

HOURS AT WORK AND TOTAL FACTOR PRODUCTIVITY GROWTH IN NINETEENTH-CENTURY U.S. AGRICULTURE

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The agricultural sector has dwindled in importance in every country that has experienced modern economic growth.¹ The United States was no exception. Agriculture's relative importance has declined steadily since at least the beginning of the nineteenth century. Nevertheless, for much of the time, especially during the nineteenth century, U.S. agriculture was an expansionary force. For the period on which we focus in this paper, 1840 to 1900, output increased at an annual rate of 2.8 percent, while the labor force rose by 1.7 percent (Weiss 1993). This fairly robust performance, however, was not enough as the sector slipped in relative importance. In the words of Willard Cochrane (1979), "for practical purposes the great period of extensive growth in American agriculture which began in 1785 had come to an end by 1900" (p. 342).

Advances in Agricultural Economic History, Volume 1, pages 1-30.

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ISBN: 0-7623-0612-2

Although the broad changes in agriculture are well known, the same cannot be said for the specific components making for expansion in the nineteenth century. The extent to which the growth of agricultural output reflected a growth of productivity rather than simply an increase in inputs is not known, perhaps especially so as regards labor. We will show that the growth of the labor input was the major source of output growth in American agriculture between 1840 and 1900 and the growth of capital was the second largest source. Total factor productivity (TFP) played some part, but was of decidedly less importance than the growth of inputs. We estimate that TFP advanced by only 0.46 percent per year between 1840 and 1900 and by only 0.52 percent per year between 1870 and 1900. These figures suggest much slower TFP growth than had been estimated by John Kendrick (1961, Table B-I). For the latter decades of the century the advance of TFP in U.S. agriculture was noticeably slower than that which was occurring in several European countries. Indeed, although U.S. agricultural output grew substantially faster than that of any European country after 1870, the share of that growth accounted for by TFP in the United States was roughly a third what it was for Europe as a whole.

Our estimate of TFP growth is lower than that of Kendrick because we have taken into account the increase in the average hours worked that occurred during the period. We argue that this increase in average hours per worker was caused by the expansion of the market and, perhaps paradoxically, technological change. We conclude that nineteenth-century U.S. agricultural progress looks a lot less “revolutionary” when one considers that the vast majority of the growth of output can be explained by the growth of inputs—especially labor.

ISSUES

Given agriculture’s initial importance, and the fact that changes occurred slowly and over a long period of time, it would seem that by now we would understand the changes that have occurred. There has not been agreement, however, on the exact pace and timing of the agricultural productivity change underlying the transition. Part of that discussion has been a recurring debate, perhaps a perennial concern, as to whether there was an “agricultural revolution.” If so, when did it occur and why? Even if there were no revolution, there would still be the matter of determining more clearly and accurately when productivity

advance occurred so that we could better understand how and when economic growth came about during the century. An unresolved matter is whether the course of productivity change in agriculture occurred gradually (and slowly) throughout the century, whether it came in varying episodes of little or no productivity advance followed by periods of sharp acceleration in productivity or whether, as with the growth of per capita income, the rate of advance accelerated from a slow traditional rate to a faster, sustained modern rate. If it were the latter case, then when did such an agricultural revolution occur?

Although the most common view has been to mark the Civil War as a turning point, not everyone agrees.² For some the war was only the beginning; they saw “the first American Agricultural Revolution” as having extended over the period 1861 to 1914.³ Other historians have placed the productivity acceleration a bit earlier. Perhaps most notable among these is Lewis Gray (1933) who claimed, “The first four decades of the nineteenth century were characterized by important beginnings in agricultural progress, rather than by striking or revolutionary accomplishments. It was a period of preparation both in the technical and in the business sides of farming—preparation for subsequent progress and expansion” (p. 254).⁴ Others, including Willard Cochrane (1979, p. 69) and Clarence Danhof (1969, pp. 140–144), may have disagreed about the specific timing and degree of acceleration in agricultural productivity advance, but there seems widespread agreement that it could not have occurred much before 1840.⁵ In the words of Cooper, Barton, and Brodell (1947, p. 6), “the year 1840 marks the beginning of worth-while results by inventors and experimenters who had been making persistent trials and studies throughout 50 years.”⁶ Peter McClelland (1997) concurs, arguing that the real revolution was in the inventive activity that took place in the decades leading up to 1840.

An alternative view emphasizes the steadiness of advance and deemphasizes the idea of an agricultural revolution. Earle Ross and Robert Tontz (1948, p. 35) surveyed a large literature about the agricultural revolution and concluded that since writers have placed it anywhere from the half-century before the Civil War to the two decades between the world wars, “our ‘revolution,’ if so it can be called, is a continuing one.” Because there were so many conflicting claims to a revolution, Ross and Tontz felt the developments should be more appropriately labeled an “evolution” (pp. 36–38). William Parker’s (1972) view was that agricultural development was shaped

by three forces—the westward movement, market growth, and technical change—but the opportunities arising out of each were numerous and subject to spurts so that “their combined result, from the perspective of two centuries, is one of continuity, of gradual, steady expansion and improvement” (pp. 370–372).⁷

In earlier work, Thomas Weiss (1993, Figure 1) reported on the growth of *output per worker* in agriculture and related that evidence to issues associated with the timing of any acceleration in the rate of productivity advance during the nineteenth century. That evidence indicated that productivity advanced more rapidly after 1840 or 1850 than it did before, but within the post-1850 period there was no obvious shift in the trend rate of growth. Weiss and Lee Craig examined more thoroughly the growth of output per worker over the Civil War decade. One of their chief findings was that workers, especially women and children, apparently increased the number of hours at work on farm tasks.⁸ Here we investigate productivity growth by focusing on total factor productivity growth as well as the impact of changes in hours of work within agriculture. As yet, our evidence does not permit an examination of decade-to-decade changes. The estimate of the trends over the entire period, however, seems secure, and that is our chief focus. The evidence for examining the pre- and post-Civil War periods may be less reliable, but we think it is strong enough to warrant a look at these two major subperiods.

Total factor productivity growth has been an item of interest in the study of economic growth since the 1930s, and especially so since the publication in the 1950s and 1960s of articles by Moses Abramovitz (1956), Robert Solow (1956), Zvi Griliches (1960), and Dale Jorgenson and Griliches (1967), and the aforementioned book by Kendrick (1961).⁹ Lying behind the interest in the concept is the simple fact that improvements in the efficiency of the economy, or any production process, can only be fully understood if all factors of production are taken into account. If one measured the productivity of only one factor, namely labor, one could miss the fact that its productivity was rising simply because more of the other inputs were being used. Thus when all factors were taken into account, the efficiency of the production process might have been advancing much more slowly than suggested by the productivity growth of a single input. There may have been much less “technological progress,” say, than the change indicated by output per worker.

Although the chief interest in TFP seems to have been for assessing an entire nation's economic advance, it has been studied at the sectoral and industrial level as well. This is where our interest lies. In particular we are interested in the course of total factor productivity advance in U.S. agriculture, especially over the nineteenth century. Our interest is twofold. On the one hand, we ultimately hope to offer a comprehensive explanation of why agricultural output and output per worker rose over the course of the nineteenth century and why the rates of change in those variables varied as they did. Advances in TFP will be a part of any such explanation. Second, we expect that the rate of advance of TFP, and its variations over time, had much to do with explaining the economy's shift out of agriculture.

Furthermore, in gauging total factor productivity advance and assessing its relative importance we have also taken into account changes in the number of hours worked. Although it has been recognized from the inception of modern growth accounting that the change in hours at work is an important source of change in the labor input, the effect of such changes has not always been taken into account. If one ignores those changes, the aggregate measures of the labor input may be seriously biased, which in turn will bias estimates of TFP.¹⁰

Figures reported by Colin Clark (1957) show that starting around the middle of the nineteenth century man-hours per capita declined in every Western nation for which the appropriate data were available. Typical declines over the subsequent century were around 0.25 percent per year, and according to Clark this was true in the United States as well. At the same time annual per capita rates of real economic growth rose (and remained) above 1 percent.¹¹ Simon Kuznets (1966) labeled this process "modern economic growth," and claimed that "the increase in national product per capita...could not have been due to greater input of man-hours per capita" (p. 75). He emphasized instead factors such as savings and capital formation as the primary sources of modern economic growth.

As a general proposition applied to the aggregate economy over the entire course of modern economic growth, the claim of Clark and Kuznets seems sound, but the trend in hours may not have always moved downward, and quite likely the behavior of hours worked was not the same in all industrial sectors. Robert Gallman (1975) conjectured that "the shift from agriculture to non-agricultural work may well have *increased* the average number of hours of labor per year engaged in by

the typical worker” (p. 55, emphasis in original).¹² Because modern economic growth in the United States appears to have begun sometime before mid-century, it would seem that a portion of that growth was brought about by an increase in hours.

At the sectoral level, there seems little question that average hours worked per week in U.S. manufacturing decreased throughout the nineteenth century, going from around 70 hours per week in 1830 to 55 hours per week by the end of the century—a decline of roughly 0.33 percent per year.¹³ Much less is known about the other sectors, but it is unlikely they all experienced the same long-run trend as that in manufacturing. This may be especially so for agriculture for which there appears to be no agreement as to what happened to average hours worked during the nineteenth century. Dewhurst (1947, p. 1073), for example, argues that average weekly hours in agriculture fell from 72 hours in 1850 to 60 hours in 1920.¹⁴ On the other hand, estimates by Harold Barger and Kendrick indicate no change in average weekly hours in the latter decades of the century. Their estimates, however, relied primarily on evidence from the first decade or so of the twentieth century and the assumption that there had been no change over earlier decades.

Barger (1955) believed that, at least for the latter decades of the nineteenth century, the net effect of changes within the farm sector resulted in little, if any, change in hours worked per year. He stated that after 1869 “actual hours worked by farm operators in each kind of farming, have probably fallen somewhat,” but due to the disproportionate growth of certain types of year-round farm activities, such as dairying, he averred that “hours worked per year, . . . , have remained remarkably stable” (pp. 10-12). According to his evidence, by the first decade of the twentieth century farm and industrial laborers were working on average roughly the same number of hours per week.¹⁵ Kendrick affirmed Barger’s conclusion, basing his estimates of average hours worked in nineteenth-century agriculture on the observation that no trend existed after 1910:

In view of the lack of trend exhibited by our estimates for the period since 1910, we have extrapolated the man-hours estimates by employment from 1870 to 1910, thus accepting Barger’s judgment that average hours were relatively constant before as well as for decades after 1910 (1961, p. 354).

The idea of constancy in the late nineteenth century seems implausible for no other reason than the sector had to adapt to a major transfor-

mation in the farm labor force in the South. The freeing of the slaves appears to have resulted initially in a large decrease in the amount of labor devoted to agriculture in the South. Some of this took the form of a decrease in the number of workers, but some must have manifested itself as a reduction in average hours. And, as we discuss below, the large declines in output between 1860 and 1870 were associated with a substantial decline in hours worked. It would seem very unlikely then that average hours worked in such an untypical year as 1870 could have been the same as in 1900.¹⁶

Even for the free workforce, it is unlikely that hours worked in agriculture were the same as those in manufacturing during the nineteenth century. Gallman (1975) has argued that hours worked in nineteenth-century agriculture were below those in manufacturing, especially so in the first half of the century as “the typical agricultural worker—slaves apart—was unable (and perhaps unwilling) to fill his year with work” (p. 56). If there were such a difference in the nineteenth century, then the equality between the two sectors that appears to have been achieved in the early twentieth century must have been brought about by a decline in manufacturing’s hours to the lower level that prevailed in agriculture, or by increases in hours worked in agriculture, or some combination of the two.¹⁷

Craig and Weiss (1993), in their study of the Civil War decade, abstracted from the impact of freeing the slaves by focusing on northern agriculture and so constructed a picture of what was likely happening among free agricultural workers. If that estimated increase represented a broader trend over at least part of the nineteenth century, then the history of long-run U.S. growth should be reconsidered. That is to say, for any given path of the labor force, capital stock, and output, an increase in average hours would have increased the labor input and lowered total factor productivity growth. Some portion of U.S. growth may have come at the cost of reduced leisure. Such a reinterpretation might alter the view that late nineteenth-century U.S. agriculture was marked by a “revolution.”¹⁸ Better estimates of hours worked in agriculture seem necessary, an effort to which we now turn.

ESTIMATES OF HOURS AT WORK IN U.S. AGRICULTURE

As the survey above indicates, a number of scholars and researchers have produced estimates of hours worked in agriculture or in some of its

Table 1. Hours of Labor Required to Produce a Unit of Output of Specific Agricultural Products at Census Benchmark Dates

Commodity	Share of output in 1840	Hours per Unit of Output				Average Annual Percent Change			
		1840	1860	1870	1900	1840-1860	1870-1900	1840-1900	
Livestock									
Hogs (cwt)	17.7%	4.17	4.17	4.02	3.60	0.00	-0.37	-0.24%	
Cattle (cwt)14.3	5.28	5.28	5.28	5.28	4.60	0.00	-0.46	-0.23	
Dairy Pro. (cwt)	8.8	3.25	3.51	3.58	3.94	0.39	0.32	0.32	
Chickens (cwt)	2.4	7.84	8.46	8.63	9.50	0.38	0.32	0.32	
Eggs (doz)	1.1	0.18	0.20	0.20	0.22	0.53	0.32	0.32	
Other Poultry (cwt)	0.2	25.9	28.0	28.5	31.4	0.39	0.32	0.32	
Crops									
Corn (100 bu)	15.8%	344	238	198	114	-1.82	-1.82	-1.82%	
Hay (ton)	7.8	35	21	17	10	-2.52	-1.75	-2.07	
Cotton Lint (100 lb)	7.2	88	82	68	55	-0.35	-0.70	-0.78	
Wheat (100 bu)	6.1	310	205	167	90	-2.05	-2.04	-2.04	
Oats (100 bu)	4.2	143	99	83	48	-1.82	-1.81	-1.80	
Irish Potatoes (ton)	2.2	25	25	25	27	0.00	0.26	0.13	
Sweet Potatoes (ton)	1.9	46	46	46	49	0.00	0.21	0.11	
Tobacco (100 lb)	1.8	44	44	44	44	0.00	0.00	0.00	
Rye (100 bu)	1.4	310	270	252	205	-0.69	-0.69	-0.69	
Buckwheat (100 bu)	0.4	264	230	215	175	-0.69	-0.68	-0.68	
Barley (100 bu)	0.3	287	197	163	92	-1.86	-1.89	-1.88	
(continued)									

(continued)

Table 1. (Continued)

Notes:

Livestock:

Baleman (1969) estimated that between 1850 and 1900 roughly one-half of the decade-to-decade growth of the yield per cow was due to an expansion of the milking season; therefore we estimated the change in hours per cwt as 50 percent of the growth of the yield. The 1840 figure was projected from the average annual compounded rate of growth between 1850 and 1900. The 1900 figures for the other livestock activities are based on the requirements for 1910–1914. Those figures are from U.S. Department of Agriculture, as reported in *Historical Statistics*, Series K445–485, which seem to be largely taken from figures reported by Hecht and Barton, *Gains in Productivity*, various tables. The figure for hog production for 1840 was assumed to equal that for 1860 which was calculated from figures reported in the annual reports of the Ohio State Board of Agriculture. The figure for 1870 was interpolated between the 1860 and 1900 values. The figures for cattle production after 1870 are based on the differences in time requirements between range and stall-fed livestock reported in Hopkins (1941, pp. 143–44) and the relative shift to range production. Narrative evidence suggests that prior to the 1860s the trend toward stall feeding probably offset the early movement to open ranges, with the result being little or no change in required hours, so we assumed that the 1840 figure equaled that for 1870. The dairy figures provide not only direct evidence for that important component, but, as suggested by Craig, *To Sow*, the trends in poultry followed those of dairying, and so we used the latter figures to project the former.

Crops:

Corn, wheat, and oats—The requirements for these three crops were derived from the estimates made by Parker and Klein (1966). We took their figures for 1840 and 1910, and obtained the figures for 1870 and 1900 by interpolating at a constant rate of change between the two dates.

Hay—For 1840 we used data from Cooper et al., and for 1900 we used the figure reported by Hecht and Barton for 1910–1914. Because most of the gains in hay production came from the use of reapers and mowers early in the period we estimated the figures for 1860 and 1870 by fitting a rectangular hyperbola between the two benchmarks.

Cotton—For 1840 we used the figures reported by Cooper, et al. The 1870 figure was obtained by interpolating between this 1840 figure and their estimate for 1890. For 1900 we used the figures reported by or derived from Hecht and Barton for 1910–1914.

Potatoes and Tobacco—We derived the potato figure for 1900 from data for 1909–1913 reported in Hopkins (1941). For 1840, 1860 and 1870 we used the lower figures for potatoes from data reported by Hecht and Barton for 1910–1914. The sweet potatoes figures are calculated from the relative time inputs reported in Hecht and Barton (1950, Table 26). In general there was no trend in potato production until after 1920. The tobacco figures are also from Hecht and Barton, and show no trend until after 1948.

Rye, Buckwheat and Barley—The 1900 figures were calculated from data reported in Hecht and Barton (1950, Tables 23, 44, and 45). The growth rate for rye was derived from the assumption that the labor requirements for rye were no greater than those for wheat during the antebellum era. We then applied the resulting growth rate to buckwheat production. The barley figures were derived from the mean growth rate of wheat and oats.

subsectors. More important, lying behind those estimates are figures on the labor requirements for specific farm tasks that can be used to calculate the number of hours worked in agriculture, or at least major portions of it.¹⁹ Although most statistics on labor requirements pertain to the early twentieth century, several key ones cover portions of the nineteenth century as well. We have assembled estimates for benchmark dates in the nineteenth century (see Table 1) so that we can see the long-term trends as well as changes over the important subperiods. We also indicate the proportion of agricultural output for which we have such data.

The products for which we have some evidence on labor requirements make up a very substantial proportion of total farm output. As can be seen in column 1, the 1840 share approximates 90 percent. Of course not all of these figures are obtained from direct observation in specific years. Some, such as the figures for poultry production, were derived by extrapolating backward a known value from a later year based on the change in a related statistic—in this case the trend in productivity in dairying, which is taken directly from estimates derived by Fred Bateman (1969). In the case of other products, we have observations near the beginning and end of the period, but the intervening years are simply the trend values between the two points. Corn, wheat, and oats are examples of this. For those crops we used the labor requirements estimated by Parker and Klein as the end-point observations, and assumed the intervening values lay along the trend line between the two points. For a few crops, namely rye, buckwheat, and barley we assumed that the requirements and/or trends were the same as those for similar products, specifically wheat and oats. (For the details of and sources for the calculations of the requirements for each product line, see the notes to Table 1.)

The use of these proxies and interpolated values obviously does not give us the actual incidence and timing of the changes that occurred, but it does give us a picture of the broad trends that took place. Perhaps even more important, although the evidence does not cover all output, the more reliable figures pertain to some of the most important crops and livestock production. Pork, beef, corn, and wheat, for example, accounted for more than half of the value of farm output and hours in 1840. In addition, dairying produced 9 percent of the value of output and accounted for 7 percent of the hours. In 1900 the shares for corn

alone were 18 percent of output and 23 percent of the hours, and dairying accounted for 10 percent and 17 percent, respectively.

The evidence assembled indicates that time requirements changed over time. In dairying, and thus by assumption poultry production, hours increased. In every other major product line there were reductions in the hours required per unit of output. In crops there were reductions in most products for which we have evidence, and between 1840 and 1900 those decreases proceeded at a fairly rapid pace of around 2 percent per year in the major crops such as corn, hay, wheat, and oats. In the case of crops these changes presumably resulted from improvements in technology including the adoption of mechanized implements, and to that extent our estimates of the changes in the number of hours captures the impact of *measured* technological progress.²⁰

In the case of livestock production, the hour requirements decreased as well, albeit at a slower pace than in the major crops. The slowness of the decrease captures the effect of changes in feeding practices. At the beginning of the era in question, farmers spent almost no time caring for livestock (Danhof 1969, pp. 160–161). James Bonner (1964) noted, for example, that in antebellum Georgia, “The work required by such excellent care and feeding [of livestock] did not appeal to the average planter” (p. 146). Indeed, one of the most salient features of nineteenth-century animal husbandry was the conversion from range-fed to stall-fed breeds, with a necessary increase in hours devoted to those tasks (Heise and Christman 1989). Of course, the increase in time requirements associated with stall feeding was offset by the opening of the western ranges, where labor requirements were lower. The figures in Table 1 show that after 1870, this latter effect dominated the former.

The changes in time requirements in dairying were due to factors other than those that shaped hours required in the production of livestock for slaughter. The increase in hours in dairying reflects the net effect of some additional time being required to comply with changes in the care of livestock and to make improvements in sanitation, which together seem to have offset whatever technological advances may have occurred.²¹ In any case, technological change was not very great and so more inputs were required to produce the higher levels of output. Nevertheless, the labor requirements used in our calculations capture the impact of whatever measured technological change did occur.

These labor requirements per unit were used to estimate the total number of hours needed to produce the agricultural output in each

Table 2. Weekly Hours per Worker by Agricultural Task

	Livestock	Crops	Combined	Land Clearing	Other Improvements	Maintenance	All Tasks
1840	3.4	18.4	21.8	3.4	1.1	5.6	31.9
1860	3.8	18.1	21.9	3.3	1.3	9.0	35.5
1870	4.6	15.7	20.3	2.5	0.9	11.7	35.4
1900	7.6	18.2	25.8	1.5	0.7	14.3	42.2
Average annual rate of change:							
1840 to 1860	0.56	-0.08	0.02	-0.15	0.84	2.40	0.54
1870 to 1900	1.69	0.49	0.80	-1.69	-0.83	0.67	0.59
1840 to 1900	1.35	-0.02	0.28	-1.36	-0.75	1.58	0.47

Notes: The hours for livestock and crop production were derived by applying the labor requirement figures shown in Table 1 to the annual production of those products. The production figures are those of Towne and Rasmussen, (1960). Those calculations yielded the hours needed to produce roughly 90 percent of the dollar value of output. For the remaining output we assumed that the average hours per dollar for the products with known labor requirements applied.

Land Clearing—Acres cleared and time per acre for 1900 are from Primack, (1963) His 1850 figures for labor requirements for forested versus non-forested land were applied to estimates of the 1840 acreage of each type. Those estimates are from Weiss, (1990).

Other Improvements—Average time spent on other improvements was derived by multiplying the ratio of "man-years" spent on other improvements to "man-years" spent clearing land (from Primack) by the average hours spent clearing land reported above.

Maintenance—Time spent on maintenance in 1900 was derived from direct estimates for 1936 reported in Hopkins (1941). Hopkins notes that his figures for 1936 probably represent a "small reduction" when compared to those prior to World War I (pp. 25–26). Because the figures reported in Hopkins include some time spent feeding and caring for livestock other than draft animals, we subtracted time spent in those activities from the resulting maintenance series. We then calculated maintenance hours per dollar of farm capital from Primack for 1900. We calculated a similar number for 1840, based on regional differences found in Hopkins. Because most of the reduction in maintenance hours per dollar of farm capital came after the opening of the plains, we estimated the figures for 1860 and 1870 by fitting a rectangular hyperbola between the 1840 and 1900 figures.

benchmark year. For each product for which we have estimates of labor requirements, we divided the quantity of output by those estimates. Although those calculations yield the number of hours worked in a very large percentage of output (see Table 1), they do not cover all the crop and livestock production. We estimated the hours in the remaining lines of production by inflating the figures for which we could calculate the number of hours worked. To do this, we divided the hours required to produce the output of those activities for which we have information by the share of the total value of output accounted for by those items. In effect, we are assuming that the value of output produced per hour in those lines of production for which we do not have information equaled that in the lines for which we do have information.²² Dividing the inflated total number of hours in crop and livestock production by the agricultural labor force gives the annual hours per worker in agriculture. We have divided those annual figures by an assumed constant number of work weeks (50) in the year in order to present in Table 2 an average weekly number of hours per worker, a figure that seems more easily grasped.

In addition, we made estimates of time spent in other farm activities. We have identified three other major activities: clearing land, making other improvements to the farm (such as drainage, fencing, and new construction), and maintenance (which includes maintaining tools, implements, and draft animals).²³ These estimates are shown in Table 2.

The time spent in crop and livestock production increased over the course of the entire 60-year period at a very gradual rate; the increase averaged only 0.28 percent per year.²⁴ Hours worked in the two major components exhibit decidedly different patterns. The number of hours devoted to crop production remained roughly steady, while those spent on livestock production rose. Time spent on crops declined dramatically during the Civil War decade, and then increased, with the net result being that the figure at the end of the period was slightly below that for the beginning of the period. The average hours spent in livestock production, on the other hand, increased in every decade, and rose at an average of 1.35 percent per year. Given that labor requirements per unit of output in livestock production, other than in dairying, fell slowly, the increase highlights the rapid growth of output in livestock production, as well as the increased relative importance of dairying.

This finding contrasts sharply with the trends in land clearing and improvements. The average amount of time spent clearing land declined throughout the era, as one might have expected. Although the average annual *number* of acres cleared was typically much higher after the Civil War than before or during it, most of the land cleared after the war was on the northern and southern prairies which required considerably less time to be brought into production than the forests of the east.²⁵

Finally, the farm activity that saw the most substantial increase per worker was the maintenance of tools and implements, fencing, and time spent on the care and maintenance of draft animals. The time spent in maintenance activities more than doubled after 1840, a finding consistent with the increased use of mechanized farm implements, which by all accounts required a great deal of maintenance. Furthermore, and perhaps quantitatively more important, was the increased reliance on draft animals and the growing importance of fencing and farm structures that were often associated with livestock production, all of which required substantial amounts of maintenance.

Although the trends in hours worked varied across farm activities, the increases in livestock production and maintenance overwhelmed the declines in land clearing and improvements, yielding a net increase in average hours worked of roughly 10 hours a week, or 32 percent overall. Average weekly hours rose over the period at an annual average rate of 0.47 percent.

Worthy of note is the result that the average weekly hours did not change during the decade of the Civil War. This is a far different picture than the 20 percent increase we estimated in our earlier work (Craig and Weiss 1993). Some of the difference no doubt reflects the fact that the hours worked were estimated in two different ways, but what is much more pertinent is that our earlier study pertained solely to northern agriculture, whereas the estimates in Table 2 cover the entire United States. The impact of including the South is profound because of the enormous declines in production that took place in the slave states between 1860 and 1870. Although the change from slave to free labor reduced the amount of labor supplied, that decrease fell far short of the declines in output.

We have looked at only four of the most important crops produced in the South for which we have evidence on labor requirements. These are cotton, tobacco, corn, and wheat, which combined required 13.7 hours per week for the entire United States in 1860 but only 9.2 hours in 1870.

This decline of 4.5 hours per week more than accounts for the decline of 2.4 hours in all crop production, and reflects the net effect of some reductions in labor requirements per unit of output, a small increase in the number of workers, and large decreases in production. Moreover, the drops in production were concentrated in the South; for example, cotton output was cut nearly in half, while tobacco production declined by 40 percent. Wheat output rose for the entire nation by 66 percent, but declined by 22 percent in the South. Corn output, the single largest source of hours fell by 9 percent nationwide, and by more than 30 percent in the slave states (U.S. Bureau of the Census 1870, pp. 688–711).

We have not yet established labor requirements for each region so cannot produce firm estimates of the impact of these decreases in production, but we can generate hypothetical figures that are very illustrative. If the requirements per unit of output were the same in every region, then the reduced output of these four crops resulted in a decline of nearly eight hours per week in the South, but only one hour in the rest of the United States. Most of the decline originated with the changes in cotton production, where if we take into account all three factors (changes in requirements, the number of workers, and production) the weekly hours per worker fell from 11 to 5.6 hours. In this case the fall in production accounts for virtually all of the change in hours worked. If the labor requirements per unit of output and the labor force had been exactly the same in 1860 and 1870, then weekly hours per worker would have fallen from 11 to 6.2 hours. In other words, a decrease of 4.8 hours can be attributable to the fall in output alone, leaving a further reduction of only 0.6 hours to be accounted for by the two other factors.

The Civil War decade was an anomaly as regards hours worked, and we should not let it distract us from the main finding: average weekly hours increased over the period 1840 to 1900 by 0.47 percent per year, and even faster in the period after 1870. Increases of this magnitude would seem to have been an important and overlooked source of growth in agricultural output. The finding gives added strength to Gallman's assertion that average hours worked *economy-wide* increased over the century. In his view, the increase emanated from the shift of the labor force from agriculture to manufacturing where average hours worked were higher, though as the quotes above attest, he surely suspected that hours per worker increased in U.S. agriculture after the antebellum era. It appears from our calculations that many of those who remained behind were also working longer hours.

CAUSES AND IMPLICATIONS

Broadly speaking two factors caused the upward trend in average hours worked in late nineteenth-century U.S. agriculture. The overriding phenomenon was the expansion of the marketable surplus, which itself was the result of a number of influences, including but not necessarily limited to transportation improvements, urbanization, and rising consumer incomes.²⁶ The second major factor that caused some increase in hours worked in agriculture was, paradoxically, technological change in the agricultural sector.

The archetypal technological breakthrough in nineteenth-century U.S. agricultural was probably the mechanical reaper, which was clearly a labor-saving device.²⁷ Farm incomes, however, are directly related to time worked during crucial periods—for example, during planting and harvesting.²⁸ The amount of time farmers could spend at work during these crucial periods was constrained by their biological limits, which in conjunction with the extent of mechanization determined the acreage that could be devoted to this crop.²⁹ Mechanical reapers and sowers lessened the peak intensity of effort in planting and harvesting and thereby may have allowed some increase in total hours worked during those periods, but perhaps more important, allowed an increase in the amount of acreage that could be farmed for any given number of hours. This increase in acreage, however, meant there was more work to be done during the rest of year in cultivating, processing, and so forth.

To see the possible effect of mechanization on hours worked, consider the following hypothetical example based on figures in Atack and Bateman. A typical owner-operated northern farm might have contained something like 80 acres of which two-thirds might have been “improved” or cleared; the amount of that land in crops being dependent on the amount of labor available during peak-demand periods, such as planting and harvesting. In a typical year the farm might have had 15 acres in wheat, 25 acres in corn, and the rest in other crops or garden. A self-rake reaper took a crew of six one day (six man-days in all) to harvest 10 acres of wheat,³⁰ at a savings of approximately one-third of a man-day per acre (three man-days in all). In other words, before the use of the reaper it would have taken this hypothetical family 13.5 man-days to harvest its wheat, which might well have been the binding constraint on the number of acres actually sown. Now, with a

Table 3. Growth of Output, Inputs and Productivity in U.S. Agriculture, 1840 to 1900

	Output	Numbers of Workers	+	Hours per worker	=	Total Labor	Land and Farm Capital	TFP
<i>Panel A: Average Annual Compound Rates of Growth</i>								
1840–1860	3.10	2.45		0.54		3.00	3.67	–0.14
1860–1870	1.96	0.12		–0.03		0.09	1.16	1.47
1870–1900	2.85	1.67		0.59		2.26	2.46	0.52
1840–1900	2.79	1.67		0.47		2.15	2.65	0.46
<i>Panel B: Shares of Output Growth Explained by:</i>								
1840–1860	—	49.8		10.9		60.9	43.7	–4.6
1860–1870	—	3.8		–0.9		2.8	21.9	75.2
1870–1900	—	36.8		12.9		50.0	31.9	18.1
1840–1900	—	37.7		10.6		48.4	35.1	16.5

Notes: Output is measured in dollars, valued at prices of 1840 (Weiss, 1990, Table A-3). Total labor is the product of the number of workers (from Weiss, “Revised Estimates”, Table A-5) times the annual hours per worker. Annual hours per worker can be calculated by multiplying the number of hours per week (shown in Table 2 above) by 50 weeks. Indices of land and farm capital were calculated from figures reported in Gallman, (1986).

The factor inputs’ contributions to output growth were calculated by assuming labor’s share of output was 0.63 and capital’s was 0.37. The shares are the product of factor prices and quantities divided by the value of total product. TFP is the residual of output growth not explained by the growth of labor and capital, and thus is influenced by the choice of these output shares. The relative importance of TFP, however, is not affected much by the choice of shares. The shares we used were taken from Kendrick (1961, Tables B-1 and B-2). The evidence indicates that for this time period the price of capital was falling, while the real prices of land and labor were rising. (see the discussion in the text). At the same time the capital-labor and land-labor ratios were rising. It is thus difficult to infer the bias, if any, of technological change during the period in question, so we have assumed that there was none. That assumption does not appear to be critical; the relative importance of TFP growth is not affected much by the use of different shares. If we used a much lower labor share (55 percent) and thus a higher capital share (45 percent) the relative importance of each of those factors is noticeably different, but the importance of TFP remains virtually unchanged. In this case, labor’s contribution would have fallen to 44 percent, capital’s would have risen to 39 percent, while TFP’s contribution to the growth of output would have slipped to 17.5 percent. If we had instead used a higher labor share (75%) and lower capital share (25%), TFP’s contribution to growth would have edged up to 18.9 percent.

reaper, the family has the option of expanding its acreage in wheat by 50 percent (7.5 acres) without having to increase the total time spent harvesting.³¹ All the other activities associated with wheat production, however—sowing, threshing, winnowing, bagging, and hauling, and caring for the horses needed to pull the implements and wagon, not to mention clearing the additional land that can now be sown in wheat, had not been subject to mechanization; or if so at least not to the same labor-saving extent as the harvesting task. Thus, the amount of time spent in those other activities must have increased in order to be consis-

tent with the more abundant harvest.³² With the same number of hours spent harvesting and an increase in hours devoted to related tasks, farm mechanization in this case would have led to an increase in total hours in wheat production. Other product lines would have been influenced in the same way, although the initiating cause was not necessarily mechanization of the harvest activity.³³ Overall then, nineteenth-century farm mechanization probably led to a substitution out of leisure into income-producing activities among those workers who remained in agriculture.

TOTAL FACTOR PRODUCTIVITY

Whatever the ultimate cause, the increased hours hold important implications for measuring total factor productivity advance and for interpreting long-run U.S. growth. If the trend in hours in nineteenth century U.S. agriculture was positive, as we have estimated, then earlier estimates that assumed no trend in hours have underestimated the rate of growth of the aggregate labor input and the share of output growth explained by growth in the labor input, and overstated the role of total factor productivity in overall agricultural growth.

We have used these new estimates of hours worked, as well as revised figures on the farm labor force, to calculate new estimates of TFP growth in nineteenth-century agriculture. These estimates, as well as figures on the average annual compounded rates of growth of real agricultural output, labor, and capital between 1840 and 1900, are shown in Table 3, panel A. In panel B we show the allocation of the growth in output among labor, land farm and capital, and TFP.

Over the entire period 1840 to 1900, the growth of the total labor input, that is total hours, which is the product of workers and annual hours, explains the largest share of output growth (roughly 50%); the increase in capital accounts for one-third; total factor productivity accounts for less than one-fifth. The relative importance of these factors varied over the periods for which we have evidence, with TFP growth explaining perhaps more than one-half the growth of output over the 1860s. Because TFP is the residual claimant, that result reflects the peculiar changes in output and labor inputs that materialized during that decade rather than the likelihood that productivity advances had occurred at a truly remarkable rate. More generally, over the long term TFP is the least important source of growth; the growth of agricultural

output in the United States seems to have been driven predominantly by the growth of inputs—especially labor.

Although the importance of the labor input (total hours) varied somewhat over time it was the dominant source of growth, except in the 1860s. Within the labor input, the growth in the number of workers was generally more important than the increase in hours, but even the latter was noteworthy. Despite the fact that the increase in hours per worker was of much less importance than the increase in the number of workers, it still accounted for nearly 11 percent of the growth in output that materialized between 1840 and 1900, and in the pre-Civil War period was more important than TFP growth. Although more complete evidence for the century might alter this pattern somewhat, it seems clear that overall the increase in hours was not negligible and quite likely at times its importance must have been substantial.

The inclusion of increased hours as part of the labor input materially affects the TFP figures. If the increase in hours were neglected, their effect on output would become part of the residual source of growth. As a consequence, TFP would have advanced at a rate of 0.93 percent per year, and would have accounted for nearly one-third of the growth of output between 1840 and 1900, instead of the less than one-fifth share that we calculate. Under those circumstances, our estimate of TFP growth and its impact would have been similar to that of Kendrick. According to Kendrick (1961, Tables B-1 and B-2), TFP advanced at a rate of 0.99 percent per year between 1869 and 1899, and “explained” 33 percent of the growth of agricultural output. It was a slightly more important source of growth than the increase in capital (30%) and only slightly less than the growth of labor (35%). Furthermore, Kendrick’s estimate of TFP growth in agriculture puts it above that in manufacturing (0.99 versus 0.82% per year), and it would have contributed nearly twice as much to the growth of output as that factor did in manufacturing. Our new figures put the rate of growth of TFP in agriculture at only 0.46 percent per year between 1840 and 1900, and only 0.52 percent between 1870 and 1900, well below the rate Kendrick found for the period 1869 to 1899, and well below the 0.82 percent that occurred in manufacturing. TFP was also a less important source of growth in agriculture. In the period 1870 to 1900 TFP growth accounted for only 15 percent of the growth of agriculture, a bit less than in manufacturing (18%).³⁴

Table 4. Comparison of Estimates of TFP Growth Based on Alternative Series on the Growth of Output, Inputs and Productivity in U.S. Agriculture, 1870 to 1900

	Source of Output	Data on Manhours	Land and Farm Capital	Average Annual Compound Rates of Growth of TFP	Share of Output Output Growth Explained by TFP
1.	Kendrick	Kendrick	Kendrick	0.98%	32.2%
2.	Kendrick	Kendrick	Gallman	1.00	32.8
3.	Kendrick	Revised	Kendrick	0.69	22.6
4.	Kendrick	Revised	Gallman	0.71	23.2
5.	Weiss	Kendrick	Kendrick	0.79	27.7
6.	Weiss	Kendrick	Gallman	0.81	28.3
7.	Weiss	Revised	Kendrick	0.50	17.5
8.	Weiss	Revised	Gallman	0.52	18.1

Notes: The shares of output growth were calculated by assuming labor's share of output was 0.63 and capital's was 0.37. The shares were obtained from Kendrick (1961, Tables B-1 and B-2). Kendrick, (1961, Tables B-I) Weiss (1990, Table A-3) Gallman (1986). The Revised figures are from Table 3 above.

The paucity of data prohibits a direct econometric estimation of total factor productivity growth in U.S. agriculture, but the duality of cost and production functions permits us to compare our results with those implied by the behavior of input prices. Although the long-run trend in the nominal prices of farm products was generally downward during the period in question, the relative price of farm products rose slightly between 1840 and 1900 (about 0.50% per year).³⁵ At the same time, real wages and land prices rose, at 0.30 and 1.40 percent per year respectively, while the price of capital was falling.³⁶ The behavior of farm implement prices and interest rates indicates that the price of capital was probably falling between 1 and 2 percent per year.³⁷ If we assume that the factor shares (as estimated by Kendrick) remained unchanged during the period, the aggregate cost function for U.S. agriculture implies TFP growth in the neighborhood of 0.20 to 0.30 percent per year.³⁸ Although this figure appears low by most accounts, it nevertheless is much closer to our revised estimate than it is to earlier estimates, especially that by Kendrick.³⁹

The difference between our estimate of TFP growth and Kendrick's (−0.46% per year between 1870 and 1900) is the net effect of three changes: (1) a slower rate of growth of output, (2) a slower rate of growth of capital, and (3) a faster rate of growth of the labor input (total hours) in our calculations. Table 4 contains the TFP growth rates and the share of output explained by TFP growth for the various combina-

Table 5. International Comparison of Agriculture,
1870–1910 Rates of Growth and Sources of Productivity Growth

	Average Annual Compounded Rates of Growth of:		Share of Growth Explained by:	
	Output	TFP	Inputs	TFP
Ireland	0.15%	0.36%	–140%	240%
Britain	0.15	0.19	–26	126
France	0.37	0.46	–24	124
Switzerland	0.80	0.78	02	98
Norway	0.52	0.48	08	92
Germany	1.68	1.53	09	91
Austria	1.41	1.21	14	86
Belgium	0.97	0.83	14	86
Sweden	1.29	1.03	20	80
Denmark	1.78	1.31	26	74
Hungary	1.61	1.11	31	69
Netherlands	1.29	0.82	34	64
Europe	1.06	0.65	39	61
Poland	1.93	0.90	53	47
Italy	0.86	0.37	57	43
United States–Kendrick	3.02	0.99	67	33
Russia	1.06	0.34	68	32
United States–Revised	2.85	0.52	82	18

Notes: Zanden did not adjust for changes in hours worked and thus his estimates are not directly comparable to ours. His labor input measure is biased upward because he assumed that women and children worked to the same extent as males, and thus worker productivity is understated (1991, p. 218). A more important consideration is whether the participation of women and children changed at the same rate as that for males. There is reason to think that their participation in some countries may have decreased more than that of males, in which case his estimate of the growth of labor would be too high and thus the growth of productivity too low. (Zanden, 1988 p. 5).

Source: Zanden, (1991, Table 4) and Table 3 above.

tions of sources for output, labor, and farm capital. Using Kendrick's figures as a baseline, the faster growth of the labor input in our "revised" estimates explains most of the difference, (0.29% out of 0.46%) and most of that reflects the growth in hours per worker. The growth in the number of workers is a bit slower in our estimates which used Weiss's labor force series, whereas the number of hours per worker grows much faster in our revised estimates simply because Kendrick assumed there was no increase in hours. The use of Weiss's output figures instead of Kendrick's reduces TFP growth by a somewhat lesser amount (0.19%); while the use of Gallman's farm capital figures actually increases TFP growth, but by only 0.02 percent per year.⁴⁰

An even more interesting comparison is with estimates for other countries and sectors. Table 5 contains growth rates of output, labor,

capital, and TFP for agriculture in several European countries and the United States in the late nineteenth century. Relative to the other countries the growth of output in U.S. agriculture was impressive; the growth rate exceeded that in each of the countries for which we have comparable data, and in the case of France and the UK, the disparities are enormous. The sources of that growth differed noticeably too. Output growth in the United States was brought about largely by the growth of inputs; TFP growth seems quite unspectacular especially compared to that for those European countries in which output grew at respectable rates, namely, Germany, Austria, and Hungary. This relative performance is especially vivid when our revised series is used for comparison, but is evident as well when Kendrick's figures are used. With his series used for comparison, the growth of inputs explains two-thirds of the growth of output, whereas our series puts the share at over 80 percent.⁴¹

TFP is simply a residual, but is often interpreted as a measure of innovation or innovative activity and is associated with terms like the "agricultural revolution."⁴² When considered in this light, the U.S. figures hardly seem revolutionary.⁴³ To understand this statement more clearly, consider the comparisons of the share of output growth attributed to inputs and TFP as shown in Table 5. As a source of change, TFP was far more important in the European countries. Even in the United Kingdom where output growth was negative, TFP was a positive force and looms large as a source of productivity growth.

CONCLUSIONS

The available empirical and narrative evidence on time at work in nineteenth-century U.S. agriculture suggests that during the antebellum era the majority of farm workers (excluding slaves) probably did not work what, by contemporary manufacturing or later agricultural standards, would have been considered "full-time," year around. The structural changes that took place over the century, however, seem to have induced farm workers to substitute out of leisure and other household or non-market activities and into (marketable) agricultural production. These structural changes occurred on both sides of the market in the form of transportation improvements, urbanization, rising incomes, and technological change in the agricultural sector. Although the estimates we provided of average hours at work suffer from the fact that we do

not have direct estimates of hours for every crop for every census year, it is hard to imagine a plausible set of assumptions that would dramatically alter either the relatively low estimates of the time input during the antebellum era or the long-run trend thereafter.

The implication of the revised estimates in average hours worked for interpreting long-run growth in U.S. agriculture is that a view of the mid- to late nineteenth century as an era of technological revolution probably cannot be sustained. The story of agricultural development during that era is one of an increase in inputs, particularly labor, which, for the era as a whole, dominated both capital and TFP as a source of output growth, and the growth of the labor force was tied to an increase in the amount of time the average worker spent in the fields and barns. Since this substitution into work was voluntary, and since it is reasonable to expect that the resulting higher incomes enhanced the welfare of nineteenth-century farm families, we should perhaps not be too pessimistic in interpreting these conclusions. Nevertheless, as we have noted elsewhere, “Increased man- and woman-hours is, of course, not the kind of ‘source of growth’ one looks for to explain improvements in economic welfare, although it has been common in the early years of rapid growth in the newly industrializing countries of Asia” (Craig and Weiss 1993, pp. 544–545). It seems, however, that a salient feature of the economic revolutions of the modern era has been the provision of incentives for agricultural laborers to work longer and harder.

ACKNOWLEDGMENTS

Earlier versions of this paper were presented at the annual meetings of the Southern Economic Association and economic history seminars at the University of Illinois, Indiana University, the University of Munich, Northwestern University, and the Triangle Universities’ Economic History Workshop. The authors thank collectively the participants for helpful comments. This project was partially funded by a grant from the National Science Foundation (#SBR-9408525).

NOTES

1. This phenomenon has been well documented by Simon Kuznets (see, for example, 1966, pp. 113-127).

2. Ross and Tontz (1975, p. 34). This view is very much alive, as evidenced by Hurt's (1990) recent affirmation that "American agriculture underwent revolutionary change during the Civil War" (p. 53).

3. Rasmussen (1960, p. 103). In Schmidt's (1930) view "The Civil War marks the beginning of the revolution in agriculture" (p. 587). See also Ross (1946, p. 389) and Schlebecker (1975) who argued that "technology and science seemed to dominate American agriculture from 1861 to 1914" (p. 151).

4. Ernest Bogart (1923, pp. 77-78), and George Rogers Taylor, echoed this sentiment. In Taylor's (1964) words, "although many improvements were being developed...their use did not become sufficiently widespread appreciably to affect production until after 1840" (p. 442). It is likely that the transition occurred earlier in New England (see Bidwell 1923).

5. More recently Rinkoon (1988, p. 23) made the same point about threshing machine adoption.

6. Their adherence to this view seems surprising in light of the substantial productivity advances in corn, cotton, and especially wheat production they estimated had occurred before 1840. Unfortunately, Cooper, Barton, and Brodell did not specify how they calculated their productivity estimates, and Parker and Whartenby (1960, p. 207) have cast doubt on their figures. Parker and Klein (1966) imply that most productivity growth occurred after 1850.

7. He does allow the possibility of some acceleration, noting that before 1830 "the processes of change moved slowly; and marked and sustained rises in productivity almost certainly did not occur." Presumably afterwards there was faster, more sustained progress.

8. Craig and Weiss (1993) concluded that the increased output could not be explained by the increase in the number of workers, so workers must have increased their number of hours or their effort per hour. Although they do not distinguish between increased hours or increased effort per hour, they argue that the latter was probably reflected at least in part in the measure of increased productivity so increased hours were the more likely phenomenon.

9. Griliches (1996) has recently summarized the history of this concept.

10. If we had panel data on inputs and factor prices at the farm level, then, under a sufficiently restrictive set of assumptions we could gauge productivity advance by estimating its dual, the parameters of the cost function (see, for example, Varian 1984, chap. 4). Such data, however, are not available for the period under investigation, and as we note below, the family-owned and operated farm did not meet all of the assumptions associated with the dual approach. Although we can not estimate the cost function, we do argue below that the behavior of input prices is more consistent with our estimates of TFP advance than with previous estimates.

11. Of the 12 European countries (and the United States) for which estimates of aggregate output dating back to 1820 exist, only Italy had an annual growth rate of real per capita output of less than 1 percent between 1870 and 1913, and the median rate for those countries was 1.30 percent. Compare that to the period 1820-1870 in which half the countries had per capita growth rates below 1 percent, and the median was 0.91 percent (Craig and Fisher 1997, Table 3.1). Before the nineteenth century, even the "first industrial nation," Great Britain, experienced a per capita growth rate substantially below 1 percent (Crafts 1987, Table 1).

12. Although Gallman's emphasis was on the United States, he may have been characterizing a more general phenomenon. In his 1993 presidential address to the Economic History Association, Jan de Vries suggested that early modern economic growth was accompanied by a substitution of work for leisure; this trend was part of a process he christened the "industrious revolution" (de Vries 1994, p. 257).

13. For a discussion of the long-run trends in hours at work in manufacturing, see Whaples (1988).

14. The preponderance of this decline occurred after 1900. John Olson (1989) thinks they have exaggerated the trend because the initial-year figure of "72 hours appears to be an excessive estimate of the length of the antebellum workweek" (p. 218).

15. The figures reported by Barger and Hans Landsberg (1942, p. 271) indicate that agricultural laborers worked on average 51 hours a week in 1909. This figure is identical to the Bureau of Labor statistics estimate for manufacturing workers in the same year (see Barger 1955, p. 11).

16. The 1870 figure must also have diverged from that for 1860 as a result of both emancipation and the decline in output of major crops. If we take Olson's estimate that the average slave worked 2,800 hours per year, and assume a work year of 50 weeks, then on average a slave worked 56 hours per week. A similar calculation from Olson's figures yields a figure of 62 hours for free workers. Combined, these figures yield a weighted average of roughly 60 hours (see Olson 1989). When compared to a figure of 63 hours for 1900 the hours worked show a slight rise over all (roughly 0.12% per year), and since there was likely an initial drop after the Civil War there would have been a sharper rise after 1870. If instead one uses Ransom and Sutch's (1977, pp. 234-236) estimates, which ranged from 3,200 to 4,000 hours per year, the weighted average would have been 65 hours in 1860, implying a decline of 0.08 percent per year.

17. An increase in hours in agriculture has seemed unlikely because the shift from slave to free labor in the South may have resulted in a choice to work fewer hours, and such a decline there may have held down the average for the nation.

18. See above or the review of the traditional interpretation of this era in Craig and Weiss (1993).

19. Debate surrounds what constituted "required" hours; that is, it is often difficult to determine whether these were hours of owner-operators, tenants, or hired hands. In cases where several sources have been employed, it is probably best to think of the estimates as averages across different types of workers. As for the technology employed, in most cases the figures in Table 1 represent simple means from a number of observations.

20. Elsewhere we have differentiated between "labor-saving" mechanization and "yield-increasing" technological change. In fact both can be elements of total factor productivity because the capital inputs are typically measured by reported dollar values. Since lower input prices and improvements in the techniques used to produce the implements can lead to lower market prices, *ceteris paribus*, the total contribution of capital to output is understated, and thus reflected in the residual—TFP (see Craig and Weiss 1997).

21. For a discussion of the forces pushing up the time required per unit of output see Bateman (1969).

22. That is, we have assumed that $VU/HU = VK/HK$. Where VK and VU are the values of for products for which the hours estimates are known and unknown, respectively,

and *HK* and *HU* are the hours for the products for which hours are known and unknown, respectively.

23. In the future we hope to disaggregate these activities further by producing estimates for the intervening decades, extending the series to 1800, and perhaps most importantly, providing regional figures.

24. The series appears to approximate a U shape, declining from 1840 to 1870 and rising thereafter. We do not make much of this for it reflects to a large extent the changes that transpired between 1860 and 1870, and as we discuss shortly, these are anomalous, reflecting the peculiar circumstances that arose in the South as a result of the Civil War and Emancipation.

25. Martin Primack (1963, p. 349) found that on average it took more than 20 times as long to clear an acre of forest than an acre of prairie.

26. These factors are neither entirely exogenous nor independent of one another and are discussed more thoroughly in Craig and Weiss (1997) and Craig, Palmquist, and Weiss (1998).

27. Lower bound estimates of the labor savings from mechanical reapers are in the neighborhood of 0.274 (manual-rake) and 0.364 (self-rake) man-days per acre (David 1966, p. 33; Atack and Bateman 1987, pp. 195-196).

28. The seasonal demands in wheat production were particularly crucial, as wheat tends to shed its grain if not harvested within a few days of ripening. For a discussion of the peak labor demand problems in nineteenth-century agriculture in general and in wheat production in particular, see Craig (1993, chap. 2).

29. By "biological limits," we mean the constraint imposed by the interaction of time, the biological characteristics of the crop in question, and the physiological limits on the human and animal inputs employed.

30. We mean literally "man-days" or adult-male equivalents.

31. Alternatively they could plant the same acreage and thus have a reduction in peak hours required. In this case some labor would be released from farming, while those who remained worked more over the year.

32. Average wheat yields in the midwest in 1860 were in the neighborhood of 8 to 10 bushels per acre. For our hypothetical farm, mechanization of reaping would have yielded an additional 60 to 70 bushels. The time associated with processing this amount of wheat using contemporary techniques in all other stages of production would have been substantial.

33. For example, one could do the same exercise with, say, a mechanical planter for corn. The resulting increase in acreage planted would have to be hoed during the summer, cut during the fall, and the extra corn shelled during the winter.

34. As discussed in the notes to Table 3, the relative importance of TFP growth is not influenced much at all by the choice of factor shares used in the calculation.

35. This figure is based on the growth of the ratio of the prices of farm products to those of all commodities (U.S. Bureau of the Census 1975, p. 201).

36. The wage rates and the prices of land and farm implements were derived from U.S. Bureau of the Census (1975 p. 468) and Lindert (1988, p. 51).

37. Mortgage rates are discussed in Atack and Passell (1994, p. 412). For yields of other securities, see Homer and Sylla (1991, in particular the discussion on pp. 313-314).

38. Kendrick's shares are reported and discussed in the notes to Table 3. Kendrick combined the land and capital inputs, which together earned 37 percent of the total product. Evidence reported by Attack and Bateman (1987) suggests that land's share of this amount must have been greater than capital's, perhaps substantially so, and therefore, we allocated 24 percent to land and 13 percent to capital. The main conclusion would not change if we varied these shares substantially.

39. The implied estimate could be low due to the underestimation of the decline in the shadow price of *household* labor, as we have discussed at length above and elsewhere.

40. The capital figures were calculated by the authors from the original series in Gallman (1986).

41. Zanden's estimates do not appear to have been adjusted for hours worked and so Kendrick's figures may be the more comparable one.

42. As a residual, it contains a number of effects, including technological change and the growth of knowledge, but also some measurement error. Perhaps the best recent discussions of interpretations of total factor productivity growth are in Abramovitz (1993) and Griliches (1996).

43. The nineteenth-century U.S. figures are roughly half those for the first 50 years or so of the twentieth century (see Johnson 1950).

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