The Journal of Economic History, Volume 61, Issue 4, December 2001

The Longest Years: New Estimates of Labor Input in England, 1760–1830

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Based on six sets of witnesses' accounts from the North of England and London over the period 1760 to 1830, new estimates of male labor input during the Industrial Revolution are derived. I present a new method of converting witnesses' activities into estimates of labor input, and derive confidence intervals. Working hours increased considerably. Moderate gains in per capita consumption during the Industrial Revolution have to be balanced against this decline in leisure. This adds further weight to pessimistic interpretations: I calculate that consumption per capita, adjusted for changes in leisure, remained essentially unchanged between 1760 and 1830.

Over the last two decades, our view of the Industrial Revolution has changed substantially. Rates of output growth have been revised downwards.[1] Capital inputs probably also grew more slowly than had previously been assumed, with the savings rate doubling over a period of seventy years instead of thirty, as had previously been thought.[2] The new orthodoxy on the Industrial Revolution now emphasizes rapid structural change as the central discontinuity, not an acceleration of productivity or output growth.[3] Numerous authors have challenged this new consensus in recent years, arguing that the underlying figures are fragile, that the methodological assumptions are dubious, and that other pieces of evidence strongly suggest more rapid and widespread productivity growth.[4] Despite these criticisms, this position (often referred to as the "Crafts–Harley" view) largely retains its place as the most likely overall interpretation of the British Industrial Revolution.[5]

The Journal of Economic History, Vol. 61, No. 4 (Dec. 2001). © The Economic History Association. All rights reserved. ISSN 0022-0507.

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Generous financial support by the Leverhulme Foundation through a Philip Leverhulme Prize Fellowship is gratefully acknowledged. Greg Clark, Penny Corfield, Jan de Vries, Charles Feinstein, Bob Gregory, Avner Offer, Adrian Pagan, Emma Rothschild, Richard Smith, Tony Wrigley, and two anonymous referees kindly offered help and criticism. Seminar audiences at All Souls College (Oxford), ANU (Canberra), LSE, the Institute for Historical Research (London), and King's College (Cambridge) made useful suggestions.

[1] Crafts, *British Economic Growth*; Harley, "British Industrialization"; and Crafts and Harley, "Output Growth."

[2] Feinstein, "Capital Formation"; and Crafts, *British Economic Growth*.

[3] Crafts and Harley, "Output Growth."

[4] Temin, "Two Views"; Cuenca Esteban, "British Textile Prices"; and Berg and Hudson, "Rehabilitating the Industrial Revolution."

[5] Feinstein's ("Pessimism") revised real wage series reinforces the "new orthodoxy"; see Antràs and Voth, "Effort." Crafts and Harley's response to Temin ("Two Views") suggests that their earlier emphasis on the positive contribution of agriculture to economic performance may need to be modified. See Crafts and Harley, "Simulating the Two Views"; and Temin, "Response."

In this line of research, one important factor has not received much attention—labor input.[6] Calculations of productivity growth during the English Industrial Revolution assume that per capita working hours remained constant, and that the only factors influencing aggregate labor input were population growth and changes in labor-force participation. Recently, though, work on the "industrious revolution" in early modern Europe has underlined the extent to which working hours may have changed over time.[7] Taking this possibility into account is important, since the potential impact is large. N. F. R. Crafts has argued that labor-input growth during the English Industrial Revolution may have been underestimated by as much as 0.2 percent per annum, enough to reduce TFP growth to zero for the period 1760–1800, and to less than half of its estimated value for 1800–1830.[8] Also, changes in working hours may have dominated the influence of other factors on the standard of living.[9] This article presents estimates of annual working hours based on six data sets from London and the North of England, for the period 1760–1830. I derive changes over time, and discuss their statistical significance. These figures for annual hours are combined with recently revised estimates of unemployment, population size, and seasonal employment presented by other authors. The new estimates of labor input are used to adjust living standards for the decline in leisure during the Industrial Revolution.[10]

METHOD AND CONFIDENCE INTERVALS

In an earlier article, I described how witnesses' accounts can be used to derive estimates of working time.[11] In essence, I exploited the fact that witnesses under oath stated as a matter of course the time and the circumstances—work, play, or other—under which they had occasion to observe an alleged crime. This new method was applied to a data set from London, covering the period 1760–1800. I recalculated productivity growth on the assumption that London was representative of the rest of England. Given the limited geographical scope (and the restricted time period), these calculations were largely illustrative: there is little reason to believe that London was highly representative of the rest of the country.[12] In particular, the most dramatic changes occurred in the North of England, where the rise of new indus-

[6] Mokyr, "Industrial Revolution," p. 32.
[7] De Vries, "Between Purchasing Power" and "Industrial Revolution." For a view to the contrary, see Clark and Van Der Werf, "Work in Progress?"
[8] Crafts, *British Economic Growth*, p. 82; and Crafts and Harley, "Output Growth," p. 718.
[9] Crafts, *British Economic Growth*, p. 114.
[10] Feinstein, "Pessimism."
[11] Voth, "Time and Work."
[12] In particular, there are good reasons to believe that agriculture experienced different patterns of change. Clark and Van der Werf, "Work in Progress?"

tries caused massive structural change.[13] London's position, in contrast, has been described as "downstream from industrialization."[14] Comparing the period 1799–1803 with 1749–1763 is also problematic. While both periods contain years of war and peace, of good and bad harvests, and of slumps and vigorous expansions, the Napoleonic wars and the unusually poor harvests at the turn of the century were clearly unusual. In order to determine whether 1800 was an outlier, or part of a broader trend, the data set must be expanded.

There are also methodological questions. By comparing the time of starting and stopping work, and subtracting mealtimes, I derived the number of working hours on an average day. Given the number of workdays in a year, total annual working hours are easily calculated. This "duration-based" method is intuitive and yields sensible estimates.[15] It is nonetheless open to a number of criticisms. First, estimates of the length of the working day are often imprecise, due to the relatively small number of witnesses that were either starting or ending work. Second, assumptions about mealtimes introduce an additional source of error.[16] Third, even the largest of the courtroom data sets that have been collected so far do not contain a sufficient number of observations to determine the number of working days per year directly. Instead, we require additional information about days that might have been holidays (as derived from contemporary calendars etc.), which permit us to determine whether these days saw markedly fewer people engaging in work activities. Fourth, the cascading assumptions needed to construct estimates of the working year compound uncertainties, and make the derivation of confidence intervals much more difficult. Even large differences between two points in time may not indicate a significant shift in actual behavior.

This article attempts to overcome some of these problems. I expand the data set to include observations from the Northern Assize Depositions, covering a substantial part of the North of England. In addition to adding the areas that saw the most dramatic changes in employment patterns, this also has the advantage of increasing the number of witnesses employed in agriculture. Moreover, the period covered now extends to 1830. I derive confidence intervals for our estimates, and present an alternative method of estimating working time on the basis of witness accounts.

The data from witness accounts can be used to estimate the length of the working year more directly than is the case with the "duration-based"

[13] Crafts, *British Economic Growth*.

[14] Schwarz, *London*.

[15] Voth, "Time and Work."

[16] The length of the working day cannot be established as the simple difference between the time of starting and stopping work, since workers took lunch (and often tea and breakfast) at their workplaces. Since information on mealtimes is scarce, we must resort to assumptions that are largely ad hoc. This introduces an additional source of uncertainty. See Voth, *Time and Work*.

method. In sociological studies, for example, study subjects are asked to carry an electronic device that periodically emits a "beep."[17] The subjects then record their activity at that moment. If this occurred randomly throughout the day, and all activities were recorded, calculating the number of hours worked per day would be straightforward: with one-third of all recorded activities classified as work, for example, we could be certain that the average working day is eight hours in length.[18] We may refer to this as a "frequency-based" method.

A similar approach can be used to analyze witness accounts, with two modifications. The number of observations fluctuates through the day (and the week). And witnesses sleep, thus reducing the interval during the day when they can observe a crime and record their own activities. I correct for the first source of bias by reweighting the data. Since every witness has 24 hours per day, a completely random pattern of crime (and a constant probability of becoming a witness and reporting one's own activities) would produce evenly spread observations. But since crime (and the reporting of it) are not in fact random, I increase the weight of observations in periods when the number of reports is unusually low, and decrease it when it is unusually high.[19] Compensating for the effects of sleep is also relatively unproblematic. Since the data set contains information on hours of sleep, we can calculate the period during which witnesses could observe a crime. The reweighted percentage of witnesses engaged in work activities during this period of "exposure" can be converted into an estimate of daily working hours. If, say, we assume eight hours of sleep per day, and we find that during the remaining 16 hours 45 percent of our witnesses performed paid work, then the best guess of daily working hours would be 7 hours and 12 minutes. The same procedure can be applied to annual estimates.

There are obvious advantages to this "frequency-based" procedure. We can derive confidence intervals for our estimates, and we require fewer assumptions. Also, we no longer require educated guesses to calculate the length of mealtimes, and so on. Finally, estimates from the duration-based method can now be checked. I pursue two approaches to calculate confidence intervals. First, I use simple asymptotic theory. By its very nature, however, the data violates some of the normality assumptions necessary for the use of asymptotic distributions: all of our cases are

[17] Robinson, "Validity and Reliability."

[18] Experiments regularly show that this is the most reliable method for time-budget analysis. See Juster and Stafford, "Allocation of Time," p. 484.

[19] I also experimented with adjustment factors for days of the week. These need to be interacted with the adjustment factors for the hourly intervals, in order not to correct twice for the unevenness of observations. The results were almost identical.

TABLE 1
PERCENTAGE OF WITNESSES AT WORK AND IMPLIED ANNUAL HOURS, LONDON

		p (work)						
		"Frequency-Based" Method			"Duration-Based" Method			
		Estimate	Lower Bound	Upper Bound	Lower Bound	Upper Bound	$100-p$ (nonwork)	Standard Error
					Percentages			
w1	1760	33	31	36			67	1.3
	1800	44	41	47			56	1.6
	1830	46	39	53			54	3.7
w2	1760	42	39	45			58	1.7
	1800	52	49	55			48	1.6
	1830	54	47	61			46	3.7
					Implied Annual Hours			
w1	1760	2,069	1,907	2,231			4,136	83
	1800	2,738	2,546	2,931			3,467	98
	1830	2,709	2,266	3,153			3,496	226
w2	1760	2,606	2,398	2,814	2,288	2,631	3,599	106
	1800	3,227	3,033	3,420	3,366	3,538	2,978	99
	1830	3,351	2,905	3,796			2,854	227

Note: Small differences are due to rounding. *w1* includes on persons at work at the time of the incident witnessed; *w2* includes also persons on their way to or from the workplace, as well as starting and finishing work.
Sources: See the text.

either working or not working. To reduce these problems, I use the bootstrapping technique popularized by Efron.[20] The standard error of a proportion is[21]

$$s = \sqrt{\frac{p(100-p)}{n}} \tag{1}$$

Table 1 gives the percentages of witnesses found at work, after appropriate reweighting of observations, during the 17 hours of the day when they were not asleep. The number of annual hours worked is then calculated as $17 \cdot 365 \cdot p$, where p is the proportion found at work.[22]

There are two alternative definitions of work that can be used, depending on whether persons in transit to or from a work shift are counted as working.[23] While this affects the level of working hours, the trend over time is very similar under both definitions of work: we find a clear increase between the middle and the end of the eighteenth century, and then stabiliza-

[20] Efron and Tibshirani, *Introduction*.
[21] Hogg and Tanis, *Probability*, p. 394.
[22] The time of going to bed, and of rising in the morning, suggested six to seven hours of sleep. I used six to eight hours, and found that seven gave the most consistent results.
[23] For a more detailed discussion of the definitions of work, see Voth, "Time and Work."

TABLE 2
BOOTSTRAPPING RESULTS

	w1[a]			*w2*[b]		
	Midpoint	Lower Bound	Upper Bound	Midpoint	Lower Bound	Upper Bound
			Percentages			
1760	33	30	36	42	39	44
1800	44	41	47	52	49	55
1830	46	40	51	54	48	59
			Implied Annual Hours			
1760	2,048	1,862	2,234	2,606	2,420	2,730
1800	2,730	2,544	2,916	3,227	3,040	3,413
1830	2,854	2,482	3,165	3,351	2,978	3,661

Note: *w1* includes on persons at work at the time of the incident witnessed; *w2* includes also persons on their way to or from the workplace, as well as starting and finishing work.
Sources: See the text.

tion. Note also that the results from this frequency-based approach are very similar to the ones derived with the duration-based approach.[24] Because of the smaller number of observations, the data set from 1830 shows much larger standard errors, and I cannot prove that the pattern of time-use by this date was any different from what it was thirty years earlier. At this stage, the observations from 1830 are useful largely in showing that the average had not changed markedly since 1800, reducing the likelihood that results from the earlier year were distorted by the Napoleonic wars.

To ensure that the use of simple asymptotic distribution theory does not distort the true degree of uncertainty of our estimates, I use a standard re-sampling method—bootstrapping—to obtain estimates of the standard error. All witnesses are classified as either working (equals one) or not working (equals zero). In 1760, for example, under definition of work *w1*, there were 278 witnesses at work, and 557 were engaged in other activities (after re-weighting to adjust for the uneven spread of observations during the day). We therefore have $n = 835$ observations. Let $\hat{F}$ be the empirical distribution. We draw a random sample of size n with replacement, say $\mathbf{x}^*=(x_1^*, x_2^*,\ldots, x_n^*)$, from our set of n observations $(x_1, x_2,\ldots, x_n)$. For each period, we generate 1,000 sets of $\mathbf{x}^*$. To calculate confidence intervals, we rank the mean of each replication $\mu(x^*)$ from highest to lowest. The 95-percent confidence intervals then extends from the fifth to the ninety-fifth percentile.[25]

The results (Table 2) are almost identical with those derived from equation 1. The error bands are slightly smaller, except for one sample where the bootstrap suggests a marginally wider confidence interval. Overall, the

[24] Ibid., table 3, p. 38.
[25] Efron and Tibshirani, *Introduction*, pp. 45–56.

TABLE 3
SHIFTS IN TIME-USE, LONDON, 1760–1830

	Increase in Work-Hours			
	Estimate	Upper Bound	Lower Bound	SE of Difference
1760–1800				
w1	670	921	418	128
w2	621	904	337	145
1800–1830				
w1	–29	454	–512	247
w2	124	610	–362	248
1760–1830				
w1	641	1,113	168	241
w2	745	1236	253	251

Sources: See the text.

bootstrapping exercise confirms that the increase in hours between 1760 and 1800 was significant, that hours in 1830 were also markedly longer than in 1760, and that no significant change occurred between 1800 and 1830.

How big, and how statistically significant, is the shift I estimate for the period as a whole? The bootstrapping exercise suggests that the standard errors derived from the standard formulas for individual estimates are fairly robust. Since the standard error of a difference is simply

$$s = \sqrt{\sigma_x^2 + \sigma_y^2 - 2(\sigma_x \sigma_y r_{xy})}$$

we can calculate confidence intervals for the size of the shift between 1760 and 1830 (Table 3).[26] The upward shift between 1760 and 1800 is relatively firmly established. Due to the smaller size of the data set in 1830, the error bands for the difference in average working hours increases for the other two comparisons. Between 1800 and 1830, there are no significant changes in our London observations. Over the period as a whole, we find an upward shift by 28.6 to 31 percent that is significant at the 95-percent level of confidence.

THE COMBINED DATA SET AND "NATIONAL" TOTALS

Expanding the data set to include observations from other parts of industrializing Britain adds further difficulties. The Northern Assize Depositions contain evidence that is similar to the Old Bailey Sessions papers. In the counties of the Northern Assize circuit, justices of the peace heard cases

[26] I assume that r_{xy} is equal to zero. This implies that the errors are neither offsetting nor mutually compounding.

TABLE 4
SECTORAL ORIGIN OF MALE WITNESSES, 1760–1841

	1760	1800	1830	1841 Census
London				
Agriculture	5.1	4.9	3.5	3.0
Manufacturing	16.1	30.1	30.1	36.9
Public	4.7	5.5	1.3	2.1
Services	48.7	32.8	42.4	45.2
Trade	25.4	26.7	22.7	12.9
North				
Agriculture	34.0	23.3	22.4	19.2
Manufacturing	23.6	26.2	34.2	44.9
Public	4.7	2.3	0.6	0.7
Services	22.6	31.4	25.5	24.8
Trade	15.1	16.8	17.3	10.4

Sources: See the text.

twice a year.[27] Witness accounts were recorded by a scribe in the third person singular. Compared to the Old Bailey records, the lack of verbatim reporting makes the evidence much less colorful; and the lag between crime and trial was, on average, longer. Nonetheless, time-use information is provided in much the same way as in London. There are markedly fewer observations than in the Old Bailey Sessions papers, since there were fewer trials in any one year. In order not to expand unduly the number of years under observation (thus obscuring changes in time use during each period), and to ensure comparability, I collected witnesses' evidence for the same set of years as for the Old Bailey (Table 4).

To examine potential sampling biases, I compare the occupations named in my data set with the distribution revealed by the census in 1841.[28] For London, for example, the 1841 census suggests that 2.95 percent of the labor force was employed in agriculture. Among the witnesses appearing before the Old Bailey in 1831, 3.5 percent worked in agriculture—a reassuringly small gap.[29] Also, the fact that the census recorded a lower figure at a later date suggests that the true gap might be even smaller, since employment in agriculture as a percentage of the labor force was probably falling in London over time (just as in the rest of England). The discrepancy is somewhat wider when we compare the share of employment in manufacturing. Our

[27] The Northern Circuit contained the counties of Westmoreland, Durham, Northumberland, Cumberland, Derbyshire, the city of York, as well as the North, East, and West Ridings of Yorkshire. The range of cases tried was also fairly similar, ranging from petty larceny to felonies. See PRO Kew, ASSI 45 (Northern Assize Depositions).

[28] Note that some of the differences between our date set and the census are caused by the difference in dates.

[29] Lee, *British Regional Employment Statistics*, pt. 2. In table 1, unclassified cases have been excluded. I have therefore also excluded Lee's "N.C." category from calculations.

Northern data fare equally well when sectoral composition is used as a proxy for representativeness. In the case of manufacturing, there appears to be some undersampling.[30] In the case of services, the discrepancy is smaller. Overall, the sectoral composition of the labor force and the occupations of our witnesses do not suggest any major problems of selection bias.

To derive estimates for the combined data set (Table 5), I focus on males only. In this way, fluctuations in the proportion of female witnesses do not affect our results.[31] Since male wages contributed 79 percent to total earnings in 1831, this still reflects the largest part of income-generating activity.[32] I also increase thereby the comparability of our estimates with those for later periods. For the combined estimates, the standard errors are weighted by the number of observations.[33]

The results for London and the North are very similar.[34] The difference in the estimated length of the annual working year is always less than 100 hours. Given the substantial differences in the sectoral composition, this is as high a degree of co-movement as can be expected. The similarity of results in these geographically and economically distinct areas increases the likelihood that patterns in the whole of England were broadly similar. This, of course, cannot be proven based on our data set, and additional data from

[30] The census gives an average of 44.9 percent, whereas we find 34.2 percent in our Northern data set. Adjusting for the difference in dates, we still find a gap of 8.8 percent. Several reasons may be responsible for this discrepancy. It is possible that structural change accelerated between 1830 and 1841. There is some evidence for this in our data set. If we use the rates of change in the manufacturing share observed between 1800 and 1830 to calculate the implied rate for 1841, the gap falls further to 7.8 percent. Unless the acceleration after 1830 was even sharper than it was between 1800 and 1830, the residual difference suggests a limited degree of selection bias.

[31] Many authors, notably Horrell and Humphries ("Labor Force Participation" and "Exploitation") have argued that opportunities for female employment contracted between 1750 and 1850. Focusing exclusively on males is unsatisfactory, but reduces the effect of shifts in sample composition. Most estimates for the second half of the nineteenth century are based on full-time hours for workers in production industries. Our estimates will be easier to compare with these when focusing on males only. See Matthews, Feinstein, and Oddling-Smee, *British Economic Growth*, table 3.11, p. 64. The estimates are for *w2*; results are largely unaffected by using an alternative definition of work. One of the implications of our results is that women's working hours are shorter than those for men: this is the result of quite a few women without (paid) employment entering our data set, and not of short hours for those in employment.

[32] Clark and Van der Werf, "Work in Progress?," table 2.

[33] I do so according to the formula

$$s = \sqrt{\sum_{i=1}^{k} N_i s_i \Big/ \sum_{i=1}^{k} N_i}$$

where N is the number of observations and s is the standard error.

[34] This also implies that differences in weighting the estimates will not affect the average substantially. It could be argued that the Northern estimates should enter with their share in the population as a whole. Such a procedure would, however, make it impossible to derive correct confidence intervals for the combined data set; it also does not change my conclusions substantially.

TABLE 5
AVERAGE ANNUAL WORKING HOURS, 1760–1830

	Hours			SE (percentages)			Percentage of Witnesses at Work			*N*	
	Average[a]	London	North	Average[a]	London	North	Average[a]	London	North	London	North
1760	2,576	2,582	2,518	2.4	2.0	6.3	41.5	41.6	40.6	626	60
1800	3,328	3,319	3,411	2.2	1.8	5.4	53.6	53.5	55.0	733	84
1830	3,356	3,367	3,294	4.7	3.9	9.4	54.1	54.3	53.1	166	28

[a] Weighted by *N*.
Sources: See the text.

other regions may lead to substantial revisions of our results.[35] However, our results cover areas containing 29 percent of English males in 1841.[36]

Note that the results for London are only marginally affected by restricting the data set to males only.[37] The standard errors in the London data are also very similar, whereas the ones in the North are uniformly larger, driven by the much smaller number of observations. What, then, is the statistical significance of our results? Table 6 gives upper and lower bounds for our estimates, as well as confidence intervals for the shift over time. Hours in 1800 and in 1830 are unambiguously higher than in 1760; for the period 1800–1830, I cannot prove that there is a statistically significant difference.[38] This suggests that the long hours earlier found for 1800 are not the result of unusual circumstances, such as poor harvests and the extra labor demand generated by the Napoleonic wars. Annual working hours were only marginally higher than those documented in wage books for Britain in 1856. Given that our data refer to numerous workers from sectors where working days were probably shorter than the norm in the factories, the overall average appears relatively high.[39] This may be the result of a certain selection bias in favor of those reporting to work. Note, however, that such a bias would leave the magnitude of changes over time unaffected, as long as the bias did not change between periods.[40]

[35] Reid ("Decline" and "Weddings") and Hopkins ("Working Hours"), for example, argue that St. Monday did not decline in the Birmingham area before the second half of the nineteenth century.

[36] Lee, *British Regional Employment Statistics*, pt. 2, table 3.36.

[37] This is possibly because women were, on the one hand, less likely to be selected as witnesses. On the other hand, being at work increased their social standing and the implied reliability of their accounts. In combination, this leads to similar probabilities of being observed at work. Note that, even if biases such as these exist, our estimates for changes in working time are only affected if the direction and magnitude of the biases changed.

[38] Note that, even if the 95-percent confidence intervals overlap, the difference between both estimates can be statistically significantly different with 95-percent probability; we are unlikely to err simultaneously on the high side of the low estimate and the low side of the higher estimate.

[39] Note, however, that Clark and Van der Werf ("Work in Progress?") find relatively long hours in agriculture, where many expect a strongly seasonal pattern of employment and hence a limited length of the overall working year.

[40] It would, however, reduce comparability with later estimates.

TABLE 6
WORKING HOURS AND PERCENTAGE AT WORK, COMBINED SAMPLE

	Working Hours (weighted average)			Percentage at Work	
	Estimate	Upper Bound	Lower Bound	Upper Bound	Lower Bound
1760	2,576	2,868	2,284	46.1	36.9
1800	3,328	3,596	3,060	58.0	49.3
1830	3,356	3,928	2,784	63.2	44.9
	Change in Working Hours				
	Estimate	Upper Bound	Lower Bound	SE of the Difference	
1760–1800	752	1,148	356	3.2	
1800–1830	28	659	–603	5.2	
1760–1830	780	1,422	138	5.2	

Sources: See the text.

The 95-percent confidence interval for the total increase in annual hours between 1760 and 1830 is rather wide, ranging from 138 to 1,422 hours. This rules out stagnation, but only suggests that labor input grew by something between 4 and 55 percent, with 23 percent the likeliest value. Much of the uncertainty results from the smaller size of the data set in 1830. Given the more tightly estimated shift between 1760 and 1800 (because of the larger data set), this strongly suggests that annual working hours increased substantially.

Disaggregating our estimates by sector is as desirable as it is problematic. We would ideally like to know how long the workyear in agriculture was, if Northern agriculture differed from Southern agriculture, and if hours in manufacturing in London diverged markedly from those in the rest of the country. The data set does not allow us to answer all these questions. The number of observations is a problem throughout. It is compounded if we stratify our data set according to the occupation of witnesses. Table 7 presents estimates for three principal sectors: agriculture, manufacturing, and trade and services.[41] In order to deal with the problem of small *N*, I restricted the number of hours in a day analyzed to 15: only observations between 6 a.m. and 9 p.m. were used to calculate work probability and the weights for adjusting the data as a result of the uneven distribution of observations.[42] The estimates for agriculture are particularly fragile, given that the number of observations ranged from 19 to 25, and that regional disaggregation is not possible. Standard errors are large. Hours appear relatively short in agricul-

[41] Differences between Tables 6 and 7 are the result of excluding all cases that cannot be assigned to a sector.

[42] This avoided giving very large weights to a handful of observations during the early hours of the morning.

TABLE 7
DISAGGREGATED ESTIMATE AND TOTALS

		1750	1800	1830
Hours	Agriculture	2,311	3,431	2,762
	Manufacturing	3,614	3,028	3,430
	Trade and services	2,510	3,365	3,340
SE (hours)	Agriculture	455	239	321
	Manufacturing	310	209	266
	Trade and services	218	151	313
N	Agriculture	19	35	25
	Manufacturing	56	170	68
	Trade and services	202	310	101
Percentage of labor force	Agriculture	52.8	40.8	31.7
	Manufacturing	23.8	29.5	42.9
	Trade and services	23.4	29.7	25.5
	Average 1[a]	2,720	3,258	3,297
	Average 2[b]	2,668	3,293	3,196
	Difference	52	–34	101

[a] Weighted by *N*.
[b] Weighted by the percentage of the labor force in each sector.
Note: Figures for 1830 are from linear interpolation. Percentage employed in trade and services is the residual of the 100 minus the percentages in manufacturing and in agriculture.
Sources: Crafts, *British Economic Growth,* pp. 62–63; see the text.

ture in 1750—a finding that is at variance with both the results from duration-based estimates and those of other researchers.[43] This is balanced by exceptionally long hours in manufacturing. Hours increased in agriculture and in trade and services between 1750 and 1800 (and between 1750 and 1830), but stagnated or declined in manufacturing.

In calculating overall averages from these figures, I use two alternative assumptions. Average 1 uses the number of observations to weight the averages derived for each sector—hence, for example, giving a very small weight to agriculture. The obvious alternative, if we are interested in "national" averages, is to weight the sectoral averages by the proportion of the (male) labor force employed therein. The difference between the two methods is small. Based on Average 1, hours increase by 19.8 percent between 1750 and 1800, and by 21.2 percent between 1750 and 1830. Average 2 suggests increases of 23.4 and 19.8 percent. These results are also very similar to those reported in Table 6. The direction and magnitudes of change in average hours are relatively robust. Where disaggregation makes a difference is in terms of the standard errors. If we weight errors by the number of observations, the increase in hours is statistically significant at the 90-percent level; if we weight by shares of the labor force, it is not significant at conventional levels.

[43] Voth, *Time and Work*; and Clark and Van der Werf, "Work in Progress?" Note that due to the very large errors, much longer hours are not ruled out.

Not all the results from examining our pooled data set are equally strong. The result that emerges most clearly is the direction of change—we find strong confirmation that hours increased.[44] The magnitude of changes is markedly less robust, even if statistical significance (at the 95-percent level) is attained. Finally, absolute levels appear least certain, since we cannot rule out some sampling biases that may have favored witnesses who were working at the time of the crime.

SOME IMPLICATIONS AND CONCLUSIONS

Given the size of the confidence intervals, our new method can offer only tentative conclusions. Our estimates are no more than "controlled conjectures" of labor input.[45] The results apply to males only, and estimated levels may have been distorted by sampling bias. Nonetheless, there are strong methodological reasons to take increasing working hours between 1760 and 1830 into account. As Austin Robinson observed: "there is no reason to regard zero as a closer approximation to the truth than a reasonable guess."[46] Insofar as our estimates offer evidence of a significant shift, the most likely value—an increase of 23 percent—should be used until the estimates presented here are augmented by further data.

Two recent contributions to the literature also need to be considered when estimating of labor input. Until recently, the population figures presented by E. A. Wrigley and Roger Schofield formed the basis of labor-input calculations. These have been improved on the basis of additional data from family reconstitutions.[47] Second, Charles Feinstein has presented estimates of industrial and agricultural unemployment in particular. I combine these with the new data on working hours to derive estimates of changes in total labor input (Table 8).

Both the demographic estimates and the adjustments for unemployment tend to reduce the growth rate of labor input between 1760 and 1830. Adjusting for changes in the length of the working year leads to a sharp upward revision for the period 1760–1800. Compared to the population-based estimates, our new results suggest a (mild) downward change for the first thirty years of the nineteenth century. For the first seventy years of the Industrial Revolution as a whole, the increasing length of the working year adds 0.38 percent per annum—equivalent to a 40-percent upward revision compared to the unemployment-adjusted figures, and still one-third larger than the estimate based on the growth of the labor force alone. Our figures derived

[44] The only exception are the disaggregated estimates when standard errors are weighted by the share of the labor force.
[45] Feinstein, "Conjectures."
[46] Cited in Feinstein and Thomas, "Plea for Errors," p. 9.
[47] Wrigley et al., *English Population History*, appendix 9, pp. 614–15.

TABLE 8
NEW ESTIMATES OF LABOR INPUT, 1760–1830

	1760	1800	1830
Population size ('000s)	6,310	8,671	13,254
Unemployment (percentage)	5.25	5.00	10.00
Labor-force participation[a]	57.17	55.62	54.48
Hours	2,576	3,328	3,356
Percentage industrial	23.90	29.50	42.90
	Indexed (1760 = 100)		
Population size	100	137.4	210.0
Labor force	100	133.7	200.2
Adjusted for industrial unemployment	100	133.4	194.0
Adjusted for agricultural unemployment	100	133.4	193.3
Adjusted for hours	100	172.3	251.9
	Growth Rates		
	1760–1800	1800–1830	1760–1830
Population	0.78	1.42	1.07
Labor force	0.71	1.35	1.00
Adjusted for industrial unemployment	0.71	1.26	0.95
Adjusted for agricultural unemployment	0.71	1.24	0.95
Adjusted for hours	1.34	1.27	1.33

[a] As proportion of the population aged 15–59. See Crafts, *British Economic Growth*.
Sources: Wrigley et al., *English Population History*; and Feinstein, "Pessimism."

from witness accounts are also comparable to the initial guesses by Crafts, who speculated that labor input estimates might have to be revised upwards by 0.2 percent per annum.[48]

The new estimates in Table 8 have implications for our view of the Industrial Revolution in two respects. First, they change the relative importance of factor inputs on the one hand, and productivity growth on the other. As noted by Crafts, revising labor-input estimates has a large impact on TFP figures because the elasticity with which labor enters the production function is considerable. There are also good theoretical reasons (and some empirical evidence) to suggest that hours should enter separately, as capital services become available for longer as hours increase.[49] However, even when the elasticity on hours is set equal to that on the number of workers, and the lowest plausible figure for η_L (0.5) is used, estimates of TFP growth nonetheless need to be revised downward sharply.[50] The first period actually records negative TFP growth. For the seventy-year period overall, annual TFP growth falls by almost half, from 0.25 to 0.14.

[48] Ibid., p. 82.
[49] See Voth, "Time and Work."
[50] Most production functions use higher values, giving a weight of up to 0.7 to labor. The fall in productivity would be even sharper in such a case, showing a slowdown from 0.3 per annum to 0.15 for 1760–1830. In line with Crafts and Harley ("Output Growth"), I use elasticities of 0.5 for both capital and labor.

Second, adjusting for changes in the number of hours worked has even stronger implications for the standard-of-living debate. The pessimists' view of the Industrial Revolution has recently been reinforced by Feinstein's work on real wages from 1770 to 1870.[51] On the basis of new price and wage series, he shows that there were minimal gains in real wages before 1850. It is only thereafter that, in Macaulay's celebrated phrase, "the tide was evidently coming in."[52]

Accounting for changes in leisure is not straightforward. Crafts, using some educated guesses about the length of the working year, has argued that the growth in per capita consumption may have been markedly slower once the loss of leisure is included in our estimates.[53] A simple way of valuing leisure was proposed by Usher; it has since been applied widely by economic historians.[54] Changes in leisure compared to a certain base-year are valued at the wage rate and added to money income. The Usher approach assumes that the productivity of leisure changes with the wage rate[55]

$$Y_t = w_t h_t + w_t (h_0 - h_t) \tag{2}$$

where Y_t is "full" (that is, money and leisure) income in year t, w_t is the wage rate, h_t is the number of hours worked in year t, and h_0 is the number of working hours in the base-year. Increases in leisure time between the base period and the current period will be added to money earnings to give full income.

Despite the limitations of the data, we can now examine to what extent Crafts's prediction that "items neglected by national income accounting may dominate conventional consumption in this period" is borne out by the data.[56] Because I impute a value to the time consumed as leisure in the earlier years, "full income" in 1760 will be raised relative to later periods; growth is correspondingly lower.[57] Table 9 gives the new estimates for the years 1760–1801, using two alternative methods for valuing leisure. The years 1760–1831 saw only very slow advances in per capita consumption, adjusted for leisure, if our estimates of annual labor input are used. The range of our estimates is relatively small: the minimum and the maximum of adjusted growth rates are 0.04 to 0.05 percent per annum. Independent of the scenario and assumption used, however, the net result remains marginally positive.[58]

[51] Feinstein, "Pessimism."

[52] Quoted in McCloskey, "1780–1860," p. 284.

[53] Crafts, *British Economic Growth*, pp. 111, 114.

[54] Usher, *Measurement*, pp. 138ff; and Crafts, "Human Development Index" and "Economic Growth."

[55] Note that the decision whether to use varying or constant wage rates has a bearing on our results only if the wage rate changed substantially. Feinstein's results suggest that it did not.

[56] Crafts, *British Economic Growth*, p. 114.

[57] Ibid., ch. 5, appendix 2, p. 114.

[58] Note that this is not true for the period 1760–1801, when per capita consumption grew more slowly than working hours (under either method).

TABLE 9
GROWTH IN PER CAPITA CONSUMPTION, 1760–1831
(percentage per annum)

Unadjusted	0.38
Leisure productivity = *Y/h* 1831	0.05
Leisure productivity = *Y/h* 1760	0.04

Sources: See the text.

Using real wages in 1851 as an indicator of leisure productivity in earlier years, combined with the rough guess that annual labor input probably increased from 2,500 to 3,000 hours per year, Crafts has argued that per capita income growth from 1760 to 1851 might have been as low as 0.1 percent per annum.[59] The upward movement suggested by witness accounts is somewhat larger than the one assumed by Crafts, and it is concentrated in a shorter period of time. Nonetheless, we find a very similar growth rate to the one inferred by Crafts, albeit for the period 1760–1830.

Better information on time-use in 1850 would clearly be welcome. It is unlikely that labor input changed as radically between 1830 and 1850 as it did between 1760 and 1830. Tranter's educated guess for 1850, which serves as the basis for Crafts's calculations, would suggest a small reduction of workloads compared with 1831.[60] Robin Matthews, Feinstein, and John Oddling-Smee use a figure of 3,185 for 1856, which would imply a slight reduction of per capita labor input between 1831 and 1856. Our findings therefore tend to reinforce the view that gains during the first seventy years of the Industrial Revolution were minimal. Only markedly longer hours enabled the slow increase in per capita material consumption found by Crafts and others. Improvements in living standards do not become visible before the middle of the nineteenth century, when rising consumption and increasing full-time earnings can be observed. Thus, taking leisure lost into account adds further weight to pessimistic interpretations of the course of living standards during the Industrial Revolution.

[59] Crafts's usage equates the wage rate with per capita consumption per hour worked. I follow this practice.
[60] Tranter, "Labor Supply," pp. 220f.

REFERENCES

Antràs, Pol, and Hans-Joachim Voth. "Effort or Efficiency? Factor Prices and Productivity Growth During the English Industrial Revolution." Working Paper No. 495, Economics Department, Universitat Pompeu Fabra, Barcelona, Spain, September 2000.

Berg, Maxine, and Pat Hudson. "Rehabilitating the Industrial Revolution." *Economic History Review* 45, no. 1 (1992): 24–50.

Clark, Gregory, and Ysbrand Van Der Werf. "Work in Progress? The Industrious Revolution." This JOURNAL 58, no. 3 (1998): 830–43.

Crafts, N. F. R. *British Economic Growth During the Industrial Revolution*. Oxford: Oxford University Press, 1985.

______. "The Human Development Index and Changes in Standards of Living: Some Historical Comparisons." *European Review of Economic History* 1, no. 3 (1997): 299–322.

______. "Economic Growth in East Asia and Western Europe since 1950: Implications for Living Standards." *National Institute Economic Review* 162 (1997): 75–84.

Crafts, N. F. R., and C. Knick Harley. "Output Growth and the British Industrial Revolution: A Restatement of the Crafts–Harley View." *Economic History Review* 45, no. 4 (1992): 703–30.

______. "Simulating the Two Views of the British Industrial Revolution." This JOURNAL 60, no. 3 (2000): 819–41.

Cuenca Esteban, Javier. "British Textile Prices, 1770–1831: Are British Growth Rates Worth Revising Once Again?" *Economic History Review* 47, no. 1 (1994): 66–105.

De Vries, Jan. "Between Purchasing Power and the World of Goods: Understanding the Household Economy in Early Modern Europe." In *Consumption and the World of Goods,* edited by Roy Porter and John Brewer, 85–132. London: Routledge, 1993.

______. "The Industrial Revolution and the Industrious Revolution." This JOURNAL 54, no. 2 (1994): 249–70.

Efron, Bradley, and Robert Tibshirani. *An Introduction to the Bootstrap*. New York: Chapman and Hall, 1993.

Feinstein, Charles H. "Pessimism Perpetuated: Real Wages and the Standard of Living in Britain During and After the Industrial Revolution." This JOURNAL 58, no. 3 (1998): 625–58.

______. "Capital Formation in Great Britain." In *The Cambridge Economic History of Europe*, edited by Peter Mathias and M.M. Postan, vol. 7, part 1, 28–96. Cambridge: Cambridge University Press 1978.

______. "Conjectures and Contrivances: Economic Growth and the Standard of Living in Britain During the Industrial Revolution." Oxford Economic History Working Paper No. 9, 1996.

Feinstein, Charles H., and Mark Thomas. "A Plea for Errors." Unpublished Manuscript, All Souls College, Oxford, 1999.

Harley, C. Knick. "British Industrialization Before 1841: Evidence of Slower Growth During the Industrial Revolution." This JOURNAL 42, no. 2 (1982): 267–89.

Hogg, Robert, and Elliott Tanis. *Probability and Statistical Inference.* New York: Macmillan, 1988.

Hopkins, Eric. "Working Hours and Conditions During the Industrial Revolution." *Economic History Review* 35, no. 1 (1982): 52–66.

Horrell, Sara, and Jane Humphries. "'The Exploitation of Little Children': Child Labor and the Family Economy in the Industrial Revolution." *Explorations in Economic History* 32, no. 4 (1995): 485–516.

______. "Women's Labor Force Participation and the Transition to the Male-Breadwinner Family, 1790–1865." *Economic History Review* 48, no. 1 (1995): 89–117.

Juster, F. Thomas, and Stafford, Frank. "The Allocation of Time: Empirical Findings, Behavioral Models, and Problems of Measurement." *Journal of Economic Literature* 29, no. 2 (1991): 471–522.

Lee, Clive. *British Regional Employment Statistics, 1841–1971*. Cambridge: Cambridge University Press, 1979.

Matthews, Robin, Charles H. Feinstein, and John Odling-Smee. *British Economic Growth 1856–1973*. Oxford: Oxford University Press, 1982.

McCloskey, Donald. "1780–1860: A Survey." In *The Economic History of Britain since 1700,* edited by Rodrick Floud and Donald McCloskey, vol. 1, 242–70. 2nd edition. Cambridge: Cambridge University Press, 1994.

Mokyr, Joel. "The Industrial Revolution and the New Economic History." In *The Economics of the Industrial Revolution*, edited by Joel Mokyr, 1–52. London: Rowman and Allanheld, 1985.

PRO (Kew), ASSI 45 (Northern Assize Depositions).

Reid, Douglas. "The Decline of St. Monday, 1776–1876." *Past and Present* 71 (1976): 76–101.

______. "Weddings, Weekdays, Work and Leisure in Urban England, 1791–1991." *Past and Present* 153 (1996): 135–63.

Robinson, James. "The Validity and Reliability of Diaries versus Alternative Time Use Measures." In *Time, Goods, and Well-Being,* edited by F. Thomas Juster and Frank Stafford, 33–62. Ann Arbor: University of Michigan Press, 1985.

Schwarz, L. D. *London in the Age of Industrialization: Entrepreneurs, Labor Force, and Living Conditions, 1700–1850*. Cambridge: Cambridge University Press 1992.

Temin, Peter. "Two Views of the British Industrial Revolution." This JOURNAL 57, no. 1 (1997): 63–82.

______. "A Response to Crafts and Harley." This JOURNAL 60, no. 3 (2000), 842–46.

Tranter, Nick. "The Labor Supply 1780–1860." In *The Economic History of Britain since 1700,* edited by Rodrick Floud and Donald McCloskey, vol. 1, 204–226. 1st edition. Cambridge: Cambridge University Press, 1981.

Usher, Dan. *The Measurement of Economic Growth.* New York: Columbia University Press, 1980.

Voth, Hans-Joachim. "Time and Work in Eighteenth-Century London." This JOURNAL 58, no. 1 (1998): 29–58.

______. *Time and Work in England, 1760–1830.* Oxford: Oxford University Press, 2001.

Wrigley, Edward Anthony, et al. *English Population History from Family Reconstitutions 1580–1837.* Cambridge: Cambridge University Press, 1997.