had between two and five workers. As a result of this dominance, the median establishment size in 1880 was three workers, having increased by just one worker from 1850 to 1880.

Panel A views the size distribution from the vantage point of the establishment as the unit of observation—one establishment, one observation. Panel

8. To be included in table 6.1, an establishment must be in the (a) "national" Atack-Bateman sample, (b) have reported value of output exceeding $500 nominal dollars (this was the cutoff used by the census), and (c) have positive reported employment. I have also excluded a small number (4) of establishments whose reported number of workers seems to be in error (too large to be credible). It is necessary to reweight the 1880 data in an attempt to correct for the underrepresentation of establishments in so-called "special agent" industries (see, for example, Atack, Bateman, and Margo 2004). My estimates of mean establishment size differ slightly from those implied by the figures on total number of establishments and total employment as published by the census; these differences are due to the fact that I am relying on sample evidence and, in particular, because of the adjustments discussed in the appendix.

Table 6.1 **Establishment size distributions in manufacturing, 1850–1880 (Atack-Bateman sample evidence)**

A. Establishments as the unit of observation

	Mean number of workers	Median number of workers	Percent with 1–2 workers	Percent with 3–5 workers	Percent with 6–15 workers	Percent with 16–100	Percent with 100 or more workers	Percent with 16 or more workers
1850	7.2	2	55.0	24.4	13.3	6.5	0.9	7.4
1860	8.3	2	54.6	23.1	13.8	7.3	1.2	8.5
1870	10.6	3	53.3	22.6	14.0	8.7	1.4	11.1
1880	12.5	3	45.3	25.0	17.1	10.1	2.4	12.5

B. Weighted by gross value of output

	Median	1–2 workers (%)	3–5 workers (%)	6–15 workers (%)	16–100 workers (%)	>100 workers (%)	16 or more workers
1850	15	14.6	15.7	20.5	31.1	18.1	49.2
1860	25	11.9	14.4	16.3	32.8	24.7	57.5
1870	44	7.6	8.1	15.7	35.9	32.6	68.5
1880	42	6.6	8.6	13.9	38.4	32.5	70.9

Source: The Atack and Bateman (1999a) national samples of manufacturing establishments from the 1850–1880 manuscript censuses of manufacturing (panels A and B).

Notes: To be included in the table, observations (establishments) must meet certain criteria; see fn 6. The 1880 data are reweighted to correct for undersampling of establishments in special-agent industries (see fn 8); sample size in 1880 is the unweighted number of establishments, the weighted sample size is 7,184. For panel B, each establishment is weighted by its gross value of output. The number of workers in 1850–1860 is the sum of male and females; the number in 1870 and 1880 is the sum of adult males, adult females, and children. The 1880 data are reweighted (see above).

B offers a different look, in which establishments are weighted by the gross (nominal) value of their output.[9] Viewed in this manner, the shift toward larger firms was more dramatic (and continuous) over time. As early as 1850 almost half of the gross value of manufacturing output was produced in factories, as I have defined by the term. This increases to 70.9 percent in 1880 or by 21.7 percentage points from the level in 1850. The median establishment, judging by its contribution to total output, had fifteen workers in 1850, whereas its counterpart in 1880 had forty-two workers, or 2.8 times larger. Clearly, while larger establishments were not increasing their numbers all that quickly relative to small establishments, their relative share of gross output increased sharply after 1850.

The increase in size evident in table 6.1 could be due to shifts in industrial structure or geographic location—that is, to shifts in composition. To determine if this was the case, I estimated a panel regression in which the dependent variable takes the value one if the establishment was a factory (sixteen or more workers), and zero otherwise. I included dummy variables for the census year, three-digit standard industrial classification (SIC) code, the state in which the establishment was located, and urban status. The left-out census year dummy was 1850 and observations are weighted by gross value of output. The coefficient of the 1880 census year dummy in this regression was 0.197, or 19.7 percentage points, only slightly less than the increase shown in panel B of table 6.1 (21.7 percentage points). Thus, while compositional shifts played a role, most of the shift toward larger establishments was a general phenomenon.

For many, perhaps most economic historians, the shift toward larger-scale production, especially that shown in panel B, is prima facie evidence that economies of scale were present in some guise.[10] Fundamentally, economies of scale arise through division of labor and/or the use of indivisible inputs. Although there is no direct evidence of division of labor in the nineteenth-century American manufacturing censuses, there is indirect evi-

9. I do not report the weighted means in panel B as these are highly sensitive to the extreme values of the distribution of employment in any given year. The medians, however, are not sensitive in this sense and, as discussed in the text, these show a marked increase in size when establishments are weighted by gross value of output.

10. See Atack (1985). Atack applies the so-called "survivor method" in which the central concept is the "minimum efficient scale of production (MES)"—the smallest size establishment such that establishments larger than this were increasing (or nondecreasing) their share of aggregate production over time. If the MES is increasing over time, the presumption is that economies of scale are present. Atack frames his paper in terms of the debate over the "origins of the modern corporation" as told by Chandler (1977). According to Chandler, truly large scale production emerged late in the nineteenth century in response to fundamental changes in technology that were not in place until well after the Civil War. However, Atack (1985, 47) shows the typical plant at the end of the century was "little different from the scale required of an efficient plant in 1870" and that, with the exception of a few industries, the long-run growth in establishment size can be interpreted as a historical drift toward an equilibrium structure whose fundamental causes were put in play much earlier in the century.

dence suggested by differences in the demographic composition or in average wages by establishment size (Goldin and Sokoloff 1982; Atack, Bateman, and Margo 2004; Katz and Margo 2013). Evidence of indivisible inputs is suggested by the fact that the diffusion of the steam engine was positively correlated with establishment size, and that larger establishments generated greater labor productivity gains by using steam than did smaller establishments (Atack, Bateman, and Margo 2008).

A variety of causal factors contributed to the rise of large-scale production. As discussed by Hilt in this volume (chapter 2; see also Lamoreaux, chapter 1, this volume; Atack 2014) a changing legal and institutional environment made the corporate form increasing accessible, which may have eased access to the working and physical capital necessary for large-scale production. Such access was also enhanced by what was, for the era, a well-developed and vigorously expanding financial system (Rousseau and Sylla 2005). The "transportation revolution" (Taylor 1951)—canals, inland waterways and, especially, railroads—played a role; a recent econometric analysis (Atack, Haines, and Margo 2011) shows that factories became more prevalent when an area gained rail access. Technological advances in steam power—and, after 1880, in electrical power—were important. These advances enabled a more intricate division of labor, as well as dramatically raising labor productivity in larger establishments and associated levels of capital intensity (Goldin and Katz 1998; Atack, Bateman, and Margo 2008).

It is one thing to observe that scale economies were likely present because over time the average establishment had more workers and larger establishments were producing ever greater shares of total output. Pinning a number on these alleged scale economies is another thing entirely. The standard approaches to measuring economies of scale require the estimation of a cost or a production function. Because the census data provided only limited information on costs, most economic historians who have worked on this issue have chosen to estimate the production function. The first such studies were by Atack (1976, 1977) who reported estimates of production functions in 1850–1870 by industry-region cells. Using a variable scale parameter specification popular in econometrics at the time, Atack (1977) concluded that there were pervasive economies of scale present in 1850 but these were exhausted at relatively low levels of output and, consequently, in just five of the fourteen industry regions cells was the typical establishment operating in the range of increasing returns.[11] By 1860, however, the corresponding figure was nine of fourteen cells, suggesting that the optimal plant size was increasing before the Civil War.

11. A variable scale production function permits the econometrician to estimate the share of establishments operating in the region of decreasing returns. The most substantial evidence of decreasing returns is found for cotton textiles in 1850 in which 28 percent of establishments in the North and 19 percent in the South are deemed to be subject to (local) decreasing returns; see Atack (1977, 348).

Laurie and Schmitz (1981, 74–75) estimate Cobb-Douglas production functions using manuscript census data for Philadelphia in 1850 and 1880 and also some supplemental data for textiles in 1870. Laurie and Schmitz assume that workers reporting zero employees had, in fact, one employee, but this was the only adjustment they made to reported labor input. In eleven of seventeen industries in 1850 and thirteen of seventeen industries in 1880, Laurie and Schmitz reject the hypothesis of increasing or even constant returns to scale. Based on their regressions Laurie and Schmitz argue that American manufacturing in the nineteenth century was not characterized by scale economies, but rather the opposite. Later in the chapter I reproduce Laurie and Schmitz's general finding using the Atack-Bateman national samples, and also show that it is reversed if Sokoloff's proposed adjustment for entrepreneurial labor is implemented.

Sokoloff (1984) is next in line, but I defer detailed discussion until the next section except to note that Sokoloff argued that there were economies of scale in nonmechanized production in both 1820 and 1850 that typically were exhausted at relatively low levels of output. The implication of this finding, as previously noted, is that division of labor likely played some role in generating labor productivity growth in manufacturing after 1820 but truly large-scale production had to await fundamental advances in and widespread diffusion of steam power transmission and its associated machinery.

Finally, Atack (1987) is a comprehensive attempt to assess the extent of economies of scale using the census samples for 1820–1870 in their mid-1980s form.[12] This chapter, as previously, embraces Sokoloff's adjustment for the entrepreneurial input, although Atack later had second thoughts (see the next section). For the majority of industries in every census year that he examined, Atack found efficiency advantages to large-scale production—economies of scale—relative to small-scale production—artisan shops. Atack accounted for the persistence of small establishments by noting that many served markets that were protected from competition from more distant competitors by high shipping costs. Improvements in internal transportation and the diffusion of new technologies, such as steam, however, caused the market share of small establishments to erode over time.

Outside of the United States, the measurement of economies of scale in historical manufacturing has received the most attention by far in the French case. France is interesting because of the well-known hypothesis by Landes (1949, 1954) that nineteenth-century French manufacturing establishments were "too small" relative to their optimal size and that by failing to capture unexploited economies of scale, French economic growth suffered in the nineteenth century.

12. Subsequently, a census sample for 1880 was added and additional refinements made to the 1850–1870 samples; see Atack and Bateman (1999a). Currently the 1850–1880 samples and associated documentation are available to the public on Atack's Vanderbilt website.

Economic historians have evaluated the Landes hypothesis by attempting to estimate the extent of economies of scale using the two relevant French censuses from the nineteenth century, 1839–1845 and 1861–1865. Using a cost function approach applied to the census of 1861–1865, Nye (1987) found little evidence that there were economies of scale left to be exploited. However, using a production function approach, Sicsic (1994) does find evidence of unexploited scale economies in sectors where the average establishment size was small. The most recent study (Doraszelski 2004) splits the difference, arguing that there were some unexploited scale economies early in the nineteenth century but not in the second half of the century.

To summarize, census data for nineteenth-century US manufacturing indicated a pervasive shift toward larger establishments. The shift toward larger size strongly suggests the presence of economies of scale, but does not provide a "summary statistic" of their quantitative importance. With one exception (Laurie and Schmitz 1981), various studies using a production function approach find some evidence of economies of scale, although these were not always fully exploited. The strongest evidence of economies of scale is found by Sokoloff (1984) for as early as 1820. In the next section I argue that this evidence is not robust to the adjustment that he made for the alleged underreporting of the labor input by the census.

6.3 The "Entrepreneurial Labor Input Problem": Was the Labor Input of Entrepreneurs Properly Measured?

The measurement of economies of scale requires accurate information on factor inputs and outputs. In particular, if any inputs are systematically underreported in small versus large establishments, an econometric analysis that fails to correct for this might show evidence of decreasing returns even if the true production process exhibited increasing returns.

Sokoloff (1984) argued that just such a problem afflicted two nineteenth-century manufacturing censuses that he was analyzing, 1820 and 1850. Sokoloff was particularly interested in whether economies of scale were present in establishments that were nonmechanized or whether inanimate power was a precondition. If economies of scale were present in nonmechanized establishments, division of labor is the most likely explanation and factors that expanded market access—the transportation revolution—were critical for industrialization. But if scale economies generally required powered machinery, scholarly attention should shift to factors that made it easier for larger establishments to acquire such machinery—for example, improvements in financial markets or greater access to incorporation (Hilt, chapter 2, this volume).

Sokoloff (1984) argued that the labor input of entrepreneurs was not properly measured by the census in 1820 or 1850. There is sufficient information in the 1820 census to distinguish establishments that were sole proprietorships

versus establishments that were two-person partnerships.[13] Sokoloff computed the difference in value added between sole proprietorships and two-person partnerships, controlling for the reported number of workers (but nothing else), for establishments reporting up to six workers. At each level of reported employment, output per worker was higher in partnership firms than in sole proprietorships. From this difference he concluded that the average number of workers reported in the census did not properly reflect the labor input of the partners relative to the sole proprietor; to correct for this it was necessary to inflate the labor input in small establishments. Otherwise, he observed, "firms with one worker would have the highest [measured] value added per worker" (Sokoloff 1984, 369, fn. 16).

For 1820, Sokoloff's correction was to add one to the count of workers if there was one owner listed or if the name of the firm was "Jones and Company"; two, if two owners listed; and three, if three or more owners were listed.[14] If the establishment was incorporated or a joint-stock company, Sokoloff assumed that it had a manager, and the manager was properly enumerated. In short, Sokoloff presumed that the owner(s) of the establishment, as a general rule, contributed their labor to production but were systematically excluded from the count of workers in 1820—in effect, that the census was measuring the labor input of employees, not that of the employers.

At the time Sokoloff wrote his paper he had no information on organizational form for the version of the 1850 sample that he analyzed, and thus he could provide no evidence similar to that for 1820 to convince the reader that the entrepreneurial labor input was not counted in 1850. Instead, he simply assumed this was so, and his correction for 1850 was simply to add one to the reported number of workers, on the theory that there was at least one owner per establishment (Sokoloff 1984, 375, fn. 21).[15]

As noted previously, Sokoloff was not the first economic historian to call attention to this alleged problem. Atack (1976; 1977, 344) asserted that

13. The key piece of information was the precise name of the establishment at the top of the census form. Atack (2014) uses similar information to measure the distribution of organizational forms for 1850–1870; see below where I use the 1850–1870 information to replicate Sokoloff's analysis of partnerships versus sole proprietorships.

14. In the 1850–1870 samples for which similar information has been inferred from the name of the establishment, some establishments were "family"-owned enterprises. Presumably there were also such establishments in 1820 but, if so, Sokoloff does not describe how he adjusted the labor input for these.

15. In their analysis of economics of scale in French manufacturing Sicsic (1994, 467) and Doraszelski (2004, 265) followed Sokoloff by adding one to their respective measures of the labor input; as best as can be determined from the published article, however, Nye made no adjustment for entrepreneurial labor. It is possible that this may explain why Nye found little or no evidence of scale economies in nineteenth-century France while Sicsic found the opposite; however, Doraszelski claims that the Sokoloff adjustment does not affect his substantive conclusions regarding scale economies and that a much more important issue is whether output is measured in value-added or gross value terms.

"proprietor and salaried managerial personnel" were "almost certainly excluded" in the 1850 and 1860 manufacturing census. Atack's proposed adjustment imputes managerial and supervisory workers based on the "ratio of [such] personnel to all employees reported in the 1890 census . . . subject to each firm being assigned at least one manager/proprietor[.]" According to Atack, the "returns to scale parameter" was "insensitive to changes in the labor input" induced by his adjustment (Atack 1976). Atack's adjustment is similar to Sokoloff's for 1850 (adding one to the count of workers) in that Atack's also adds at least one to each establishment count of workers, but for establishments with a sufficiently large number of employees, the adjustment will be greater than one because such establishments, based on the 1890 ratios, were more likely to employ managers and supervisors. Compared with Sokoloff's adjustment, therefore, which adds a uniform number—one—to each worker count, Atack's adjustment is closer to proportional, which may explain why he found no substantive effect on his estimates of returns to scale—unlike the case with Sokoloff's adjustment, as shown below.[16]

Every economic historian of the United States knows that nineteenth-century census data are fraught with error. With regard to the manufacturing censuses, the list of potential pitfalls is long and serious. Information on months of full-time operation is not reported prior to the Civil War, and information on daily hours of operation is not reported until 1880. As such, only in 1880 is it possible to construct even a rough estimate of annual labor input measured in hours (Atack and Bateman 1992; Atack, Bateman, and Margo 2002; Atack, Bateman, and Margo 2003). With the exception of some information on water and steam power, physical measures of the capital stock are not reported; instead, the capital figures, which are reported in dollars, refer to capital "invested" in the establishment, which could be book or market value or some combination of both, nor is it clear if the capital figures include or exclude working capital prior to 1890 (Gallman 1986; Atack 1977; Atack and Bateman 2008).

Given this laundry list of woes—which, to be clear, is just the highlights, not a complete list—why privilege the entrepreneurial labor input problem? Table 6.2, which reports parameters of Cobb-Douglas value-added production functions with and without Sokoloff's adjustment for the entrepreneurial labor input, provides the answer.[17] In panel A of table 6.2 I report the Cobb-Douglas scale

16. Even if one accepts Atack's reasoning, it is far from obvious that it is appropriate to apply 1890 employment ratios to the 1850 data. Unfortunately, the 1890 census was the first to separately report production and nonproduction workers.

17. The dependent variable in the regressions is the natural logarithm of value added. The independent variables are the logarithms of the labor input (variously defined, see the text), the logarithm of capital invested and dummy variables for three-digit SIC industry codes, urban status (= 1 if the establishment was located in an incorporated town or city with 2,500 or more population, 0 otherwise), and state. The purpose of including the geographic variables is to control for otherwise unexplained variation in value added due to variation in output prices (but see footnote 24).

Table 6.2 **Cobb-Douglas estimates of economies of scale, 1850–1880 (value-added production functions)**

A. Uses reported employment and capital

Sample	Number of observations	Scale parameter	Absolute value of *t*-statistic of scale parameter	Scale parameter	Absolute value of *t*-statistic of scale parameter
Sokoloff adjustment?		No		Yes	
1850	5,018	–0.056	5.54	0.093	7.45
1860	5,067	–0.007	0.69	0.131	10.29
1850–1860 pooled	10,085	–0.031	4.24	0.112	12.57
1870	3,858	–0.045	3.68	0.078	5.31
1880	7,178	–0.101	13.55	0.023	2.52
1870–1880 pooled	11,036	–0.081	12.70	0.042	5.53

B. Uses reported capital and demographically adjusted employment

Sample	Scale parameter	Absolute value of *t*-statistic of scale parameter	Scale parameter	Absolute value of *t*-statistic of scale parameter
Sokoloff adjustment?	No		Yes	
1850	–0.038	3.74	0.122	9.53
1860	0.011	1.05	0.163	12.48
1850–1860 pooled	–0.013	1.75	0.143	15.60
1870	–0.029	2.30	0.111	7.26
1880	–0.091	11.99	0.052	5.63
1870–1880 pooled	–0.068	10.58	0.073	9.20

C. Uses reported capital and demographically adjusted labor input, nonmechanized establishments

Sample	Number of observations	Scale parameter	Absolute value of *t*-statistic of scale parameter	Scale parameter	Absolute value of *t*-statistic of scale parameter
Sokoloff adjustment?		No	No	Yes	Yes
1850	2,814	–0.066	9.83	0.110	7.25
1860	1,595	–0.058	3.19	0.120	4.78
1850–1860 pooled	4,409	–0.061	5.64	0.115	8.70
1870	1,872	–0.096	4.89	0.071	2.81
1880	4,708	–0.149	15.28	0.023	1.87
1870–1880 pooled	6,580	–0.134	15.18	0.037	3.27

Source: For all panels, see text and Atack and Batemen (1999a).

Notes: For panel A, to be included in the regression the establishment has to meet the sample restrictions indicated in footnote 8 and, in addition, report positive values of capital invested, value of raw materials, and value added; in addition, establishments with unusually high or low estimated rates of return to capital invested are excluded. Dependent variable is logarithm of value added (value of outputs – value of raw materials). Scale parameter: sum of the coefficients of ln (labor) + ln (capital) – 1 from an OLS regression of ln (value added) on ln (labor) and ln (capital). Labor in 1850 and 1860 is the sum of reported male and female employees. Labor in 1870 and 1880 is the sum of adult men, adult females, and children. All regressions include dummy variables for urban status (= 1 if establishment is located in incorporated town or city with population of 2,500 or more, 0 otherwise), state, and three-digit SIC industry code. The 1880 data are reweighted to correct for undersampling of special agent industries. For panel B, demographically adjusted labor input without Sokoloff adjustment: men + 0.6*women in 1850 and 1860; men + 0.5*women + 0.33*children in 1870 and 1880. Sokoloff adjustment: add one to demographically adjusted labor input. For panel C, nonmechanized, 1850–1870: as indicated by the Atack-Bateman variable MPOWER = 3 (hand power) or MPOWER = 4 (animal power). In 1880: nonmechanized establishments are inferred from the absence of steam or water horsepower in production.

parameter, which is the sum of the coefficients of labor and capital minus one, along with its associated *t*-statistic. In column (2), the labor input is the sum of the number of male and female workers in 1850 and 1860, and the number of adult male, adult women, and children in 1870 and 1880. As can be seen in column (2), not only is there is no evidence for economies of scale, the evidence is overwhelmingly for the opposite—decreasing returns to scale. Column (2), in effect, replicates Laurie and Schmitz (1981) for the whole country rather than just Philadelphia and arrives at the same conclusion. The situation is very different in column (4) of panel A where I implement Sokoloff's adjustment, adding one to the count of workers. Now the evidence is strongly in favor of economies of scale and, with the exception of 1880, these are substantial.

Most economic historians who have estimated production functions from the nineteenth-century manufacturing data have preferred a modified total of the number of workers, which weights female and child workers less than male workers—that is, in "adult-male-equivalent" units. The presumption is that female and child workers were less skilled, on average, than male workers. Such an adjustment to the count of workers will also have implications for estimates of economies of scale because, as first demonstrated by Goldin and Sokoloff (1982; see also Katz and Margo 2013), the female/child share of workers was increasing in establishment size—larger establishments were more likely to employ women and children than small establishments.[18]

Accordingly, in panel B, I replicate the analysis in panel A using a demographically adjusted version of the labor input. Without the Sokoloff adjustment the scale parameter is now closer to zero than in panel A but it is still negative and significantly so, except in 1860 where the parameter is slightly positive (but insignificant). Applying the Sokoloff adjustment, the evidence for scale economies is stronger than in panel A.

In panel C, I replicate the analysis in panel B for the subsample of establishments that were nonmechanized—that is, made no use of water or steam power in production. This is as close as the census data permit of a test of pure division of labor in generating economies of scale. Again, the crucial effect of the Sokoloff adjustment is clearly evident on the magnitude of the scale parameter. If the adjustment is used, there is evidence of economies of scale even for nonpowered establishments, except perhaps in 1880. If it is not used, there are diseconomies of scale across the board.

18. Behind this adjustment is an assumption that larger establishments engaged in division of labor, substituting less skilled workers—women and children—and machines for the skilled male labor of the artisan. While the adjustment is plausible, it is also not fully adequate to account for differences in skill composition between small and large establishments because no adjustment is made for such differences among adult males. See Atack, Bateman, and Margo (2004) who argue that additional information on variations in skill composition by establishment size can be inferred from differences in average earnings (or what Atack, Bateman, and Margo call the "establishment wage").

The upshot of table 6.2 is that, for the 1850–1880 manufacturing samples, the presence of scale economies as an average treatment effect is not robust to Sokoloff's adjustment. Fundamentally, this nonrobustness arises because, as Sokoloff pointed out himself, measured labor productivity in very small establishments is high relative to very large establishments, making it difficult for any parametric procedure (e.g., OLS estimation of a Cobb-Douglas production function) to find economies of scale. Assuming this cross-sectional pattern to be a flaw in the census data rather than historical fact, one could imagine "corrections" for it other than Sokoloff's, but implementing these would either be difficult (or impossible) with the available information.[19]

Another alternative is to identify subsets of the census data for which a conclusion of economies of scale is robust without Sokoloff's adjustment. I explored this possibility using the 1870 sample.[20] There are two basic findings. First, if one is willing to restrict the econometrics to establishments with between two and fifty workers, there is robust evidence of economies of scale on average for powered (steam or water) establishments, but not for nonpowered establishments.[21] Second, at the two-digit industry level, there is robust evidence of economies of scale overall for powered establishments in the textile industry, but not otherwise. For an economic historian whose prior is that the emergence of large-scale production was a

19. For example, one could argue that some very small establishments had high output prices, either because they possessed local monopoly power or for other reasons; to correct for this, one could value output at national prices. In theory this could be done for 1850–1870 because the Atack-Bateman samples report physical output as well as values. But the enormous diversity of manufacturing output makes this conceptually as well as empirically difficult to implement. One could also argue that the effective labor input in large establishments was much lower than reported because of division of labor and that the demographic adjustment used in table 6.2 is very inadequate as a correction for this because a majority of establishments did not hire female or child workers (see Atack, Bateman, and Margo 2004). While this is certainly true, designing a defensible and robust correction for skill composition with respect to establishment size is arguably asking for more than the census data can deliver.

20. An appendix summarizing the results of the exploration in a table is available from Robert A. Margo on request. In brief, I estimate Cobb-Douglas value-added production functions like those reported in table 6.2, except that I restrict the analysis either to a subset of the data defined in terms of the reported number of workers by mechanization status (e.g., two to fifty workers, nonmechanized, or two to fifty workers using steam or water power) or at the two-digit (SIC code) industry level. The labor input in the regressions is adjusted for demographic composition as in table 6.2. The 1870 sample is good for this purpose because there is greater demographic detail on the labor input, allowing a better adjustment for skill than for the pre–Civil War censuses; unlike the 1880 data, no reweighting is necessary to correct for undersampling in particular industries (there were no "special agent" industries in 1870) and there is information about months of operation (allowing one to distinguish full- from part-year establishments; see Atack, Bateman, and Margo [2002]).

21. For nonpowered establishments with two to fifty workers, the scale parameter is –0.021 ($|t| = 0.70$). For mechanized establishments with two to fifty workers, the scale parameter is 0.114 ($|t| = 3.08$). However, if the regression for mechanized establishments is reestimated with a linear control for the number of months that the establishment operated, the scale parameter is 0.040 and is statistically insignificant. Larger establishments, in other words, were more likely to operate full year than part year (see Atack, Bateman, and Margo 2002).

major factor in American industrial ascendancy, these are disappointing results.[22]

Data problems in economic history range from the trivial to the highly consequential. The entrepreneurial labor input problem is an example of the latter. The beauty of Sokoloff's proposed adjustment is its simplicity; by itself, it generates strong evidence of economies of scale as an average treatment effect. In light of this, it is easy to see why the adjustment would have been favored by economic historians in the 1980s, given the prevailing wisdom at the time about census enumeration practices. In the next section, I argue that this prevailing wisdom was in error.

6.4 Is Sokoloff's Adjustment Warranted? Textual and Statistical Evidence

The analysis in the preceding section demonstrates that Sokoloff's proposed adjustment for the alleged undercount of entrepreneurial labor has a quantitatively large and significant effect on the estimated magnitude of the scale parameter in Cobb-Douglas production functions estimated from the Atack-Bateman nineteenth-century census manufacturing samples. As appealing as the results are when the adjustment is made, it cannot be justified on such grounds. Rather, the adjustment is justified if evidence, direct or circumstantial, may be found that the census did, in fact, fail to include the labor of entrepreneurs. In addressing this issue, it is useful to divide up the problem into two parts. Part one concerns the enumeration of labor in firms that are identified as sole proprietorships, while part two concerns the enumeration of the labor input of partnerships and other organizational forms.

One direct way to address whether an adjustment is warranted is to examine the written instructions to enumerators to see if these gave sufficient guidance as to whom to count as a worker (or not). To be sure, economic historians who hang their hats on the census instructions to enumerators do so at their own peril. The instructions were notoriously sketchy and there is no assurance that they were followed in the field—indeed, as I show below, there is evidence in the case at hand that they were not always followed. That said, the textural evidence does suggest that enumerators were expected to count

22. In addition to the findings for 1870, I also performed some additional regressions for 1850 and 1860. Specifically, if the analysis is restricted to mechanized establishments (steam or water power), there is evidence of economies of scale in 1850 and 1860 (pooled sample) if one includes industry dummies but not geographic controls (that is, the urban and state dummies; the scale parameter is 0.069 ($|t| = 5.11$)). Excluding the geographic dummies assumes, in effect, that geographic variation in value added unexplained by the labor and capital inputs or industry affiliation reflects true variation in total factor productivity (such as might be due to agglomeration economies in the case of an urban location) rather than variation in output prices. This seems a rather extreme assumption for the antebellum United States, in which there were large (albeit narrowing) regional differences in output and factor prices; see Berry (1943) and Margo (2000). It should also be kept in mind that it is not possible to control for months of operation in 1850 or 1860 and, judging from the 1870 analysis, this could explain the positive scale parameter.

sole proprietors as "workers"—that is, for sole proprietorships, the reported number of workers should be at least one.

The specific textual evidence comes from the instructions to enumerators that pertain to wages and to which establishments were at risk of being enumerated, and are taken from Wright's (1900) compilation. As to the former, consider for example, the instructions for questions no. 10 and no. 11 in 1850 and 1860, which reads as follows:

> 10, 11. Wages—Under 10, and 11, entitled Wages, is to be inserted the average Monthly amount paid for all the labor of all the hands, male and female, employed in the business or manufacture during the course of the year. In all cases where the employer boards the hands, the usual charge of board is to be added to the wages, so that cost of labor is always to mean the amount paid, whether in money or partly in money and partly in board; and the average number of hands and the average monthly wages to be returned, so that by dividing the latter by the former the result will show the average earnings of individuals. This is also to be included in the individual labor of a producer, working on his own account, whose productions are separately enumerated. (Wright 1900, 313–14)

A plausible reading of this paragraph is that, for sole proprietors working alone ("the individual labor of a producer, working on his own account, whose productions are separately enumerated") meeting the test for inclusion in the census, the labor input should have been reported at exactly one worker.[23] The test for inclusion, which is what the phrase "separately enumerated" at the end of the quotation is referring to, was specified in 1850 and 1860: separate enumeration was to occur as long as "annual productions" exceeded $500.00 in gross value. This was further clarified in 1870:

> The smallest shop must not be omitted, provided the production reaches $500 annually, including the cost of materials. It is believed that but few shops which employ the labor of one able-bodied artisan, fall short of this limit at the present prices of labor. Assistant Marshals will take pains to reach all the productive establishments, large and small, within their subdivisions. It is not necessary that there should be a distinct shop to constitute an establishment of productive industry in the meaning of the law. A room finished off in the barn, or a chest of tools kept in the corner of the house, may constitute a distinct establishment, provided the artisan does not habitually work in any other shop which could be separately enumerated. (Wright 1900, 162)

In sum, the census made provision for counting sole proprietors properly as workers if the owner, "working on his own account," was sufficiently pro-

23. Certainly there is no doubt that sole proprietorships were at risk of being enumerated because, at the top of the census form in, say, 1850, the "owner of the establishment, or business inquired into, either individual, company or corporation" was to be inserted.

ductive to have the establishment enumerated as a separate manufacturing entity.

Data on the distribution of establishment sizes from the 1850–1870 Atack-Bateman samples supports the conclusion that the labor input of sole proprietors in these circumstances was counted properly most of the time. As Atack and Bateman (1999b) first noted, if such workers were *not* counted even when their establishments met the condition to be enumerated—$500 in gross value—we should expect to see a great many zeroes in the distribution of employment across establishments, because sole proprietorships were ubiquitous in nineteenth-century manufacturing.[24] There is no question that there are "zeros" in the distribution of workers hired in the Atack-Bateman samples. These are more common after the Civil War—4.2 percent in 1870 and 5.2 percent in 1880—possibly because the census seems to have been more relentless in canvassing the "smallest shops," as the above instruction to enumerators suggests. Before the war, however, zeros are uncommon—in the 1850 and 1860 Atack-Bateman samples, less than 1 percent of the establishments report having zero workers.[25]

Obviously, zero is the wrong answer for any firm of any size. For sole proprietorships reporting zero workers, therefore, a plausible approach is to impute one worker.[26] For sole proprietorships already reporting one worker, however, it is not credible to change the one to two workers, because then the distribution of establishment sizes will have too few one-worker establishments.[27] This is the fundamental problem with Sokoloff's blanket adjustment.

That said, one can find instances of sole proprietorships with one worker in which the "worker" was probably not the proprietor. In the 1870 Atack-Bateman sample, there are six establishments that are identified as sole proprietorships with one worker—except that the worker is a child. Almost surely these are errors—the worker was an apprentice, not the owner.[28] For these establishments, the count of workers could be changed to "two" but

24. Atack (2014, table 17.1) estimates that 83 percent of manufacturing establishments in 1850 were sole proprietorships; the share declined over the next two decades, but was still very substantial at 78 percent in 1870.

25. The exact proportions are 0.65 percent in 1850 and 0.81 percent in 1860—that is, in both cases less than 1 percent of establishments report "0" as the number of workers. These figures pertain to the Atack-Bateman "national samples" and thus are nationally representative of the population of surviving manuscript schedules of manufacturing.

26. See Laurie and Schmitz (1981). Alternatively, one can simply exclude establishments with missing data on any relevant variable, such as employment; this is the procedure followed by Atack, Bateman, and Margo in their various papers.

27. See Inwood and Keay (2012) for a very similar analysis in the case of the 1871 Canadian census of manufactures. Inwood and Keay also argue that, in the case of the Canadian census, the enumerator instructions called for counting the labor input of entrepreneurs when it was economically relevant. Inwood and Keay find little evidence, as well, of establishments reporting zero workers in the Canadian data.

28. One can also find sole proprietorships in which the one worker is female. It is less clear whether these are errors.

the substantive effect is minimal because there are very few such observations in 1870.

I conclude that, on the basis of the textual and distributional evidence, it would appear that the labor input in sole proprietorships was enumerated correctly, at least most of the time. However, this leaves open the question of whether the census enumerated the labor input correctly in partnership or other types of establishments.

In particular, what are we to make of Sokoloff's observation that, in the 1820 census, establishments with two owners had higher value added per worker than sole proprietorships, controlling for the reported number of workers? Sokoloff showed this was the case in 1820 but was unable to investigate this issue for 1850. Subsequently, Atack added the information on ownership to the 1850–1870 samples, so it is possible to replicate Sokoloff's 1820 analysis for the later census years.[29]

Table 6.3 reports the coefficients of a dummy variable for dual (two-person) partnerships in a regression of the logarithm of value added for establishments with one reported worker. For each year I show the coefficient and its associated *t*-statistic with no additional controls in the regression, with controls for location and industry, and finally, capital invested. The results with no controls are intended to replicate the specification used by Sokoloff, which simply compared output per worker between the two organizational forms, holding the reported number of workers constant.

For 1850–1870 I find the same general pattern that Sokoloff did—namely, that output is higher in partnership establishments versus single proprietorships, even though ostensibly these are all establishments with just one worker. That said, all but one of the coefficients is statistically insignificant at conventional levels; even this is no longer the case once controls for industry, location, and capital invested are included. Note that the inclusion of these controls generally reduces the magnitude of the partnership effect, which suggests that the partnership dummy variable could easily be capturing unmeasured factors associated with higher output that had nothing to do with a higher level of the labor input. It is difficult to conclude on the basis of the statistical evidence in table 6.3 that an adjustment for the entrepreneurial labor input is warranted.

6.5 The Meaning of the Labor Input in the Nineteenth-Century Manufacturing Censuses: Evidence from 1880

I have argued that the textual, distributional, and statistical evidence does not favor the adjustment for entrepreneurial labor advocated by Sokoloff (1984). However, that does not end the matter because, rather surprisingly, there is evidence that the census understated the labor input in small

29. See Atack (2014) for further analysis of the ownership information.

Table 6.3 **The difference in value added: Sole proprietorships versus dual partnerships, one reported adult male worker (1850–1870)**

Year	Sample size (estab.)	Dual = 1	Controls	Coefficient of dual partnership dummy	Absolute value of *t*-statistic
1850	992	0.037	None	0.230	2.12
1850			Location + industry dummies	0.128	1.08
1850			Ln (capital) + location and industry dummies	0.130	1.24
1860	985	0.052	None	0.145	1.56
1860			Location + industry	0.163	1.76
1860			Ln (capital) + location + industry dummies	0.142	1.59
1870	615	0.031	None	0.319	1.64
1870			Location + industry dummies	0.314	1.59
1870			Ln (capital) + location + industry dummies	0.183	0.99
1870	390	0.041	Ln (capital) + location + industry dummies, full year establishments	0.160	0.83

Source: See text and Atack and Bateman (1999a).

establishments relative to large, although for a very different reason than claimed by Sokoloff.

In 1880 the census asked a question about employment that it had not asked previously and, to the best of my knowledge, has not asked since. This question ascertained the *maximum* number of workers employed at the establishment at any point in time during the census year. To understand why the answers to this question are useful in shedding light on whether a Sokoloff-like adjustment to the measured labor input is defensible, it is necessary to look again at the instructions to enumerators, this time at those pertaining specifically to the measurement of the labor input.

Consider, for example, the relevant instructions in 1850 and 1860. "These numbers"—male and female workers—"are to be estimated either by an average of the whole year, or by selecting a day when about an average number was employed, and inserting the number on such day as the average. You will observe that the enumeration of hands is not to apply to any particular day but to express the average number employed throughout the year." The instructions here were not changed for 1870 and 1880, except that in both years separate information was collected on adult males, adult females, and child workers.

Although it is certainly possible that some establishments reported a literally correct average of the number of workers, the answers to the additional question in 1880 suggest, rather, that the numbers reported were "typical"—that is, workers present on a day "when about an average number was employed." To see this, consider the subset of establishments in the 1880 Atack-Bateman sample with one reported worker who was an adult male that claimed to have been in operation for the full year (twelve full-time equivalent months). It is possible to identify such establishments because the 1880 census also asked (in detail) about months of full-time equivalent operation. By definition, these establishments did not shut down at any point during the year so they could not have experienced a period of time during which the number of workers fell (temporarily) to zero, the only integer below the average reported (one). If the one worker as reported was the true average, there should not be any establishments that report a maximum number of workers greater than one. However, 43 percent of these establishments claimed to have had a maximum number of workers greater than one at some point during the year (fully 15 percent reported a maximum of three or more). Conditional on reporting a maximum greater than one, the mean was 2.5 and the median was two.

The reporting of a maximum number of workers exceeding the average was not confined to the subset of one worker, full-year establishments just described. As the first row of panel A of table 6.4 shows, substantial fractions just short of a majority did so, regardless of size. But as the second row of panel A shows, the percentage difference between the maximum and the average declined sharply with the average number of workers.

Table 6.4 Analysis of 1880 question on maximum employment

A. Average versus maximum employment, sample statistics

Reported average number of workers	1	2–5	6–15	16 or more
Weighted sample mean of maximum number of workers	1.646	3.71	11.66	57.2
Weighted sample mean of average number of workers	1	2.83	8.96	47.6
Weighted sample mean of [(maximum – average)/average] × 100 percent	64.6	31.7	29.4	24.4
Percent reporting maximum > average	43.1	38.8	46.9	52.0
Number of establishments	1,102	1,719	475	207

B. Ln (value added) regressions, 1880 establishments hiring only adult males, full-year operation (by average number of workers reported)

Reported average number of workers	1	1	2–5	6–15	16 or more
Maximum number of workers	0.088	0.064	0.038	0.017	0.006
	(0.019)	(0.018)	(0.009)	(0.004)	(0.006)
Ln (capital)		0.169	0.221	0.216	0.247
		(0.019)	(0.016)	(0.030)	(0.037)
Ln (no. of workers)			0.631	0.618	0.616
			(0.058)	(0.118)	(0.103)
Adjusted *R*-square	0.262	0.317	0.517	0.452	0.768

Source: For both panels, see text and Atack and Bateman (1999a).

Notes: In panel A, in addition to standard sample inclusion criteria in table 6.1 (panel A), establishments had to operate for twelve full-time equivalent months and only employ male workers. Data are reweighted to correct for underreporting of special-agent industries (see text for panel A in table 6.1). In panel B, data are reweighted (see text for panel A in table 6.1).

The potential for bias, in other words, appears greater for the smallest establishments.[30]

In panel B, I report coefficients from a regression of the logarithm of value added for establishments in 1880 that operated for the full twelve months of the year. As in panel A, I only focus on establishments that hired adult males in order to avoid complications that arise because of adjustments to

30. Let $M(N)$ be the maximum number hired for establishments with an average number of workers equal to N. By definition (and empirically) the distributions of $M(N)$ are right-skewed. For the smallest establishments, the empirical distributions are smooth and steeply decreasing. For example, among firms hiring one worker on average and reporting M greater than one, fully two-thirds hired exactly one additional worker (that is, a maximum ever employed of two workers) and another 21 percent hired exactly two additional workers (a maximum of thirteen). But among firms with, say, fifteen workers on average but hiring additional workers during the year, the first mode was not sixteen but rather twenty—that is, five additional workers (the second mode was ten or a maximum of twenty-five). In other words, when larger establishments hired occasional workers, it appears these were added in discrete chunks or multiples of the average, which might reflect additional shifts.

worker characteristics. The regressions include dummies for urban status, state, and SIC industry code.

In the first column, I include the maximum number of workers in the regression for one-worker establishments, but do not control for capital invested. The marginal impact of an additional worker hired in this manner is to add about 8.8 percent to value added, and the effect is statistically significant. If we make the assumption that these additional workers were as productive *per day employed* as was the one average worker year round, the coefficient can be interpreted as the fraction of the year that the maximum was employed—in this case, 8.8 percent of the work year, or about one month. Economically speaking, this seems long enough to make a difference to measured output, but not long enough to warrant inclusion as a "typical" worker.

The current version of the 1880 Atack-Bateman sample does not include information on the organization of the firm, as do the 1850–1870 samples. However, if some of the firms reporting a maximum greater than two were partnerships, it stands to reason that they would have more capital invested, which could account for some of the effect of extra workers evident in column (1). As column (2) shows, when I control for capital invested, the effect diminishes to about 6.4 percent, but it is still statistically significant.

The remaining columns in the table repeat the same regression for establishments of larger size. For these regressions I also include the log of the number of average number of workers, since the bin sizes include establishments of different size, unlike the first two columns. As can be seen, having a maximum greater than the average contributes in a statistically significant way for establishments with two to five average workers, and even six to fifteen workers. But the effect is declining in size, and is entirely absent for establishments with sixteen or more workers.

The fact that the maximum number hired contributes less to output as size increases and eventually vanishes is consistent with an asymmetric measurement error interpretation. For a firm with, say, a reported average of twenty workers and a maximum of twenty-four, it is entirely possible—indeed probable—that at some point during the year, *fewer* than twenty persons were at work. That is, even if the larger establishments were also reporting the "typical" number of employees instead of a true average, the typical number for a large establishment is a better estimate—less biased, and possibly not at all—than it is for a small establishment.

Obviously, the evidence in table 6.4 pertains solely to 1880; it is simply not known (and probably unknowable) whether the same phenomenon was present in the early years. However, because the wording of the employment question did not change and because there is some association between organizational form and value added, as shown in table 6.4, it is quite plausible that the same bias is present in 1850 through 1870.

In summary, Sokoloff (1984) was correct that some adjustment to the reported labor input in manufacturing is needed, but was wrong about the

reason. The adjustment is greater in size for smaller establishments, and thus serves to lower the level of labor productivity in such establishments relative to larger ones. The size of adjustment, however, is much smaller than Sokoloff advocated and, consequently, any correction for it has a much smaller effect on the estimated returns to scale.

A simple way to make this point is to add the term for the bias in percentage terms, (Maximum Labor – Average Labor)/Average Labor, to the conventional Cobb-Douglas value-added production for 1880, and to compare the returns to scale parameter with and without this additional variable. For this exercise, I adjust the labor input for its demographic composition, as in panel C of table 6.2, and I also include dummy variables for urban status, state, and SIC industry code. If the bias term is not included, the returns to scale parameter is –0.089 (as shown in panel C of table 6.2). If it is included, the returns to scale parameter is –0.072. Thus, correcting for the asymmetric measurement error in the labor input increases the estimated scale parameter by about 19 percent (in absolute value), but the parameter is still significantly (and well) less than one.

6.6 Concluding Remarks

In a famous paper Sokoloff (1984) argued that the labor input of entrepreneurs was not properly counted by the census and, therefore, labor productivity in small establishments, particularly those not using inanimate power, was considerably overstated. He proposed an elaborate correction for this alleged bias in 1820 but had to make do with a much simpler adjustment—adding one to the count of workers—in 1850. Initially, economic historians were favorably disposed to his correction (Atack 1987) but as research continued doubts set in, with no resolution. This chapter has taken a fresh look at the controversy using data that were not available to Sokoloff (1984) or his chief critics (Atack and Bateman 1999b) at the time. After evaluating textual and statistical evidence for the period 1850–1880, I conclude that Sokoloff's particular adjustment cannot be justified. Without the adjustment the evidence from the census for economies of scale on average in nineteenth-century American manufacturing adduced from production function estimates is not robust. That said, Sokoloff was correct that the labor input in very small establishments was biased upward, but not for the reason he thought. There is an upward bias because most establishments in nineteenth-century manufacturing appear to have reported the "typical" number of workers rather than a true average. Using novel data for 1880, I show that this tendency understates the labor input in small establishments relative to large. A correction for this is warranted but by itself does not deliver parametric evidence of returns to scale.

The findings of this chapter can be seen as half empty (negative) or half full (positive). On the half-empty side, the nineteenth-century manufacturing

censuses are among the great historical documents of US economic history but the information in them does not seem up to the task to reliably summarize differences in productivity between small and large establishments in a parametric—that is, production function—framework. In particular, economic historians who believe that division of labor by itself generated significant widespread productivity gains from the very beginning of the American industrial revolution will likely have to forgo their systematic measurement from the census, relying instead on case studies or extrapolation back in time from much better, noncensus evidence from late in the century.[31]

On the half-full side, perhaps economic historians have made too much of the "rise of big business" as a crucial feature of the growth of American manufacturing in the nineteenth century. Taken at face value, the census data suggest that very small establishments remained quite productive throughout the nineteenth century even as the distribution of establishment sizes was shifting toward larger firms.[32] American manufacturing had its behemoths, but the success of the industrial sector in the nineteenth century may have owed much to having exceptionally productive artisan shops. Rather than dismissing these as data artifacts, future research might profitably concentrate on the underlying sources of differences in productivity across very small establishments at points in time as well as changes in their productivity over time.

31. An important example is the US Department of Labor (1899), an extraordinary study of differences in labor productivity between establishments using hand versus machine methods of production conducted by the department in the late nineteenth century. The department collected detailed data on each step in the production of a very specific product—manila envelopes, for example—when made entirely by hand versus machine, including the amount of time of each step, the number (and characteristics) of workers employed at each step, and the specific capital goods used. Atack (1987) provides some limited comparisons of hand and machine productivity using these data noting that they seem to imply a much larger effect of scale than the census manufacturing data do. Other than Atack (1987), these data have been almost wholly neglected by economic historians. See Atack, Margo, and Rhode (2014) for a preliminary analysis of these data. The unit of analysis is the product by type of labor (hand versus machine) and the dependent variable is the logarithm of the amount of time needed to produce one unit of the good. Atack, Margo, and Rhode (2014) estimate a regression of this dependent variable on the total number of workers that shows a large, negative coefficient—that is, establishments with more workers produce each unit of a product more quickly or equivalently, more units in a given period (the regression includes product fixed effects). This is much clearer evidence of economies of scale in nineteenth-century manufacturing than can be adduced from the census data. If a dummy variable for machine production is included in the regression, the coefficient on the number of workers is halved in size. Because the steps in production are known, it is possible to construct summary measures of the division of labor (number of tasks per worker, total number of tasks). Including these summary measures in the regression changes the sign of the number of workers to positive but the coefficient is no longer significant. The Atack, Margo, and Rhode (2014) preliminary analysis of the BLS data suggests, therefore, that larger establishments were more productive than smaller establishments, and that mechanization and division of labor both contributed to the productivity advantage.

32. Selection/survivor bias may be an important part of this story. Specifically, as very small establishments were being displaced, only the most productive remained in business. Small firms were very risky enterprises; this and selection bias could go some distance in explaining why their ex-post rates of return were quite high relative to larger establishments (see Atack and Bateman 2008). I am grateful to William Collins for this point.

Appendix

Beginning in 1850, it was the goal of the census to include the smallest establishments, those with one worker, in its enumeration of manufacturing, as long as the minimum cutoff of $500 of gross value of output was met. Its intentions aside, the census believed that its enumeration of very small establishments was less than complete before the Civil War, and it sought to improve coverage in 1870. Evidence that it was successful can be found in changes after the war in the relative distribution of one- versus two-worker establishments. In both the 1870 and 1880 Atack-Bateman samples, one-worker establishments are more numerous than two-worker establishments. However, the reverse is true in the 1850 and 1860 samples. It seems unlikely that the postbellum shift reflects underlying economic trends; a more likely explanation is that one-worker establishments were undercounted in 1850 and 1860. To estimate the missing one-worker establishments in 1850 and 1860, I assume that the ratio of establishments with two workers to establishments with one worker is the same as in the 1870 Atack-Bateman national sample, meeting the sampling criteria indicated in footnote 8; this ratio is 1.334. For panel A of table 6.1, I multiply 1.334 by the number of two-worker establishments in 1850 and 1860, to generate revised estimates of the total number (rounded to the nearest integer) of one-worker establishments and adjust the overall frequency distributions accordingly. I do the same in panel B, also assuming that the average gross output of the additional one-worker establishments is the same as for the one-worker establishments reported in the census.

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