Explaining the Relative Efficiency of Slave Agriculture in the Antebellum South

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In 1968 we undertook to measure and explain the relative technical efficiency of input utilization in the agricultural sectors of the North and South in 1860. The principal instrument that we employed for this task was the geometric index of the relative total factor productivity, which is defined by equation (1) (symbols are defined in Table 1):

$$(1)\quad G_s/G_n = \frac{Q_s/Q_n}{(L_s/L_n)^{\alpha_L}(K_s/K_n)^{\alpha_K}(T_s/T_n)^{\alpha_T}}$$

This index[1] was originally computed from published census data and the results were reported in 1971, both with and without adjustments for differences in the quality of outputs and inputs. The ratio of G_s/G_n yielded by the unadjusted computation was 109.2.[2] Crude adjustments for differences between the weights of northern and southern livestock, for land quality, for the proportion of women and children in the labor force, and for other factors, did not reduce this ratio as we thought they would, but increased it to 138.9.[3]

All differences between the northern and southern indexes of total factor productivity are, in a certain sense, errors of measurement. If output was correctly measured, and if all the inputs and conditions of production were fully specified and correctly measured, the ratio G_s/G_n would be equal to 100. To explain why G_s/G_n deviates from 100, then, is a process of accounting for such errors of measurement as omitted inputs, failure to adjust for differences in the quality of inputs, neglect of economies of scale or of improvements in the organization of production, omitted outputs, disequilibria in markets, and differences in product mixes.[4]

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[1] In the computations that follow, this index is multiplied by 100 to put it in percentage form. Hereafter we refer to G_s/G_n as the geometric index of total factor productivity, or the productivity index, or the index of efficiency. See the authors (1974a) (hereinafter referred to as *TOTC*), II, pp. 126–31.

[2] See Table 1 for brief descriptions of the way in which Q, L, K, and T were measured in the various computations. For further details see the authors (1971) and *TOTC*, II, pp. 131–36.

[3] Because of differences in the values of the α_i, the values of G_s/G_n presented in Tables B.20 and B.21 of *TOTC*, II, were 106.4 and 140.8. In the 1971 article the factor shares were $\alpha_L = 0.60$, $\alpha_K = 0.20$, and $\alpha_T = 0.20$. In *TOTC* the corresponding factor shares, which were derived from a production function for the cotton South by dividing the output elasticities by $1 + \sigma$, were 0.58, 0.17, and 0.25. See fn. 8, below.

[4] To restate the point more formally, equation (1) assumes that the production function in the ith region is $Q_i = f(L_i, K_i, T_i)$ rather than $Q_i = f(L_iA_{iL}, K_iA_{iK}, T_iA_{iT})$, where A_{iL}, A_{iK}, A_{iT} are the factor-augmenting coefficients in the ith region needed to transform the inputs of labor, capital, and land into "efficiency units." Note that in the augmenting formulation, differences in rainfall or sunshine between regions do not necessarily imply different regional production functions. As long as the output elasticities are the same for both regions, and there are no problems in aggregating output, the production functions will be the same even though the factor-augmenting coefficients differ. However, to the extent that the greater rainfall and sunshine of the South raises A_{sT} relative to A_{nT}, the failure to convert the land input in

In order to measure the effect of slavery on the process of production, it is therefore necessary to distinguish those mismeasurements that represent specific features of the slave system from those that are due merely to imperfections in the data, imperfections in methods of aggregation, or other mismeasurements that have no particular bearing on the operation of the slave system. In other words, we wish to obtain a residual measure of efficiency limited exclusively to measurement errors called "specific features of slavery." We then have the further task of identifying which specific features of slavery account for what parts of the aggregate value of the residual.

In our 1971 paper we stressed that a higher productivity index for the South than for the North did not necessarily imply that the southern advantage was due to special features of the slave system. We thought it was possible that slave-using plantations were less efficient than those using free labor, but that for some still undisclosed reason free southern farms were extraordinarily efficient. The high value of the southern productivity index would then be the consequence of averaging over a high index for free farms and a low index for slave plantations. Another possibility was that both slave and free farms that engaged in diversified agriculture were about as efficient as free farms in the North but plantations specializing in the export staples were highly efficient. In that case the relative productivity of the South might be due not to slavery per se, but merely to an unusually favorable market situation in 1860 for those export staples that happened to be produced by slave labor.

While we did not at that time rule out these alternatives, evidence in the 1860 Census indicated that the large slave plantations produced not only more cotton per capita but also more food per capita than small free farms in the South. It therefore seemed likely that the relative efficiency of southern agriculture was probably related to certain special features of the slave system. We conjectured that two features of slavery were particularly important. The first is that labor, and perhaps other inputs, were employed more intensively under the system of slavery than under the system of farming with free labor. There is much testimony for the proposition that slaves worked more days per year and, perhaps, more hours per day than free farmers. Since our efficiency indexes measured the labor input not in man-hours but in man-years, the more intensive utilization of labor shows up not as greater labor input but as a higher level of productivity. In 1971 we were inclined to believe that our failure to take account of the greater number of hours worked per year by slaves than by free men explained all, or nearly all, of our index of the superior efficiency of slavery. We also considered the much-debated possibility that there were economies of scale in the slave sector of agriculture. Even scholars who thought that slave labor was less efficient than free labor had suggested that the lower quality of labor might have been offset by the superior entrepreneurship associated with large-scale plantations.

To test these hypotheses we launched a search for additional data. A sample of 5,700 estates containing information on the price, age, sex, skills, and handicaps of slaves was retrieved from the probate records of southern courts. Southern archives yielded a sample of the business records of roughly 100 large plantations containing

both regions into units of equal efficiency, as is the case when equation (1) is employed, raises G_s relative to G_n even when the production functions are identical.

When the output elasticities, and hence the factor shares, in the North and the South differ, an index number problem arises, since the same factor shares must be applied to the North and the South in order to prevent the unit of measurement from affecting the result. If the factor shares of the two regions do not differ greatly, the index number problem will be minor. As we pointed out in our 1971 article, the value of G_s/G_n is robust to plausible alternative estimates of the factor shares. Had we reduced the labor share from 0.58 to 0.5, and raised the capital and land shares proportionately so that they summed to 0.5, the partially adjusted index of G_s/G_n would have risen from 138.9 to 147.6. Had we made the labor share 0.7, while reducing the capital and land shares proportionately, the value of G_s/G_n would have declined from 138.9 to 132.2. The issues posed by differences between the northern and southern product mixes are discussed in Section IV, below.

TABLE 1—DEFINITIONS OF SYMBOLS USED IN EQUATIONS AND TABLES

Q = output. For unadjusted G_s and G_n, both Q_s and Q_n were based on the quantities reported in the 1860 Census of agriculture. The factors for seed and feed as well as the ratios for converting the stock of livestock into annual production were obtained from Towne and Rasmussen. Uniform national prices of 1860, again taken from Towne and Rasmussen, were used to aggregate the quantities produced in each region into Q_s and Q_n. In partially adjusted and more fully adjusted G_s, the output of animal products was reduced to take account of the low slaughter weights prevailing in the South relative to northern slaughter weights.

L = input of labor. *Free Labor in the North:* In unadjusted G_n, L_n was taken to be equal to the census count of farmers and other agricultural occupations listed in the 1860 Census plus 17 percent of males aged 10–15. Thus children under 10 and females were excluded from the labor force. Those included were counted as equivalent full hands. In partially adjusted G_n, females and children under 10 continued to be excluded and males 60 or over were also excluded. Males between 10 and 59 were converted into equivalent full hands, using the weights applied to male slaves in partially adjusted G_s. *Free Labor in the South:* In unadjusted and partially adjusted G_s, the procedures were those employed in the corresponding northern indexes. In more fully adjusted G_s, free males age 15 or over were given the age-specific weights derived from the age-earning profiles of male slaves. On farms with 0–5 slaves, free females age 10 or over were given one half the corresponding age-specific weight for female slaves, and free boys aged 10–14 were given the same age-specific weight as male slaves of that age category. The weights applied to free females and children on plantations with over 5 slaves were reduced linearly as plantation size increased, reaching zero for plantations with 50 or more slaves. *Slaves:* In unadjusted G_s, 83 percent of all slaves aged 10 or over were assumed to be in the labor force and all were counted as equivalent full hands. In partially adjusted G_s, a deduction was made for rural slaves employed as domestics rather than in agricultural production. Rough estimates of age- and sex-specific weights based on reports of various authorities were used to convert males and females into equivalent full hands. The weights employed for males were: ages 10–14, 0.40; ages 15–19, 0.88; ages 20–54, 1.0; ages 55–59, 0.75; ages 60 or over, 0. Weights for females at each age ranged between 70 and 78 percent of the corresponding weights for males. In more fully adjusted G_s, the weights used to convert males and females into equivalent full hands were based on age-earnings profiles reported in *(TOTC) Time on the Cross* for slaves of each sex. No adjustment was made for females engaged in domestic service. However, a deduction was made for males who were engaged in activities, primarily artisan crafts, not covered by the output measure.

K = input of capital. In unadjusted and partially adjusted G_s and G_n, K was measured as the annual rental value of livestock, implements and machinery, and buildings. This was taken to be equal to the value of these items multiplied by the rate of return on farm capital (10 percent) plus average annual rates of depreciation of 2 percent for buildings and 10 percent for implements and machinery. In more fully adjusted G_s, K was measured by the value of implements and machinery, and a corresponding adjustment was made in G_n for purposes of comparison with more fully adjusted G_s.

T = input for land. In unadjusted G_s and G_n, T was measured by total acres in farms. In partially adjusted G_s and G_n, T was measured by the value of land plus improvements. In more fully adjusted G_s, T was measured by the value of land plus improvements and buildings, and a corresponding adjustment was made in G_n for purposes of comparison with more fully adjusted G_s.

$\alpha_L, \alpha_K, \alpha_T$ = shares in value of output of labor, capital, and land

α_i = output elasticities of the inputs

A = the intercept of the production function

G = geometric index of total factor productivity

σ = the scale factor $(\alpha_1 + \alpha_2 + \alpha_3 - 1)$

Y = the age of land (years of land settlement)

V = the value of land plus improvements

δ = the rate of land depletion

i = the rate of interest

I = number of improved acres

U = number of unimproved acres

γ_1 = price per acre of I

γ_2 = price per acre of U

s = a subscript denoting the South

n = a subscript denoting the North

$\hat{}$ = a "hat" over a variable denotes the logarithm of that variable

TABLE 2—INDEXES OF TOTAL FACTOR PRODUCTIVITY ON SOUTHERN FARMS, BY SUBREGION AND SIZE OF FARM ($G_n = 100$)

Size of Farm as Measured by the Number of Slaves Per Farm	Slave Exporting States (Old South)	Slave Importing States (New South)	All States in Parker-Gallman Sample (Cotton South)
0	98.4	112.7	109.3
1-15	103.3	127.2	117.7
16-50	124.9	176.1	158.2
51 or more	135.1	154.7	145.9
All slave farms	118.9	153.1	140.4
All farms (slave and nonslave) in the subregion	116.2	144.7	134.7

Source: *TOTC*, II, p. 139. The slave-exporting (Old South) states are Georgia, North Carolina, South Carolina, and Virginia; the slave-importing (New South) states are Alabama, Arkansas, Florida, Louisiana, Mississippi, Tennessee, and Texas.

either detailed information on the organization of production, including the daily activities of each slave in the labor force, or demographic information needed to adjust the labor input of women.[5] The data in these sources, combined with the data in the Parker-Gallman sample of over 5,000 southern farms listed in the manuscript schedules of the 1860 Census,[6] made it possible to refine the input and output measures of G_s. The net effect of these refinements was to reduce G_s/G_n to 134.7.[7] The new data also permitted the computation of total factor productivity indexes by farm size and subregion. Tables 2 and 3 show that the superior efficiency of southern agriculture was not due primarily to the high performance of the free farms of the South. Free farms of the Old South fell below the efficiency of northern farms by 2 percent, while free farms in the New South exceeded the efficiency of northern farms by 13 percent. Thus only 4 percent of the efficiency advantage of southern over northern agriculture was due to the superior performance of the free sector. Slave farms accounted for 96 percent of the southern advantage.

Table 3 shows that within each region

[5]A further description of these two samples, as well as of 21 additional samples containing evidence relevant to the analysis of the slave economy, is contained in the authors (1975), Table 2, pp. 6-8. The appendix of the same source (pp. 137-39) contains a state and county distribution of the 77,000 slaves in the probate sample, by plantation size. It also contains more extended descriptions of 6 of the other 22 samples.

[6]James Foust gives a detailed description of the design of the Parker-Gallman sample and of the information contained in it. He also tests various statistics computed from the sample against the aggregate 1860 Census to assess the representativeness of the sample.

[7]The evidence collected between 1971 and 1973 indicated that our previous belief that slaves worked more hours per year than free farmers was incorrect. We continued, therefore, to measure the labor input of slaves and free men in man-years, presenting only a brief and, in retrospect, inadequate justification for this procedure (see *TOTC*, I, pp. 207-08). The question is discussed more fully in Section III of this paper.

Paul David and Peter Temin (p. 277) have argued that the interim weights that we applied to labor in the North biased the productivity comparison in favor of the South rather than in favor of the North. However, the ratio of equivalent peak-productive hands to persons on farms in the North yielded by our partially adjusted procedure is 0.273. If we had applied the same age- and sex-specific weights in the North that we did for the free farmers in the South under the more fully adjusted procedure, the ratio of equivalent peak-productive hands to persons on farms would have been 0.389. In other words, if we had used the procedure proposed by David and Temin, the labor input of northern farms would have increased by 42.5 percent. As a consequence the ratio G_s/G_n would have been not 134.7, but 165.4.

TABLE 3—THE RELATIONSHIP BETWEEN TOTAL FACTOR PRODUCTIVITY AND FARM SIZE IN EACH REGION
(Index of Free Farms in Each Region = 100)

Number of Slaves Per Farm	Slave Exporting States (Old South)	Slave Importing States (New South)	All States in Parker-Gallman Sample (Cotton South)
0	100.0	100.0	100.0
1–15	105.0	112.9	107.7
16–50	126.9	156.3	144.7
51 or more	137.3	137.3	133.5
All slave farms	120.8	135.8	128.5

Source: TOTC, II, p. 139.

efficiency increased with farm size, except that in the New South the efficiency index is higher for medium than for large plantations.[8] While we considered the possibility that in the West this intermediate category of slave plantations was actually more efficient than large plantations, we believed that the reversal was probably due to measurement errors. One was a failure to adjust adequately for the locational component of land values, which might have accounted for a much larger share of total land value on slave plantations with 51 or more slaves, especially in the New South, than on slave plantations in the 16–50 category. Another was the inadequacy of our adjustment for omitted products. Large slave farms, especially in the West, probably engaged much more heavily in home manufacture than did small ones. Large slave farms also appear to have devoted a larger share of the labor force to domestic services than did small plantations. We did not think that when these adjustments were made the entire differential in efficiency between the Old and New South would disappear. The continuous flow of labor from the Old South to the New South suggests that the long-run equilibrium between the two regions had not been attained by 1860. Hence one would expect to find some efficiency advantage in the newer area.

The criticism of our efficiency computation have largely followed the lines of analysis set forth in both our 1971 essay and in *Time on the Cross*. The important and widely cited critique of our productivity measures by Paul David and Peter Temin, for example, is largely a restatement of the caveats that we incorporated in the presentation of our findings, except that in virtually every place where we said that the measurement bias was negligible or went against the South, David and Temin sought to make the case that it was large or went in favor of the South. In this effort, the critics did not present new bodies of evidence that we overlooked but either conjectured upon the possibility that missing evidence could be found that would overturn our findings or else dwelt upon what they considered to be internal inconsistencies in our analysis or between various parts of the evidential corpus. The debate over efficiency has thus focused on a set of issues

[8]Table 3 suggests economies of scale. To test for this possibility we fitted

$$\hat{Q} = \hat{A} + \alpha_2(\hat{K} - \hat{L}) + \alpha_3(\hat{T} - \hat{L}) + (1 + \sigma)\hat{L}$$

to measures of the inputs and outputs derived from the Parker-Gallman sample. The resulting regression was

$$\hat{Q} = \underset{}{2.898} + \underset{(0.0113)}{0.1815(\hat{K} - \hat{L})} + \underset{(0.0125)}{0.2606(\hat{T} - \hat{L})} + \underset{(0.0124)}{1.0645\hat{L}}$$

(figures in parentheses are standard errors). The scale factor ($\sigma = 0.0645$) is significant at well beyond the 0.001 level. Similar regressions, fitted to data for various regions, indicate that the scale factor was larger in the New South than in the Old South. A more complete discussion of these regional regressions will be presented in the authors' forthcoming book.

that both sides view as the agenda for a new round of research.[9] The balance of this paper reports on our progress in working through that agenda.

I. The Use of 1860 Price Relatives and Cotton Output

In chapter 3 of *Time on the Cross* we presented evidence indicating that the 1850's were a boom period for cotton planters, with the demand for cotton increasing rapidly and cotton prices generally well above their long-run trend. These findings led Thomas Haskell, David and Temin, Gavin Wright, Harold Woodman, and a number of others to argue that the high relative efficiency of southern agriculture indicated by the ratio G_s/G_n is merely an artifact of the temporarily inflated price of cotton in 1860—of our decision to use 1860 price relatives instead of those of a more normal year in computing the aggregate output of both the North and the South.

Even if this argument about the direction of the bias were correct, there would still be the question of the magnitude of the bias. Between 1857 and 1860 there was a very substantial supply response on the part of cotton producers, which led to a fall in prices from the 1857 peak. By 1860, cotton prices had declined to within 8 percent of their long-run trend, or equilibrium, value. If, in aggregating southern output, we reduced the price applied to cotton by 7.5 percent $[1 - (1/1.08) \approx 0.075]$, the ratio G_s/G_n would decline from 134.7 to 131.8.[10]

What has been overlooked by Haskell and others is that 1860 was a boom year for all of agriculture and not merely cotton. Consequently, the direction of the bias introduced by using 1860 prices to aggregate output does not turn on whether cotton was high relative to its price in other years, but whether it was higher than normal relative to other agricultural prices, particularly to those of the principal northern agricultural products. Table 4 shows that the prices of the principal northern products relative to cotton were *higher* in 1860 than in 1850 (the only other year in which the data are sufficiently complete to permit the type of inter- and intraregional efficiency comparisons that we require). Had we chosen the 1850 set of price relatives or computed our efficiency indexes for 1850, as some have advocated, we would have increased (not reduced) the measured efficiency of slave agriculture relative to that of free agriculture as well as the advantage of large plantations relative to small farms.

TABLE 4—THE RATIO OF THE PRICES OF THE PRINCIPAL PRODUCTS OF NORTHERN FARMS TO THE PRICE OF COTTON

	1860 (1)	1850 (2)	(3)[a]
Corn/cotton	4.0	3.4	118
Wheat/cotton	8.9	6.8	131
Hogs/cotton	42.5	27.5	155
Cattle/cotton	33.4	24.3	137

Source: Computed from data in Marvin Towne and Wayne Rasmussen, pp. 283, 284, 294, 297, 308. Cotton is in dollars per pound, hogs and cattle in dollars per hundredweight, corn and wheat in dollars per bushel.
[a]Columns (1) ÷ (2) × 100.

Is it possible that both 1850 and 1860 are rare exceptions and that the price relatives of most other years would in fact support the case of the critics? Table 5 provides an answer to that question. It shows that the ratio of all farm product prices to that of cotton was 18 percent higher in 1860 than it was on average over the entire half century from 1811 to 1860. Thus in choosing the price relatives of 1860 to construct the output indexes, we chose a set of prices less favorable to the South than those that prevailed in 34 of the 49 years preceding 1860.

Wright (1975) argued that the choice of 1860 biased the productivity computation in favor of the South for still another reason. He believes that the South was the beneficiary of "random fluctuations in yields around their normal levels" (pp. 449–50)

[9]Other important critiques of our efficiency measures include Lance Davis, Thomas Haskell (1974, 1975), Harold Woodman, and Gavin Wright (1974, 1975).

[10]The cotton share of southern farm output (0.284) was computed from data underlying the computations described in *TOTC*, II, pp. 131–38.

TABLE 5—THE RATIO OF AN INDEX OF ALL FARM PRODUCT PRICES TO THE PRICE OF COTTON
(ratio for 1811–20 = 100)

1860	135
Average for the Half Century	
1811–60	114
Decade Averages	
1811–20	100
1821–30	96
1831–40	115
1841–50	136
1851–60	143

Source: Computed from U.S. Bureau of the Census, 1960, pp. 115, 124. For each time period the average value of the index of all farm product prices was divided by the average price of cotton. The resulting ratios were then expressed as a percentage of the ratio for 1811–20.

that made the cotton crop of 1860 unusually large. This fortunate event, he conjectured, caused cotton production in the New South to be between 35.2 and 43.5 percent above its predicted, or normal, level (p. 444). Wright presented no actual evidence on yields to support this conjecture. Since the U.S. Department of Agriculture (*USDA*) did not begin collecting data on cotton acreage until after the Civil War, there is no basis for systematic estimates of annual cotton yields per acre harvested during the antebellum years.

Over the years 1867–1900, for which data on cotton yields are available, the average annual yield per acre is 177.1 pounds and the standard deviation is 20.10.[11] Thus a chance deviation in yields of between 35 and 44 percent above the mean (between 3.1 and 3.8 standard deviations) is an event so rare (less than one in a thousand) that one would expect it to have occasioned great comment among planters and in the agricultural publications of the time. Yet while much was said about the large size of the 1860 crop, the available commentaries are devoid of references to an extraordinarily high yield (see, for example, U.S. Bureau of the Census, 1862, p. 84; Lewis Cecil Gray, chs. 30 and 37; James Watkins, p. 10).

Wright based his conjecture on a supply curve for cotton that he has estimated, in which the output of cotton in a given year is made a function of the price of cotton (lagged one year) and the cumulative sales of public land (lagged two years) in four states of the New South and Florida (Wright 1971, pp. 111, 114). When Wright argues that the 1860 production of cotton in these states was above the predicted level, he means that observed output was above the level predicted by a model in which only cumulated past sales of public land can shift the supply curve of cotton. He arbitrarily assigns the entire residual for 1860 to cotton yields, although at least some part, if not all of it, is merely the artifact of an equation that failed to take account of such other determinants of supply as the proportion of privately held land that was in farms, the proportion of land in farms that was improved, the proportion of improved land sown in cotton, and the labor to land ratio. Rather than being fixed during the decade of the 1850's, as Wright assumed, these ratios were changing in such a manner as to increase the supply of cotton more rapidly than the cumulative total of public land sales. Between 1850 and 1860 the amount of improved land in the farms of the four states of the New South singled out by Wright increased by 59 percent, which was 1.6 times more rapid than corn production, 8.4 times more rapid than sweet potato production, and 20 times more rapid than the stock of hogs (U.S. Bureau of the Census 1862, pp. 196–236). This suggests that cotton was getting an increasing share of improved land at the expense of the principal food and feed crops.[12] In several cases, in-

[11]Computed from *USDA*, 1955, p. 5. The observation for 1866 was dropped because yields in that year were abnormally low as a result of the postwar disorganization of southern agriculture. But its inclusion would not affect the argument.

[12]Regressions relating yield per acre of cotton and yield per acre of corn in the cotton states estimated for the period 1867–1900 indicate that the elasticity of corn yields with respect to cotton yields was 1.1. It follows that if weather caused the cotton yield of these states to be 35 percent above normal, one would expect corn yields to be 38 percent above their normal level. Since Wright argues that yields in 1850 were below

cluding oats and rice,output not only failed to keep pace with rate of growth of improved land but declined absolutely. Public land sales are, of course, irrelevant to the supply of cotton in states that accounted for over a quarter of the crop of 1860, since they were not public-land states. In South Carolina, for example, cotton production increased by 17 percent between 1850 and 1860, although land in farms decreased slightly (see U.S. Bureau of the Census 1862, pp. 196–209).

What then explains the big increase in the output of cotton between 1850 and 1860? A complete answer to this question is beyond reach, but factors explaining about 91 percent of the increase can be identified. While we do not know what *annual* cotton yields were prior to the Civil War, in 1868 the U.S. commissioner of agriculture asked his corps of crop reporters to ascertain the normal cotton yields, as well as the normal share of tilled land sown in cotton, that had prevailed in 1860 and the years immediately preceding it. The figures obtained by this survey (pp. 414–15) indicate that the shift in the geographic locus of cotton production from the Old to the New South explains about 8 percent of the increase in output between 1850 and 1860. Assuming that within each state cotton just maintained its share of improved land, the increase in improved land explains 41 percent of the growth in the cotton crop. The amount of land switched within states from other crops to cotton cannot be known with certainty. But if we assume that the entire shift was confined to corn, the failure of corn production to keep pace with the increase in improved land implies that within-state reallocations of improved acreage explain another 42 percent of the growth in the cotton crop. These estimates leave a residual of 9 percent to be explained by all other factors including increases in the use of fertilizers, increases in the labor to land ratio, and random fluctuations in yields.[13]

But even if one grants so fortunate an event in 1859–60 as cotton yields that were 1.65 standard deviations above the mean (an event expected only once in 20 years), and assuming that northern farmers shared none of the benefits of the favorable weather that supposedly visited the South during 1859–60, the appropriate adjustment would just reduce G_s/G_n from 134.7 to 128.7. If we grant both fortuitously high cotton yields and inappropriately high price relatives, the ratio G_s/G_n declines to 126.3.[14]

II. Problems in Measuring the Land Input

We turn now to the two principal criticisms of our measure of the land input. In

normal, if the acreage devoted to corn had been held constant, one would expect the random fluctuation of yields hypothesized by Wright to have made the 1860 output of corn at least 38 percent greater than in 1850. That corn output actually increased by only 19 percent, therefore leads to the improbable conclusion that there was not only a proportionate decline but an absolute decline of 16 percent in the acreage devoted to corn between the two dates.

[13]The increase in output due to interstate shifts has two components: that due to the increase in the Southwide proportion of land in cotton and that due to the increase in the Southwide average yield per acre. Data for estimating both components were obtained from U.S. Bureau of the Census, 1895, pp. 92, 100; and *USDA*, 1868, pp.414–15. The reallocation of corn land to cotton within states was computed by subtracting the actual 1860 production of corn in each of the 10 cotton states from the crop that would have been observed in each state if the growth of output had kept pace with the increase of improved land. The sum of these differences divided by 13.350 bushels, the average corn yield per harvested acre in these states between 1867 and 1900 (*USDA*, 1954), gives the number of acres switched from corn to cotton (there was no trend in corn yields between 1867 and 1900). The 1860 output of cotton divided by 177.1 pounds, the average per acre yield of cotton between 1867 and 1900, gives the number of acres in cotton in 1860. The last figure divided into the acreage that would have been in cotton if corn land had not been switched to cotton, represents the percentage increase in the output of cotton due to the within-state shift of land into cotton. This computation assumes that none of the increase in corn production between 1850 and 1860 is due to random fluctuations in yields. As fn. 12 indicates, such a fluctuation implies a greater reallocation of corn land to cotton than we have allowed. The distribution of interaction terms was resolved by converting the calculation to annual rates of change.

[14]The reduction in price, of course, only applies to the output of cotton reduced by 15.8 percent, the reduction which corresponds to 1.65 standard deviations. To grant a random increase in yields of 1.65 standard deviations above the mean is to attribute more than 175 percent of the unexplained increase in the cotton crop to good fortune.

our quality adjustment of the land input we used land values (V) rather than the rental value of land $[(i + \delta)V]$, which contains a term for land depletion. It has been argued that land was depleted in the South, especially in the slave-selling states, much more rapidly than in the North.[15] To test this hypothesis we examined the relationship of land yields to the length of settlement in the selling states.[16] The effect of the length of settlement on land yields was estimated from equation (2):

$$(2) \quad \hat{Q} - \hat{T} = \beta_0 + \beta_1(\hat{L} - \hat{T}) + \beta_2(\hat{K} - \hat{T}) + \beta_3 Y$$

The equation was fitted to output and input measures constructed from the Parker-Gallman sample. When T was measured by total acres, the resulting regression was

$$(3) \quad \hat{Q} - \hat{T} = 3.988 + \underset{(0.0243)}{0.6070}(\hat{L} - \hat{T}) + \underset{(0.0174)}{0.2682}(\hat{K} - \hat{T}) - \underset{(0.00077)}{0.00570}Y$$

$$R^2 = 0.5045; \quad N = 1{,}539$$

When T was measured by improved acres, the resulting regression was

$$(4) \quad \hat{Q} - \hat{T} = 3.336 + \underset{(0.0242)}{0.3736}(\hat{L} - \hat{T}) + \underset{(0.0167)}{0.1786}(\hat{K} - \hat{T}) - \underset{(0.00071)}{0.00558}Y$$

$$R^2 = 0.2589; \quad N = 1{,}539$$

In both regressions, β_3, which we interpret as the rate at which land yields changed with the length of settlement, is statistically significant, negative, but small. Whether this rate of decline, barely 1/2 of 1 percent per annum, was more or less than in the North remains to be determined. However, even if one assumes that the northern depletion rate was zero, an adjustment for depletion in the South would raise that region's input of land by less than 6 percent. This rise, in turn, would reduce G_s/G_n from 134.7 to 132.9. Combining the adjustment for depletion with those for high cotton prices and fortunate yields, reduces G_s/G_n to 124.5.

David and Temin centered their criticism of our adjustment for differences in land quality on our failure to remove the locational component of land values. This omission created a more serious problem than the neglect of depletion, especially for the intra-South efficiency comparisons. The problem would not arise if farm-gate prices had been used in constructing the output index. For then farms located far from markets would receive lower prices for their products and also have lower values per acre of land than farms close to markets. Since uniform national prices were employed in constructing the output index, we implicitly assumed that all farms used the same average amount of transport service. If, as is frequently asserted, large slave plantations were generally better located than small farms, the assumption would introduce a bias against large plantations in the productivity comparisons. To test this hypothesis we estimated equation (5), on farms of various sizes, both by state and for the South as a whole.[17]

$$(5) \quad V = \gamma_1 I + \gamma_2 U$$

The preliminary results of the analysis are summarized in Table 6, which shows that the locational component of land (estimated as γ_2 per acre) for the South as a whole was an average of 44 percent of land values. Thus 56 percent of so-called land values were due to investment in the land, and not, as is so often argued, to locational rents. Plantations with 51 or more slaves, however, were an exception. These large plantations, it turns out, were much better

[15] See Cairnes, pp. 52–53; Phillips, pp. 332, 336; Gray, pp. 447–448; Genovese, pp. 85–105.

[16] See Wright (1969), ch. 4, for an earlier attempt to test this hypothesis. Wright did not, however, construct an aggregate index of output nor adjust for differences in the quality of the inputs of labor.

[17] See Wright (1969), p. 95. Wright's regressions were fitted to the counties in the various soil categories that were constructed by Gray. Wright did not attempt to produce state or Southwide estimates of γ_1 and γ_2 by farm size but he did point out that it was γ_1 that explained most of the value of farmland and improvements.

TABLE 6—THE SHARE OF IMPROVEMENTS IN THE TOTAL VALUE OF LAND PLUS IMPROVEMENTS, BY FARM SIZE

Number of Slaves per Farm:	0	1–15	16–50	51+	All Farms in Cotton South
(1) Improved acres per farm (I)	46.85	121.25	349.76	930.24	141.94
(2) Unimproved acres per farm (U)	140.41	315.69	653.37	1,710.85	320.72
(3) Price per acre of I in \$ (γ_1)	13.138	20.243	23.294	30.949	22.30
(4) Price per acre of U in \$ (γ_2)	2.572	2.533	2.931	12.613	4.288
(5) $\gamma_1 - \gamma_2$ (\$)	10.566	17.710	20.363	18.336	18.012
(6) $\gamma_2(I + U)$ (\$)	481.63	1,106.77	2,940.17	33,312.07	1,983.89
(7) $(\gamma_1 - \gamma_2)I$ (\$)	495.02	2,147.34	7,122.16	17,056.88	2,556.62
(8) Total value of land and improvements per farm (Row 6 + Row 7 in \$)	976.65	3,254.11	10,062.33	50,368.95	4,540.51
(9) Improvements as a share of total value of land and improvements (Row 7/Row 8, percent)	50.69	65.99	70.78	33.86	56.31
(10) Location as a share of total value of land and improvements (100 – Row 9, percent)	49.31	34.01	29.22	66.14	43.69

Source: Computed from data in the Parker-Gallman sample, using the values of γ_1 and γ_2 estimated from the Southwide regressions run on equation (7) for each size class. Values of γ_1 and γ_2 were, in all cases, significant at the 0.001 level. The entries in rows 1–4 of the all-farms column are weighted averages of the corresponding entries for columns 1–4. The weights in rows 1 and 2 are the proportion of farms. The weights in rows 3 and 4 are the proportion of improved and unimproved acres, respectively.

located than small ones. The average locational rent per acre on large plantations was more than four times that on smaller-sized farms, whether slave or free.[18] Consequently, even though investment per improved acre on large plantations exceeded

[18]It might be argued that better (more fertile) land was brought into production first. In that case $\gamma_1 - \gamma_2$ would measure not only the average investment per improved acre but also the superior quality of the land on which the improvement had been made. Even if this were the case all of $\gamma_1 - \gamma_2$ belongs in the quality adjustment, since whether this amount is due entirely to improvements or reflects some superior virgin quality, it is "more" land in an economic sense. We can test the hypothesis that more fertile land was improved first by making use of Martin Primack's estimates of labor required to improve an acre (pp. 154–55, 233–43), and annual wage rates on southern farms (*USDA* 1868, p. 416). These indicate that the average value of improvements per acre was \$20.05. Since $\gamma_1 - \gamma_2 =$ \$18.01, Primack's data suggest that all of $\gamma_1 - \gamma_2$ is investment. Probably ease of land clearing rather than natural fertility was the principal factor determining which land was improved first.

It might also be argued that the land belonging to plantations with 51 or more slaves was more fertile than the land of smaller farms. If so, some part of γ_2 for this class would represent not locational advantage but the superior fertility of land yet to be brought into production, and the subtraction of all of γ_2 from γ_1 would underestimate the quantity of quality-adjusted land plus improvements that must be included in the land input of this class. Alternative assumptions regarding the distribution of γ_2 between locational advantage and superior fertility led to variations in the index of total factor productivity for this class of farms ranging from 147.7 to 132.8 (see Table 7, col. 3). Two aspects of this result should be stressed. First, even if we assumed that the locational advantage of farms with 51 or more slaves was no greater than that of farms with 16–50 slaves, none of the arguments in the balance of this paper would be altered. Second, the principal effect of variations in the distribution of γ_2 is on the assessment of the comparative efficiency of intermediate and large plantations. Assuming that plantations in the 51-or-more class had greater locational advantage than those in the 16–50 class leads to the conclusion that they were more productive than those in the 16–50 class. If we assumed that locational advantages were identical, then both classes would have roughly the same indexes of total factor productivity.

TABLE 7—THE EFFECT OF CORRECTING FOR THE LOCATIONAL COMPONENT OF LAND VALUES ON THE RELATIVE VALUES OF THE INDEXES OF TOTAL FACTOR PRODUCTIVITY
(Index of Free Southern Farms = 100)

Number of Slaves per Farm	Index Before Correction, All States in Parker-Gallman Sample	Index After Correction, All States in Parker-Gallman Sample
0	100.0	100.0
1-15	107.7	100.8
16-50	144.7	133.1
51 or more	133.5	147.7

the cotton-South average, investment accounted for only 34 percent of land values.[19]

It follows that the previous failure to correct for locational rents biased the efficiency index for plantations with 51 or more slaves downward, while the indexes for plantations with 1-15 and 16-50 slaves were biased upward. Table 7 shows that after correction for locational rents, total factor productivity on slave farms increases continuously with farm size, but small slave farms have no productivity advantage over free farms.

III. The Length of the Work Year

One of the most important results of the work over the past two years is the finding by Jacob Metzer and John Olson that slaves worked fewer hours per year than free farmers. This directly contradicts the hypothesis of our 1971 paper that the measurement of the labor input in man-years rather than man-hours was the principal reason that G_s exceeded G_n. The belief that slaves worked more days per year than free men is not only widely held but was recently reasserted by David and Temin (pp. 768-71) who attributed the phenomenon to the fact that there were more frost-free days in the South than in the North. They put the average length of the work year of northern farmers at 2,163 hours. Noting that there are between 220 and 240 frost-free days in the South but only between 160 and 180 such days in the North, David and Temin argued that it was reasonable to assume that slaves worked 10 percent more days per year than free northern farmers. Moreover, since the days during the winter were both longer and warmer in the South than in the North, they also reasoned that slaves probably averaged more hours per day than northern farmers.

Systematic data bearing on the average number of days worked per year and per season during antebellum times are available only for the South. Such averages have been computed by Metzer and Olson from the daily work records that were kept by the owners or overseers of slave plantations.[20] Processing of most of these is still in progress, and the computations employed in this paper are based on a subsample of 7 cotton plantations that are displayed in Table 8.

This table shows that there was relatively

[19]For the North γ_2 is just $1.80 per acre. Thus the locational component per acre was lower in the North than in the South. The result is surprising only if considered in a partial rather than a general equilibrium context. Between 1840 and 1860 over 15,000 miles of railroad track were built in the North, bringing millions of acres close to a rail route. This massive increase in supramarginal land brought about by railroad construction probably lowered rather than raised the average locational rent (see Fogel, 1964, p. 223, n. 10). According to Haskell (1975) our assumption that "an acre of northern farmland was an average of 2.5 times better in quality than southern farmland" is "extraordinary" (p. 38). But an "average" acre of northern farmland was superior to an "average" southern acre in 1860, not primarily because of its natural qualities, as Haskell appears to believe, but because more capital had been invested in its improvement. Over 54 percent of northern farmland had been improved by 1860 but for the South the corresponding figure is only 30 percent. Consequently, even if land in both regions had been of equal quality in the natural state and if expenditures per improved acre had been the same in both regions, the average northern acre would have been 1.8 times better than the average southern acre. But northerners invested about 30 percent more on each of their improved acres than did southerners. Thus about 90 percent of the "superior" quality of northern land represented investment. (Computed from data in Primack, pp. 154-55, 233-43; U.S. Bureau of the Census, 1895, pp. 84-100; Clarence Danhof, p. 77; and *USDA*, 1868, p. 416).

[20]The periods covered by these records range from a single season to several years. The detail contained is uneven, but it is possible to determine the daily work records of fieldhands and sometimes also that of artisans, servants, and others engaged in nonagricultural labor. It is also possible to determine holidays and days lost due to rain or illness.

TABLE 8—DAYS WORKED PER SEASON FOR A SAMPLE OF SOUTHERN COTTON PLANTATIONS

	Spring	Summer	Fall	Winter	Total
Prudhomme-Bermuda (LA)	71.6	72.1	65.6	61.9	271.2
Flinn Green River (MS)	70.3	72.6	71.9	67.0	281.8
Monette-Hope and Pleasant Hill (LA)	73.9	74.5	67.1	65.6	281.1
Le Blanc (LA)	75.7	68.1	67.2	70.7	281.7
Pre Aux Cleres (LA)	73.5	69.5	68.6	68.2	279.8
El Destino (FL)	72.6	68.9	70.2	67.7	279.4
Average of six short-staple plantations (equal weights)	72.9	71.0	68.4	66.8	279.1
Kollock-Ossabow Island (GA)	77.6	73.5	70.9	70.7	292.7
Average of seven plantations (equal weights)	73.6	71.3	68.8	67.4	281.1

Source: Olson.

little variation in the number of days worked per season, although the number of work days during the spring planting and cultivating period was about 7 percent greater than during the peak harvest months of the fall. The average number of days worked per year within the sample ranged from 271 to 293. The average number of days worked per year in the sample of 6 short-staple plantations is 279. Adding the long-staple Kollock plantation raises the average to 281 days.

Thus the number of days in the work year of slaves appears to have fallen short of the potential by about 23 percent. This result is explained primarily by the almost total absence of Sunday work.[21] Occasionally, a few hands were used on Sundays for special tasks. But such incidents were rare. This nearly total absence of Sunday work is a unique feature of the large slave plantations, and it bears on the special nature of the slave-labor system.

Unfortunately, information on the length of the agricultural workday for the antebellum era is fragmentary, although a recurrent theme is that the day extended from sunrise to sunset. The earliest systematic studies of regional and seasonal variation in the length of the workday carried out by the *USDA* pertain to the first third of the twentieth century. Olson points out that these studies yield seasonal estimates of the length of the workday that are quite similar to those obtained by subtracting standard time allowances for meals during antebellum times from the interval between sunrise and sunset in each region and season. Combining the information on the number of workdays presented in Table 8 with these seasonal estimates of the average length of the workday, Olson produced Table 9, which presents the number of hours in the slave work year for the sample of 7 cotton plantations. The total hours worked per year within the sample ranged from a low of 2,709 to a high of 2,912. The average for the entire sample is 2,798 hours.[22] Since the last figure is 29 percent *greater* than the 2,163 hours that David and Temin hold was typical on northern farms, and 18 percent greater than their estimate of the length of the slave work year, this finding might seem to substantiate the proposition that the slave work year exceeded the free one.

But such a conclusion is warranted only if one accepts the contention that the average work year of antebellum farmers in the North was just 2,163 hours. David and Temin cite a *USDA* report by John Hopkins on changing conditions of agricultural

[21]The balance of the shortfall is explained by other holidays and half-days on Saturdays (6 days), by illness (11 days), and by rain and inclement weather (15 days).

[22]Ralph Anderson, using a different sample of plantations and working independently of Olson, produced an estimate of the length of the slave work year that is quite similar to Olson's.

TABLE 9—HOURS WORKED PER SEASON AND PER YEAR FOR A SAMPLE OF SLAVE COTTON PLANTATIONS

	Spring	Summer	Fall	Winter	Average per Season	Total
Prudhomme-Bermuda	759	771	702	477	677	2,709
Flinn-Green River	745	777	769	516	702	2,807
Monette-Hope and Pleasant Hill	783	797	718	505	701	2,803
Le Blanc	802	729	719	544	698	2,794
Pre Aux Cleres	779	744	734	525	696	2,782
El Destino	770	737	751	521	695	2,779
Average of six short-staple farms	773	760	732	514	695	2,779
Kollock (long staple) Ossabow Island	823	786	759	544	728	2,912
Average of seven cotton farms	780	763	736	519	700	2,798

Source: Olson.

labor and technology between World War I and 1936 as the source for this figure. But Hopkins put the length of the northern work year during this period at between 2,800 and 3,370 hours (pp. 23, 27). Combining the samples reported by Hopkins with those of several other *USDA* studies, Olson computed the average length of the agricultural work year in the various subregions of the North. Although there was a fair degree of variation from sample to sample, as well as by the principal subregions, the average of every sample exceeded the 2,163 hours asserted by David and Temin by at least 31 percent. The lowest subregional average of 3,006 hours was found in the corn and general farming belt; the highest was 3,365 hours in the western dairy region. The average for the overall sample of 1,605 northern farms was 3,130 hours.

Comparison of these figures with Table 9 reveals that slaves worked approximately 10 percent fewer hours than northern farmers.[23] The contention that the number of frost-free days (or the length of the growing season) was the principal factor determining the length of the work year is, thus, incorrect. While the number of frost-free days determines which plants can be raised in a particular region, there is little relationship between the length of the growing season

[23]This conclusion, of course, rests on the assumption that the northern work year was not shorter in antebellum times than during the first third of the twentieth century. The assumption is consistent with available fragmentary data. See Olson and the sources cited there. The discussion of the length of the northern work year involves two issues. First, since David and Temin turned to *USDA* data on hours worked by farmers during the first third of the twentieth century, there is the question of the average length of the work year indicated by this body of evidence. The second issue is whether or not an average derived from data for the early twentieth century may be applied to the antebellum period, given the changes that occurred in income and in the technology of feeding, milking, planting, and harvesting. Gallman has pointed to factors which suggest that hours worked in northern agriculture may have been longer in the early twentieth century than in the mid-nineteenth. These are discussed in some detail by Olson. Clearly, a continued search for evidence in antebellum sources bearing on this question is called for. But even if we granted the contention that the slave work year was 10 percent longer than the northern work year G_s/G_n would fall from 134.7 to 127.5. Combining this adjustment with the previous ones for high cotton prices, fortunate yields, and land depletion, reduces G_s/G_n to 117.9. So even if these conjectured corrections of southern inputs and outputs advanced by the critics were all correct, the efficiency of southern agriculture would still exceed that of northern agriculture by 18 percent. There is, of course, also the adjustment to the input of northern labor proposed by David and Temin. But as we pointed out in fn. 7, the direction of this adjustment is opposite to that conjectured by the critics. If we made it, G_s/G_n would rise from 117.9 to 144.8, thus wiping out the effect of the proposed adjustments to southern inputs and outputs.

and the duration of the period from seedtime to harvest for particular crops. The growing season in South Dakota, for example, is about 150 days but the period from seedtime to harvest is 310 days for winter wheat and only 115 days for spring wheat (see James Covert pp. 35, 36, 43, 44).[24]

The length of the work year was determined not only by the duration of the planting, cultivating, and harvest seasons of a particular mix of crops but also by the mix between field crops and animal products (including dairy products). Olson stresses that the length of the northern work year was positively correlated with the degree of specialization in livestock and dairying. The implications of the labor-intensive methods of rearing livestock (which was already characteristic of the North by 1860)[25] and of dairying are revealed by a *USDA* study showing that the average duration of the workday increased by over an hour on both weekdays and Sundays in counties that switched from general farming to dairying (see Olson; Hopkins, pp. 26–27). The principal reason for the longer work year in the North than on slave plantations is that the North specialized in dairy and livestock while slave plantations did not. Olson estimates that about 38 percent of the product of northern farms in 1860, as measured by value-added, originated in livestock and dairying. The corresponding figure for the cotton South is just 9 percent; for large plantations it is hardly 5 percent.

The finding that the slave work year was shorter than the free work year does not contradict the proposition that slave labor was more intensely exploited than free labor, but only the proposition that such exploitation took the form of more hours per year. What had been insufficiently emphasized is the possibility that slaves worked more intensively per hour than did free men.

[24]The relationship between the growing period, the growing season, and the period between seedtime and harvest are clarified by Covert, p. 14.

[25]See Fogel (1965), p. 216. Corn consumption per equivalent hog more than doubled in the North between 1840 and 1860 but remained relatively constant in the South. See Percy Wells Bidwell and John Falconer (pp. 393, 437), Gray (pp. 842–45), and Gates (pp. 199, 218).

IV. The Problem of Differences in Product Mix

There is still the problem of the regional differences in the mix of products. Because the output mixes of northern and southern agriculture differed, the attempt to compare G_s and G_n poses an index number problem. This is an issue which, of course, plagues all productivity comparisons, whether over space or time. David and Temin argue that in our case the problem is insuperable because cotton could be grown only in the South, not in the North. Fortunately, the problem is not quite so intractable.

The influence of product mix can be tackled by taking advantage of the fact that there was a class of free farms that could, and did, produce cotton. While it is true that free southern farms were slightly more efficient than northern farms, this edge explained only 4 percent of the ratio $(G_s - G_n)/G_n$. Thus nearly all of the southern productivity advantage is explained by the extent to which the productivity of medium and large slave plantations exceeded the efficiency of small free farms, whether these small farms were located in the North (where they could not produce cotton) or in the South (where they did produce cotton).

To put the issue somewhat differently, while both the large slave and small free farms of the South produced cotton, the large slave plantations were 48 percent more efficient than small free farms (see Table 7). Of course, the cotton share of output on these small farms (29 percent) was less than that of large slave plantations (61 percent). But since there was no climatic obstacle that prevented the free southern farms of the cotton belt from choosing exactly the same mix of products that was selected by large slave plantations, it may be assumed that they chose the product mix that was most efficient for them. Presumably a product mix with a larger cotton share would have decreased, or at least not increased, their efficiency. In other words, it appears that it was the manner in which cotton was produced, rather than the mere capacity to produce cotton, that is the principal factor accounting for the superior efficiency of large plantations. This interpretation is supported by the finding that small slave plantations, those with 1–15 slaves, were not more efficient than free southern farms (see Table 7) even though their cotton share (39 percent) was a third greater than that of free farms.

The last point needs elaboration, since Gavin Wright (1974, 1975) has argued that free farmers in the cotton belt were just as efficient in the production of cotton as large plantations but that they chose to produce less cotton in order to reduce riskiness. The basic propositions of his argument are that both small free and large slave farms were equally efficient in the production of cotton, that both were equally efficient in producing other commodities, and that the difference in mix between cotton and other commodities alone explains the differences in the indexes of total factor productivity by farm size. If Wright's conjectures are correct, the overall efficiency index of farms of each size class would be given by geometric averages of the indexes for cotton and other commodities, with the weights on each invariant commodity index being the share of that commodity in total output—the shares varying with size classes (see Evsey Domar).

If we let A_c equal the efficiency index for cotton and A_0 equal the efficiency index for all other commodities, the relationship of the overall efficiency index in each size class to A_c and A_0 is given by the following four equations:

$$A_c^{0.29}A_0^{0.71} = 1.00 \quad \text{(0 slaves)} \tag{6a}$$

$$A_c^{0.39}A_0^{0.61} = 1.01 \quad \text{(1–15 slaves)} \tag{6b}$$

$$A_c^{0.53}A_0^{0.47} = 1.33 \quad \text{(16–50 slaves)} \tag{6c}$$

$$A_c^{0.61}A_0^{0.39} = 1.48 \quad \text{(51+ slaves)} \tag{6d}$$

Since there are only two unknowns, only two equations are needed for a solution. If A_c and A_0 were invariant with size class, or approximately so, the ratio between A_c and A_0 should be approximately the same, regardless of which two equations are used to solve for A_c and A_0. However, as the following classification shows, this is not the case. The ratio A_c/A_0 varies from 1.1 to 7.1.

Equations used to solve for A_c and A_0	Ratio of A_c to A_0
(6a) and (6b)	1.1
(6a) and (6c)	3.3
(6a) and (6d)	3.4
(6c) and (6d)	3.8
(6b) and (6d)	5.7
(6b) and (6c)	7.1

In other words, it was not the mere difference in product mix but the manner in which cotton was produced that made large slave plantations more efficient than either small free farms or small slave farms. The threshold size for the efficiency of the gang system appears to be above 15 slaves.[26]

There is another aspect to Wright's argument. That is the contention that small free farms chose the observed mix in order to reduce riskiness—to reduce the variance of their income. In order to explore the implications of this suggestion, let us for the moment accept Wright's assumption that both large slave and small free farms were equally efficient in producing cotton. In that case, as we have seen, the income yield per average unit of input was more than three times as large in the production of cotton as in other products on farms of both sizes.[27] Consequently, by increasing the cotton share of their output from 29 to 61 percent (the share on large slave plantations), small farmers could have increased their mean income by 48 percent.

Wright's conjecture implies, therefore,

[26]This is not to say that the level of the overall efficiency index of each size class was independent of the share of cotton in total output. Quite the contrary, farms that were more efficient in cotton production should have been more heavily specialized in that crop. In other words, the optimum share of cotton in total output was a function not only of relative prices but of a farm's comparative advantage in that crop. Moreover, the mix of crops was a major determinant of the degree to which the labor force was utilized (see Section V, below).

[27]This result is obtained by solving equations (6a) and (6d) for A_c and A_0.

that farmers were willing to forgo close to half of their mean income in order to gain some unspecified reduction in the variance of that income. Not only is this an extraordinary price to pay for insurance, but there is no evidence to show that within the relevant range (cotton shares between 29 and 61 percent of gross farm product) the relative variance of income was positively correlated with the share of income originating in cotton. The absence of a positive correlation between cotton shares and the relative variance is indicated by the facts that yields in cotton were no more variable than those of other farm products and that the price of corn, which Wright argues was the principal substitute for cotton, was actually more variable than the price of cotton.[28] Nor do the benefits of a more mixed "portfolio" seem to have been potent enough to have provided less variation in price than that associated with cotton. Over the years 1831-60, Thomas Senior Berry's index (p. 564) of the average price of 20 or more agricultural products "identified" with the North (i.e., excluding cotton, sugar, and rice) has a coefficient of variation (0.23) that is quite similar to that for cotton alone (0.25).[29]

Wright has also argued that the objective of small farms may have been not the minimization of the variance of their income but "safety first." The exact meaning of safety first is never clearly defined, but Wright appears to equate it with the guaranteeing of the food supply. Thus before turning to the market with all its risks to obtain products that they did not produce, free farmers first sought to insure that they would not starve. However, as we showed in our analysis of the slave diet (1974b), free southern farmers could have guaranteed a nutritious diet, not only high in protein but exceeding all other nutrient requirements, out of their own production for less than six cents per capita per day. Thus it took less than one-third of the average annual product of a free farm to insure an adequate diet for all those living on such farms. If the free farms of the cotton belt were as efficient in cotton production as were the large plantations, they could have had both an insured food supply and a 48 percent increase in their mean income by raising the cotton share of their output from 29 to 61 percent.[30]

V. Sources of Efficiency on Large Plantations

The finding that large slave plantations were 48 percent more productive than the small free farms of the South poses a new problem: What feature, or features, of the organization and operation of large slave plantations gave them such a marked advantage? Examination of the managerial records of these plantations suggests that part of the answer lies in the persistence with which planters sought to exploit complementarities and interdependencies made possible by concentration in the production of one or the other of the four principal slave crops: cotton, sugar, rice, and tobacco.

[28]The relative variance of incomes on free and slave farms in 1860 was computed from the Parker-Gallman sample by weighting outputs on farms of all sizes by uniform national prices. The coefficient of variation was between 30 and 40 percent larger on free farms (with an average cotton share of 29 percent) than on slave farms (with average cotton shares ranging between 39 and 61 percent). Over the years from 1867 to 1900 the coefficient of variation in corn yields fell below that of cotton yields by just 0.02 (*USDA*, 1954, 1955). The relative variance of the price of corn in New Orleans over the years 1840-60 was 25 percent greater than the relative variance of cotton prices over the same period (computed from Cole).

[29]For the period 1831-46 there are 20 commodities in Berry's index for northern agriculture. For the period 1846-60, the number of commodities is 29. Cotton prices are from U.S. Bureau of the Census, 1960, p. 124.

[30]To farmers in debt, safety-first could well have meant guaranteeing a high enough cash income to meet mortgage and other debt calls. The point at issue is not whether the food supply mattered to antebellum farmers but whether they perceived it as the most binding constraint in the determination of their economic decisions. Illiquidity could well have appeared as a more serious menace than an inadequate food supply. Wright does not explore this issue, although it is widely suggested in the traditional literature on nineteenth-century agriculture. Moreover, if A_c exceeded A_0 by 3.4 times, and if farmers sought to insure some minimum absolute level of income, then given the relative variances of income from cotton and corn, the much higher mean income associated with specialization in cotton indicates that the choice of the higher cotton share would have reduced rather than increased the likelihood of falling below that minimum.

The central focus of planters was the organization of the labor force into highly coordinated and precisely functioning gangs characterized by intensity of effort. "A plantation might be considered as a piece of machinery," said Bennet H. Barrow (Edwin Adams Davis, p. 409) in his Highland Plantation rules. "To operate successfully, all its parts should be uniform and exact, and its impelling force regular and steady." "Driving," the establishment of a rigid gang discipline, was considered the crux of a successful operation. Observers, such as Robert Russell, said that the discipline of plantation life was "almost as strict as that of our military system" (p. 180). Frederick Law Olmsted described one instance in which he observed two very large hoe gangs "moving across the field in parallel lines, with a considerable degree of precision." He reported that he repeatedly rode through their lines at a canter with other horsemen, "often coming upon them suddenly, without producing the smallest change or interruption in the dogged action of the labourers" (p. 452).

Each work gang was based on an internal division of labor that not only assigned every member of the gang to a precise task but simultaneously made his or her performance dependent on the actions of the others. On the McDuffie plantation, the planting gang was divided into three classes which were described in the following way (as quoted by Metzer):

> 1st, the best hands, embracing those of good judgment and quick motion. 2nd, those of the weakest and most inefficient class. 3rd, the second class of hoe hands. Thus classified, the first class will run ahead and open a small hole about seven to ten inches apart, into which the second class drop from four to five cotton seed, and the third class follow and cover with a rake. [p. 135]

Interdependence and tension were also promoted between gangs, especially during the period of cultivation when the field labor force was divided into plow gangs and hoe gangs. The hoe hands chopped out the weeds that surrounded the cotton plants as well as excessive sprouts. The plow gangs followed behind, stirring the soil near the rows of cotton plants and tossing it back around the plants. Thus the hoe and plow gangs each put the other under an assembly-line type of pressure. The hoeing had to be completed in time to permit the plow hands to carry out their tasks. At the same time the progress of the hoeing, which entailed lighter labor than plowing, set a pace for the plow gang. The drivers or overseers moved back and forth between the two gangs, exhorting and prodding each to keep up with the pace of the other, as well as inspecting the quality of the work. In operations such as cotton picking, which did not lend themselves as naturally to interdependence as planting and cultivating, planters sought to promote intensity of effort by dividing hands into competing gangs and offering bonuses on a daily and weekly basis to the gang that picked the most. They also made extensive use of the so-called "task" methods. These were, literally, time-motion studies on the basis of which a daily quota for each hand was established.

In addition to the use of assembly-line methods and time-motion studies to insure maximum intensity of effort in a particular operation, planters sought to allocate their slaves among jobs in such a manner as to achieve "full capacity" utilization of each person. In this connection slaves were given "hand" ratings—generally ranging from one-eighth to a full hand—according to their age, sex, and physical ability. The strongest hands were put into field work, with the ablest of these given tasks that would set the pace for the others. Plow gangs were composed primarily of men in their twenties or early thirties. Less sturdy men and boys, as well as prime-aged women, were in the hoe gangs. Older women were occupied in such domestic duties as house servants and nurses; older men worked as gardeners, servants, and stock-minders. Metzer's analysis (p. 134) of the records of the Kollock plantations indicates that the "hand"-to-slave ratio was 0.9 in field work but only 0.6 in nonfield work. Metzer points out that in allocating slaves among jobs, planters pursued the

TABLE 10—COTTON-PICKING RATES OF PREGNANT WOMEN AND NURSING MOTHERS AS A PERCENTAGE OR THE COTTON-PICKING RATES OF WOMEN THE SAME AGE WHO WERE NEITHER PREGNANT NOR NURSING

Weeks Before (−) or After (+) Childbirth	Age 20	25	30	35
−12 to −9	82.3	83.3	84.1	84.8
−8 to −5	77.4	78.8	79.8	80.6
−4 to −1	74.8	76.3	77.4	78.3
+2 to +3	3.9	9.8	14.1	17.4
+4 to +7	64.9	67.1	68.6	69.8
+8 to +11	91.3	91.8	92.2	92.5

principal of comparative, rather than absolute, advantage. Thus during the harvest period, most of the labor of picking cotton was provided by women, even though women had lower daily cotton-picking rates than men. On the Pleasant Hill plantation, for example, women provided 31 percent more labor time in cotton picking than did men.

Data on the cotton-picking rates of pregnant women and nursing mothers provide still another illustration of the degree to which planters succeeded in utilizing all those in the labor force. Estimates derived from Metzer's regression of the daily cotton-picking rates of women by age, and by weeks before and after childbirth, are summarized in Table 10. This table shows that down to the last week before birth, pregnant women picked three-quarters or more of the amount that was normal for women of corresponding ages who were neither pregnant nor nursing. Only during the month following childbirth was there a sharp reduction in the amount of cotton picked. Some mothers started to return to field work during the second or third week after birth. By the second month after birth, picking rates reached two-thirds of the level for nonnursing mothers. By the third month, the level rose to over 90 percent.

Another way in which planters sought to achieve full capacity utilization of labor was in the selection of the product mix. Labor requirements in cotton production had a very marked seasonal pattern, with one peak reached in the late spring and a second in October. Consequently, secondary crops were chosen so that their peak labor requirements were complementary to those of cotton (see Metzer, Figure 1). Corn was an excellent match. It could be planted before cotton and could be harvested either early or late, depending on other pressures, because the kernels, protected in the ears, did not suffer if harvesting was delayed beyond maturation.

VI. Some Issues of Interpretation

It should not be assumed that slave labor was more efficient than free labor in all occupations. There is no evidence that the productivity of slave labor exceeded that of free labor in urban industries. As Claudia Goldin (pp. 104–05) points out, the much higher elasticity of demand for slave labor in the cities than in rural areas (the ratio is more than 10 to 1) indicates that whatever advantage there was in slave labor was specific to agriculture.

Preliminary analysis also suggests that within *U.S.* agriculture, the slave system of labor raised productivity only for slave farms that specialized in one of four principal products: sugar, cotton, rice, and tobacco. Economies of scale seem to have been greatest in sugar, since nearly 100 percent of all cane sugar in the United States was produced on large slave plantations. The slave system seems to have been less productive in tobacco than in cotton. The scale factor in the Old South (where tobacco was a relatively important crop), while statistically significant, was only a third as large as the scale factor for the New South. Although the issue is now under investigation, there appears to have been no productivity advantage to slave labor in general farming and relatively few large slave plantations engaged in general farming.

The available evidence indicates that greater intensity of labor per hour, not more hours of labor per day nor more days of labor per year, is the reason why the index of total factor productivity is 48 percent higher for slave plantations than for free farms. There is no evidence that land was used more intensively in the South than in the North, but even if it was, the depletion rate of southern land yields was so low (0.6 percent per annum) that this can, at most, account for 5 percent of the value of $(G_s - G_n)/G_n$. The interim estimates thus indicate that slaves employed on medium and large plantations worked about 72 percent more intensively per hour than free farmers. In other words, on average, a slave on these plantations produced as much output in roughly 35 minutes as a free farmer did in a full hour.

Once it is recognized that the fundamental form of the exploitation of slave labor was through speed-up (increased intensity per hour) rather than through an increase in the number of clock-time hours per year, certain paradoxes resolve themselves. The longer rest breaks during the work day, and the greater time off on Sundays, for slaves than for free men appear not as boons that slave-owners granted to their chattel but as conditions for achieving the desired level of intensity. The finding that slaves earned 15 percent more income per clock-time hour is less surprising when it is realized that their pay per equal-efficiency hour was 33 percent less than that of free farmers.

David and Temin argue (pp. 778–83) that while the index of total factor productivity may be acceptable in comparing the relative efficiency of free countries it cannot be applied to a comparison of the free North and the slave South—that in this instance a morally weighted index of efficiency is required. However, the issue of the relative efficiency of slave labor did not originate with *Time on the Cross*. It is an issue with a long history that traces back to such commentators on slavery as Adam Smith, Alexis de Tocqueville, Cassius Marcellus Clay, Hinton Rowan Helper, Frederick Law Olmsted, and John Cairnes. Is the geometric index of total factor productivity appropriate to the resolution of the question of the efficiency of slave labor as that question actually evolved in historical literature?

Much of chapters 5 and 6 of *Time on the Cross* was devoted to reviewing both the pre- and post-Civil War debates on the inefficiency of slave agriculture and slave labor. From this review it is clear that what the critics of slavery meant was: other inputs held constant, but substituting slave for free labor and slave managers for free managers, the output of slave farms would be much less than the output of free farms. About this "fact" Clay, Helper, Olmsted, and most other antislavery critics had no doubt. This confidence stemmed from the conviction that slavery "degraded" labor, that slavery turned plantation owners into "idlers," that "comparing man with man," slave laborers were less than half as productive as whites, that Africans were "far less adapted for steady, uninterrupted labor than we are," and that "white laborers of equal intelligence and under equal stimulus will cut twice as much wood, split twice as many rails, and hoe a third more corn a day than Negroes." (See Clay, p. 204 and Olmsted, pp. 91, 467–68.)

Nor does the geometric index of total factor productivity do violence to the issue of efficiency as it was perceived and discussed by the principal scholars who preceded us. Certainly neither Ulrich Bonnell Phillips, nor Gray, nor Ralph Betts Flanders, nor Robert R. Russel, nor Kenneth M. Stampp were talking about a morally weighted measure of productivity, but of the comparative efficiency of slave and free labor, in just the manner that the issue was raised by the antebellum critics of slavery.

To the extent that the argument for moral weighting is really an objection to using observed prices for aggregating southern output, one needs to assess the effect of slavery on the observed prices. On all agricultural commodities except slave-produced staples, the South was a price taker. Since the South contributed about three-quarters of the world's supply of cotton, its behavior did affect the world price of cotton. In the absence of slavery, however, the supply of cotton would presumably have shifted to the left. This implies that the observed price of cotton was lower, not higher, than it would have been if slaves had been free to make their own choices about the provision of their labor. Consequently, the use of observed prices to aggregate output yields a lower value of G_s/G_n than would be obtained by aggregation based on the counterfactual price of cotton.

Of course, the fact that blacks who toiled on large plantations were more efficient than free workers does not imply that blacks were inherently superior to whites as workers. It was the system that forced men to work at the pace of an assembly line (called the gang) that made slave laborers more efficient than free laborers. Moreover, the gang system, as already noted, appears to have raised productivity only on farms that specialized in certain crops.[31] It should, of course, be emphasized that greater efficiency does not mean greater good. As we attempted to demonstrate in *Time on the Cross*, freedom has value and the loss of freedom by slaves was greater than the gain in measured output to free persons.

[31] It is important to distinguish between the technological characteristics of the production process and the manner in which the labor employed in that process was obtained. While it was force, not volunteerism, that ultimately permitted gang labor to exist, it does not follow that force alone would have led to high levels of productivity, if that potential was not inherent in the production process. If force alone created high levels of productivity, small plantations with 1–15 slaves should have been more efficient than free farms, even though they did not utilize the gang system. Similarly, the argument that some mix of coercion and volunteerism may have been necessary in the initial creation of a factory labor force does not rule out economies of scale or other technological efficiencies as features of the factory system.

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