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The Relative Technical Efficiency of Slave and Non-Slave Farms in Southern Agriculture

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A variety of new techniques for analyzing efficiency empirically have been developed.[1] Almost all of these techniques involve the construction of frontiers, either production or cost, and deviations from the frontiers are attributed to various types of inefficiency. These techniques can be applied to analyze various efficiency issues that have, in the past, been raised in various fields. For example, in the early 1970s Fogel and Engerman argued that slave agriculture was relatively profitable and that its profitability was due to the productive superiority of slave labor.[2] More specifically, slave farms were more technically efficient than non-slave farms. The new methods for estimating efficiency provide a much improved methodology for analyzing the issue.

This paper applies a non-parametric method for measuring technical efficiency to data drawn from a sample of Southern farms for the year 1860. Specifically, an attempt is made to compare the relative technical efficiency of slave and non-slave farms. An advantage of using the non-parametric methodology is that it is possible to determine whether technical inefficiency is the result of operating off the isoquant (pure technical inefficiency) or operating at an inappropriate scale.

The results indicate that the relative profitability of slave agriculture was not the result of its being more technically efficient than non-slave agriculture. Instead, it indicates that the profitability of slave agriculture was most likely linked to its output composition relative to non-slave farms.

The next section of this paper reviews some of the recent literature concerning the relative technical efficiency of slave relative to non-slave agriculture. Section three discusses the methodology used in this paper to measure the technical efficiency of farms. Section four presents and analyzes the empirical results and section five summarizes the paper.

I

Before reviewing the literature concerning the measurement of the technical efficiency of slave and non-slave farms, a few comments need to be made to clarify the meaning of certain terms. In economics, a firm is said to be technically efficient if it maximizes output regardless of the input combination used. Alternatively, a firm is allocatively efficient if it chooses that input combination at which the marginal product per dollar spent on an input is equal for all inputs. The work referred to here and all of the analysis undertaken in this paper is concerned with the measurement of technical efficiency.

In their seminal work on measuring and comparing the technical efficiency of farms in the North and South, Fogel and Engerman use an index of total factor productivity for Southern relative to Northern

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Two technical appendices relating to the data used in this study are available on request from the authors.

agriculture (1971, pp. 356–359). This index is written as

$$(1) \qquad \frac{A_S}{A_N} = \frac{Q_S/Q_N}{(L_S/L_N)^{\alpha_1}\,(T_S/T_N)^{\alpha_2}\,(K_S/K_N)^{\alpha_3}},$$

S, N = subscripts for the South and North;
A = the index of total factor productivity;
Q = total agricultural output;
L = the labor input;
T = the land input;
K = the capital input;
$\alpha_1, \alpha_2, \alpha_3$ = the share of labor, land, and capital in agricultural income.

Using the above approach, the index of total factor productivity for Southern relative to Northern agriculture was calculated. Fogel and Engerman found that productivity in Southern agriculture was 9 percent higher than in the North. They also derived an adjusted index, modifying the method of measuring inputs, which showed that Southern agriculture was 39 percent more efficient (1971, pp. 356–357).

One criticism that can be made of their approach is that the relative advantage of Southern agriculture was due to the fact that non-slave farms in the South were more efficient than slave farms and, for some unknown reason, also much more efficient than Northern farms. In response to this, the factor productivity index was calculated for slave and non-slave farms in the South. They found that within the South slave farms were more technically efficient than non-slave farms (Fogel and Engerman, 1977). Fogel and Engerman also derived an adjusted index in which certain attempts were made to modify the measurement of inputs and output. Using this modified approach they found that slave farms were 25 to 46 percent more efficient than non-slave farms (Fogel and Engerman, 1980).

There are a number of criticisms of Fogel and Engerman's work. However, since this paper is only concerned with comparing the technical efficiency of slave and non-slave farms within the South, only criticisms relating to this part of their work are discussed. One of the most important problems with their approach is that it is based on the use of factor share data. The factor shares actually used were rather arbitrarily chose, given the fact that empirical estimates vary significantly.

A second major criticism has been raised by David and Temin (1979) and Wright (1979). They point out that the output figures used in the construction of the productivity index are measured in revenue terms. Thus what Fogel and Engerman are measuring is revenue efficiency, the extent to which farms can extract revenue from their inputs. In addition, the method of deriving the revenue figures implies that slave and non-slave farms in the South faced identical output prices. By evaluating the outputs produced by Southern slave and non-slave farms, Fogel and Engerman conclude that slave farms are more efficient, i.e., more revenue efficient. However, this result could occur if both slave and non-slave farms are of equal technical efficiency but, for one reason or another, grow different combinations of crops. Specifically, slave and non-slave farms could be equal in technical efficiency, but because slave farms devote a larger proportion of their inputs to cotton production and because cotton has a higher relative price, the slave farms will have a higher revenue efficiency. Thus differences in output composition could account for Fogel and Engerman's result.

Related to the above discussion, Gavin Wright (1979) also objects to Fogel and Engerman's results because of the unrepresentativeness of the 1860 census year. He argues that demand conditions were unusually favorable and the cotton yields unusually high that year. Given that the output composition of slave and non-slave farms in the South was drastically different, as discussed above, this would bias the efficiency measure in favor of the slave farms.[3]

The contribution of this paper is related mainly to some of the issues related to the last two criticisms discussed above. Specifically, if slave agriculture was profitable, was this due to the technical superiority of slave labor, as Fogel and Engerman maintain, or was it due to the differences in output composition emphasized by David and Temin and Wright. If the analysis in the next section indicates that slave

agriculture was not technologically superior to free agriculture, then the profitability of the former was most likely due to the particular output composition of slave relative to free agriculture.

Although the approach used in this paper has significant advantages over that used by Fogel and Engerman, there are still some significant problems. First, Wright's criticism concerning the unrepresentativeness of the 1986 census year is still pertinent. Also the fact that the census year is just prior to the civil war may have influenced the efficiency of slave agriculture.[4] In addition, the data used is drawn from a cross-sectional sample for only one year. Thus differences in efficiency among the various observations may be related to differences in the technology available to the farms. Thus calculated levels of inefficiency may very well be the result of the fact that certain farms had adapted new techniques, others were in the process of adapting, and still others had not yet begun to innovate.

II

This section discusses the model utilized by this study. The next section of this paper contains a discussion of the data. The model presented in this section allows for the calculation of the relative technical efficiency of slave and non-slave farms. The model will avoid three of the limitations of the methodology utilized by Fogel and Engerman.

First, this model allows us to disaggregate the sources of technical inefficiency between scale inefficiency (i.e., not producing at constant returns to scale) and pure technical inefficiency (operating off of the isoquant). In addition, it is possible to further disaggregate the source of inefficiency to include congestion of inputs (i.e., producing on the backward bending portion of the isoquant, negative marginal physical output of an input). However, for the purposes of this study, congestion of inputs is not measured.

Second, this methodology avoids the problem of output aggregation that confronted Fogel and Engerman. Unlike Fogel and Engerman, who were forced to aggregate all output into a single revenue value, this methodology allows for multiple outputs.

There have been a number of studies which utilize a non-stochastic procedure to calculate the technical efficiency of a firm producing a single output. Färe, Grosskopf, and Lovell present a detailed exposition of these techniques (1985). The work of Byrnes, Färe, Grosskopf, and Kraft (1987) is the only previous study which utilized this multiple output methodology for two or more economic goods.

In the discussion of the methodology, it is assumed that there are n inputs, denoted by $x = (x_1, x_2, \ldots, x_n) \in R^n_+$, m outputs, denoted by $y = (y_1, y_2, \ldots, y_m) \in R^m_+$, and k observations (or farms) of x and y. Denote the matrix of observed inputs as X, where X is of dimension (n, k), and the matrix of observed outputs by Y, where Y is of dimension (m, k).

Following the work of Färe, Grosskopf and Lovell (1985), the transformation set formed by X and Y satisfying constant returns to scale and strong disposability can be written as

$$(2) \qquad T = \{(x, y): y \leq Yz,\ Xz \leq x,\ z \in R^k_+\},$$

where z is the intensity vector showing to what intensity a particular activity (x_i, y_i) is utilized. This transformation set is illustrated in Figure One with m = n = 1, i.e., one output and one input. The transformation set is bounded by the line OT and the x axis and corresponds to the notion of a total product curve.

Since we are dealing with a single input and a single output and three observations, Y and X are of dimension (1, 3) in Figure 1. Intuitively, one can think of the z's as weights attached to each observation. The upper bound of the transformation set (T) is constructed by using observation B as the reference point. Specifically, the weights are assigned to each observation so as to guarantee a theoretical maximum output equal to or greater than the actual output while at the same time requiring no more of the input used than is actually available. Thus for input level x_0, which is assumed to be $\frac{1}{2}(x_1)$, the weight attached to observations A and C is zero, while that attributed to B is ½. Thus with ½ the input of B, observation A would produce ½ the output of B, $\frac{1}{2}y_1 = y_0'$, as long as constant returns to scale prevail. Alternatively, for input level x_2, which is assumed to be $2(x_1)$, the weight attached to A and C is zero, while that attributed to

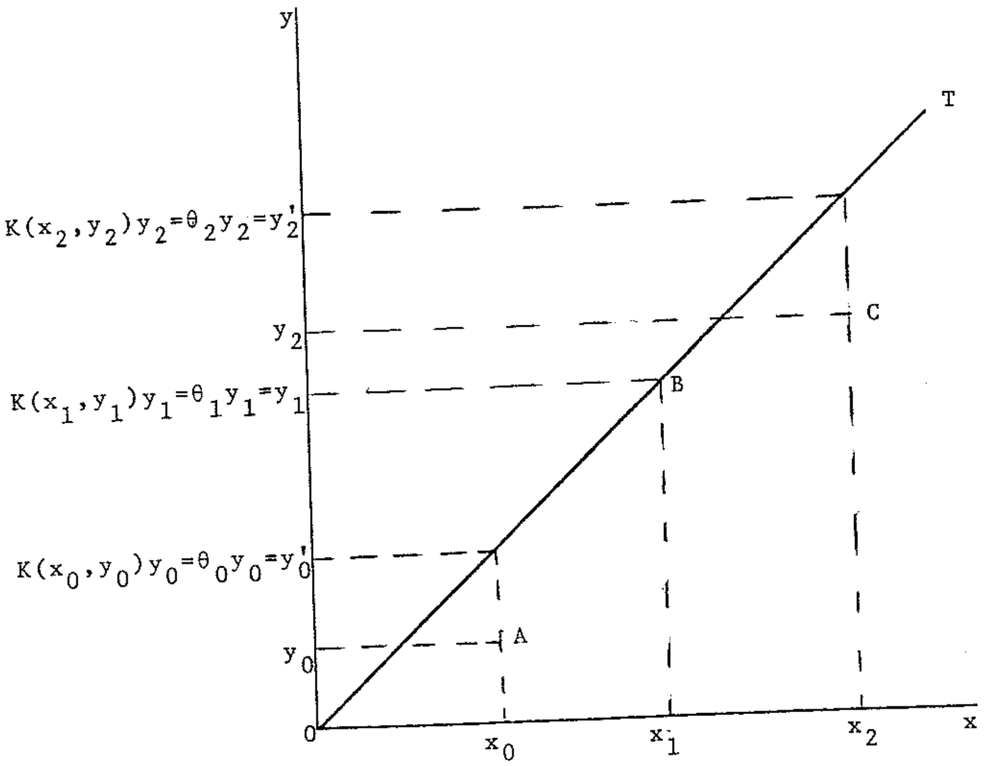

Figure 1.

B is 2. Thus with twice the inputs of B, observation C would produce twice the output, $2y_1' = y_0$. Finally, for input level x_1 the weight attached to A and C is zero, while that attached to B is one.

For the observation (x_0, y_0) the overall measure of technical efficiency is written as

$$K(x_0, y_0) = \max \{\theta_0: (x_0, \theta y_0) \in T\}. \tag{3}$$

In terms of Figure One, the overall technical efficiency measure $K(x_0, y_0)$ increases $\theta_0 y_0$ as much as possible while still staying in T at the given x_0. Alternatively, one can think of $K(x_0, y_0)$ as the ratio of potential to actual output. Alternatively $1/K(x_0, y_0)$ is the ratio of actual to potential output. In the same manner, the overall technical efficiency measure for observation C, $K(x_2, y_2)$, increases $\theta_2 y_2$ as much as possible while still staying in T at the given x_2. Finally, for observation B the overall measure of technical efficiency is equal to one, i.e., this observation is overall technically efficient.

With respect to the issues involved in this paper, the linear programming (LP) problems utilized to calculate overall technical efficiency, K, is:

$$\begin{aligned} &\text{Max } \theta \\ \text{s.t.}\quad & C_1z_1 + C_2z_2 + \cdots + C_kz_k \leq C_i \\ & N_1z_1 + N_2z_2 + \cdots + N_kz_k \leq N_i \\ & L_1z_1 + L_2z_2 + \cdots + L_kz_k \leq L_i \\ & y_1z_1 + y_2z_2 + \cdots + y_kz_k - y_i\theta \geq 0. \end{aligned}$$

The first three constraints are input constraints. In this paper, three inputs are used: C is capital, N is labor, and L is land. The constraint for capital are discussed in detail in order to give the reader an economic interpretation of the constraint. The left-hand side of the constraint constitutes the theoretical efficient farm against which the ith farm is to be compared. The value of the right-hand side, C_i, is the capital stock of the ith farm whose relative efficiency we are calculating. This constraint states that the theoretical efficient farm will use an amount of capital that is less than or equal to the amount utilized by the ith farm to produce the output of the ith farm.

The last constraint is the output constraint. Since this paper investigates farms producing multiple outputs, the actual LP Problem has a separate constraint for each output. The left-hand side of the constraint consists of two parts. The component $(y_1z_1 + y_2z_2 + \cdots + y_kz_k)$ measures the level of output of the hypothetical efficient farm. This is the maximum output that can be produced by the ith farm given its actual level of inputs. The component $(-y_i\theta)$ is the actual level of output of the ith farm, y_i, multiplied by the level of inefficiency, θ. If the farm is overall technically efficient, then $\theta = 1$. As a result, the component $(y_1z_1 + y_2z_2 + \cdots + y_kz_k)$ is exactly offset by $(-y_i\theta)$. Hence, the level of output of the ith farm is the same as the theoretical efficient farm. If the farm is technically inefficient then $\theta > 1$. This results in the theoretical maximum output $(y_1z_1 + y_2z_2 + \cdots + y_kz_k)$ being greater than the actual output of the ith farm, y_i.

Overall technical efficiency, as discussed above, is disaggregated into two components: scale and pure technical. In order to distinguish between these two components the original transformation set T given in equation two is modified to allow for increasing and decreasing returns to scale. This is accomplished by restricting[5] the intensity variables, z, so that $\Sigma_{i=1}^{k} z_i = 1$. Thus the new transformation set is written as

$$T' = \left\{(x, y): y \leq Yz, Xz \leq x, z \in R_+^k, \sum_{i=1}^{k} z_i = 1\right\}. \tag{4}$$

Such a transformation set for $m = n = 1$ is illustrated in Figure Two.

The upper bound of this transformation set is constructed in the following manner. At input level x_0,

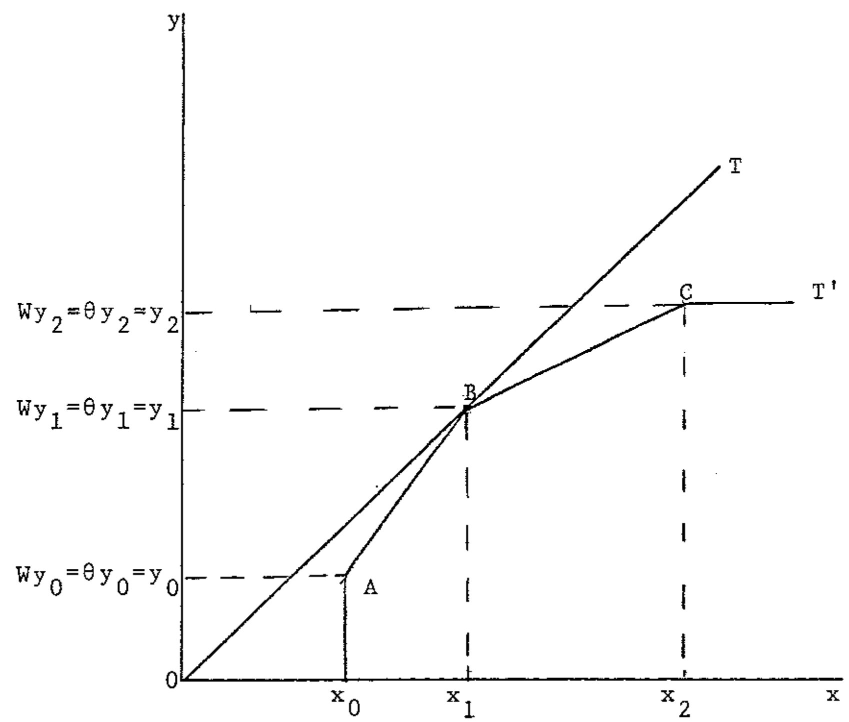

Figure 2.

the weight attached to observation A is 1 while that for B and C is 0. For any input combination between x_0 and x_1, the technology is represented by a linear combination of the technology of A and B, i.e., the weights attached to A and B are less than one and sum to one, while the weight for C is zero. At x_1, the weight attached to B is one with zero for A and C. For input combinations between x_1 and x_2, the technology is represented by a linear combination of observation B and C, with the weight for A equal to zero.

Pure technical inefficiency is measured with reference to T′ and this measure is written for observation (x_0, y_0), as

$$W(x_0, y_0) = \max \{\theta_0 : (x_0, \theta_0 y_0) \in T'\}. \tag{5}$$

Thus $W(x_0, y_0)$ increases $\theta_0 y_0$ as much as possible while still remaining on T′ for a given x_0.

Now, the measure of scale efficiency, for observation (x_0, y_0), is defined as

$$S(x_0, y_0) = K(x_0, y_0)/W(x_0, y_0). \tag{6}$$

In Figure Two, $\theta = 1$ for all three observations. Of course, this need not always be the case. With respect to Figure Two, only observation B is experiencing constant returns to scale. At B both $W(x_1, y_1)$ and $K(x_1, y_1)$ are equal to one and thus $S(x_1, y_1) = 1$. Observations A and C represent cases of increasing and decreasing returns respectively. $W(x_0, y_0)$ and $W(x_2, y_2)$ are both equal to one, while $K(x_0, y_0)$ and $K(x_2, y_2)$ are both greater than one. Non-constant returns to scale occurs when $S(x_0, y_0)$ is greater than one and constant returns to scale occur when $S(x_0, y_0)$ is equal to one.

With respect to the issues involved in this paper, the linear programming (LP) problem used to calculate W is:

$$\begin{aligned} &\text{Max } \theta \\ \text{s.t.}\quad & C_1 z_1 + C_2 z_2 + \cdots + C_k z_k \leq C_i \\ & N_1 z_1 + N_2 z_2 + \cdots + N_k z_k \leq N_i \\ & L_1 z_1 + L_2 z_2 + \cdots + L_k z_k \leq L_i \\ & y_1 z_1 + y_2 z_2 + \cdots + y_k z_k - y_i\theta \geq 0. \\ & z_1 + z_2 + \cdots + z_k = 1 \end{aligned}$$

Thus by taking the ratio of K to W for an observation, one can determine if the farm operates under constant or non-constant returns to scale.

Calculating scale efficiency (S) allows us to determine whether a particular observation is operating at constant or non-constant returns to scale, but does not allow us to determine whether increasing or decreasing returns to scale prevail. This is done by modifying the transformation set so as to impose non-increasing returns to scale. This is accomplished by restricting the intensity variables so that $\sum_{i=1}^{k} z_i \leq 1$. The new transformation set is written as

$$T^* = \left\{(x, y): y \leq Yz, Xz \leq x, z \in R^k_+, \sum_{i=1}^{k} z_i \leq 1\right\}. \tag{7}$$

This transformation set is presented in Figure Three for the case when m = n = 1.

The upper bound of this transformation set (T*) is constructed as follows. At input level x_0, the weights for observations A and C are zero and, assuming x_0, $\tfrac{1}{2}x_1$, the weight for observation B is ½. Thus with ½ the input of B, observation A will product ½ the output of B, $\tfrac{1}{2}y_1 = y_0'$. For input level x_1, the weights attached to A and C are zero, while that attached to B is one. For any input combination between x_1 and x_2, a linear combination of the technologies used at B and C is used, i.e., the z's for B and C are less than one, but sum to one, while the z for observation A is zero. At x_2 the weight attached to C is one, while that for A and B is zero.

Given the above transformation set, a new measure of efficiency relative to this set is written, for observation (x_0, y_0), as

$$W^*(x_0, y_0) = \max \{\theta_0 : (x_0, \theta_0 y_0) \in T^*\}. \tag{8}$$

Given x_0, $W^*(x_0 \cdot y_0)$ increases $\theta_0 y_0$ as much as possible while still staying on T*, given x_0. From Figure Two, we can see that observation A is experiencing increasing returns to scale. Figures Two and Three show that this occurs when $S(x_0, y_0) \neq 1$ and $W^*(x_0, y_0) = K(x_0, y_0)$. Alternatively Figure Two shows us that observation C experiences decreasing returns to scale. Figures Two and Three also show that $S(x_2, y_2) \neq 1$ and $W^*(x_2, y_2) \neq K(x_2, y_2)$. If $S \neq 1$ and $W^* \neq K$, then decreasing returns to scale occur. Alternatively, if $S \neq 1$ and $W^* = K$, then increasing returns to scale occur.

The linear programming problem used in this paper to calculate W* is:

$$\begin{aligned} &\text{Max } \theta \\ \text{s.t.}\quad & C_1 z_1 + C_2 z_2 + \cdots + C_k z_k \leq C_i \\ & N_1 z_1 + N_2 z_2 + \cdots + N_k z_k \leq N_i \\ & L_1 z_1 + L_2 z_2 + \cdots + L_k z_k \leq L_i \\ & y_1 z_1 + y_2 z_2 + \cdots + y_k z_k - y_i\theta \geq 0. \\ & z_1 + z_2 + \cdots + z_k \leq 1. \end{aligned}$$

There are two possible cases when $S \neq 1$. If $K = W^*$ then IRS exist and if $K \neq W^*$ then DRS exist.

As was stated previously, the total technical efficiency measure for any observation (K) can be decomposed into two components. First, pure technical efficiency which is measured by W. Remember W measures the ratio of potential to actual output based upon the transformation set T′. For observation (x_0, y_0), illustrated in Figures One, Two, and Three, m = n = 1, and $W(x_0, y_0) = y_0/y_0 = 1$ (Figure Two). This observation has attained pure technical efficiency. The second component is scale inefficiency which for observation (x_0, y_0) is measured by $S(x_0, y_0) = K(x_0, y_0)/W(x_0, y_0)$. In Figure One, $K(x_0, y_0) > 1$ and in Figure Two, $W(x_0, y_0) = 1$, as a result $S(x_0, y_0) > 1$ and the observation is scale inefficient. Overall

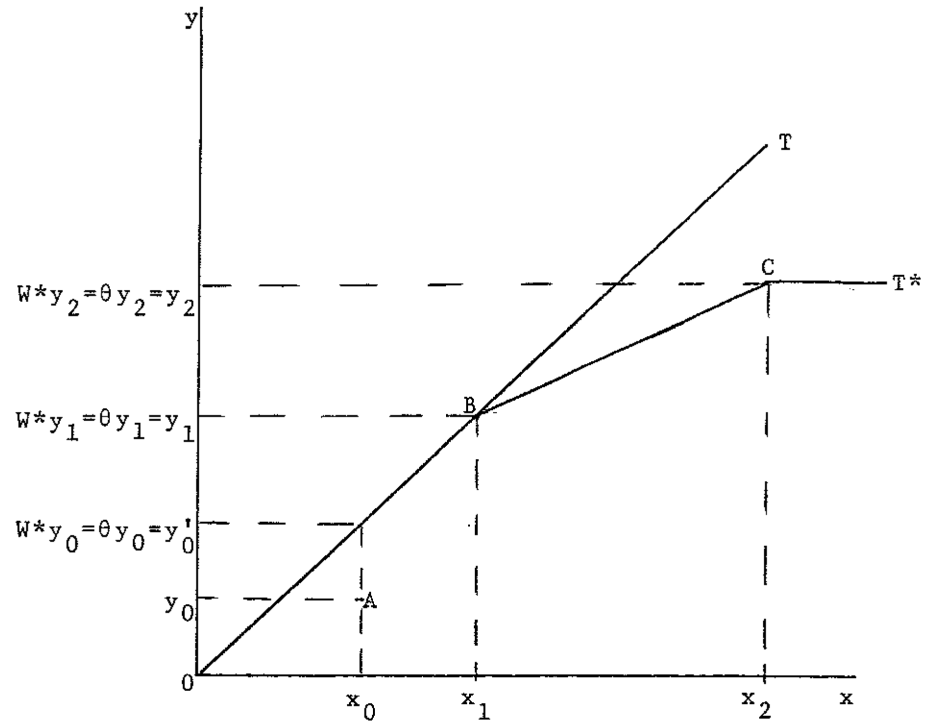

Figure 3.

technical efficiency for (x_0, y_0) is expressed as

$$K(x_0, y_0) = \frac{K(x_0, y_0)}{W(x_0, y_0)} \cdot W(x_0, y_0) = S(x_0, y_0) \cdot W(x_0, y_0) \quad (9)$$

Finally, if $S(x_0, y_0) \neq 1$ one can compare $W^*(x_0, y_0)$ to $K(x_0, y_0)$ in order to determine if decreasing or increasing returns to scale prevail. The technical efficiency measures and their definitions are summarized in Table One below.

III

Each of the three linear programming problems (K, W, and W*) was calculated for each of 122 Southern farms. These farms are a subset of a 5228 farm data set for the year 1860 collected by Parker and Gallman.[6] The sample is obtained by taking every 40th observation in the original data set. The data for each farm includes the quantities of land, labor, and capital used in production as well as the quantities produced of each of 10 output categories. The input measures are derived using procedures described by Fogel and Engerman.[7] Summary statistics concerning the variables used are presented in Table Two. Separate statistics are presented in Tables Three and Four for slave and non-slave farms.

One can of course raise questions concerning whether or not our sample is representative of the Parker-Gallman data set[8] and, furthermore, whether the Parker-Gallman data set is representative in general of Southern farms in 1860. With respect to the latter point, economic historians will render the final verdict. With respect to the representativeness of our sample, it can be argued that as long as the error or bias that might exist is the same for both the slave and non-slave farms in our data set, the results of this paper will not be altered. In other words, what is important is that comparison of crop composition and input utilization for slave and non-slave farms should reveal patterns that one would expect to find in general for Southern farms. Examining the summary statistics in Tables Three and Four, one can see that the relative differences in crop production and input usage are indeed what one would expect. That is, one would expect to find that the slave farms were on average larger than non-slave in terms of land, capital, and labor utilized. Indeed this is the case. In addition, one would expect to find that non-slave farms devoted relatively more of their inputs to the production of grains and home manufactures, while slave farms produced relatively more cotton. That this is true is not immediately obvious from examining Tables Three and Four. However, it will be shown later in this paper, utilizing price data, that indeed it is true. Thus this comparison indicates that the quantitative relationships between the two groups, slave and non-slave, within the sample are indeed what one would expect.

The linear programming problems discussed above were calculated for each of the observations. For each observation, (x_0, y_0), $K(x_0, y_0)$, $W(x_0, y_0)$ and $W^*(x_0, y_0)$ are calculated. The scale measure of efficiency is calculated by taking the ratio of $K(x_0, y_0)/W(x_0, y_0)$. $W^*(x_0, y_0)$ is used to determine if scale inefficiencies were due to operation at decreasing or increasing returns to scale.

The overall measure of technical efficiency, K, for non-slave farms, was on average, 1.36. The average for slave farms was 1.64. This indicates that non-slave farms were, on average, more technically efficient. Specifically, if all non-slave farms operated on the frontier, output could have been increased by

TABLE 1
Efficiency Measures

Symbol	Title	Definition
$K(x_0, y_0)$	Overall Efficiency Measure	$K(x_0, y_0) = \max \{\theta_0 : (x_0, \theta_0 y_0) \epsilon T\}$
$W(x_0, y_0)$	Pure Technical Efficiency Measure	$W(x_0, y_0) = \max \{\theta_0 : (x_0, \theta_0 y_0) \epsilon T'\}$
$S(x_0, y_0)$	Scale Efficiency Measure	$S(x_0, y_0) = K(x_0, y_0)/W(x_0, y_0)$
$W^*(x_0, y_0)$	Non-Increasing Returns Efficiency Measure	$W^*(x_0, y_0) = \max \{\theta_0 : (x_0, \theta_0 y_0) \epsilon T^*\}$

TABLE 2
Summary Statistics of Output and Input Variables

Variable Name	Units of Measurement	Mean (St. Deviation)	Minimum Value	Maximum Value
Home Manufacturers (plus 3 other outputs measured in dollars)	Dollars	187.29 (184.50)	0.00	1050.00
Grain	Bushels	540.88 (661.03)	0.00	4310.00
Cotton	Bales	9.81 (20.62)	0.00	136.00
Wool	Pounds	15.40 (45.30)	0.00	400.00
Peas and Beans	Bushels	40.75 (88.76)	0.00	500.00
Potatoes (Irish and Sweet)	Bushels	105.12 (128.28)	0.00	600.00
Butter and Cheese	Pounds	97.43 (103.37)	0.00	500.00
Hay	Tons	.95 (2.32)	0.00	18.00
Molasses	Pounds	10.98 (58.28)	0.00	560.00
Beeswax and Honey	Pounds	25.54 (61.21)	0.00	350.00
Labor	Numbers	4.75 (6.80)	0.17	49.48
Capital	Dollars	175.59 (250.95)	1.50	1642.86
Land	Acres	365.15 (542.22)	5.00	3680.00

36%. Alternatively, if all slave farms had been operating on the frontier, their output could have been increased by 64%. With respect to the scale measure of efficiency, S, the results are very similar to that for the overall measures in than non-slave farms appear to be relatively more efficient. The average scale efficiency measures for slave and non-slave farms respectively were 1.48 and 1.10. These results indicate that output could have been increased by 48% and 10% respectively if both slave and non-slave farms had been operating at constant returns to scale. Finally, with respect to pure technical inefficiency the result is different from that presented above. The average pure technical efficiency measures for non-slave and slave farms respectively are 1.25 and 1.16. Output could have been increased by 25% and 16% respectively if non-slave and slave farms had been purely technically efficient.[9]

Because of our inability to measure such things as entrepreneurial skill and the variation in the fertility of the soil, the efficiency measures derived from the production frontier may be biased. In other words, the extent of inefficiency would be overstated. However, as stated previously, unless the measurement error of the slave farm data set is different from the measurement error of the non-slave farm data set, the conclusions of this study regarding the relative efficiency of slave vs. non-slave farms should be accurate.

Aigner, Lovell, and Schmidt (1977) and Meeusen and Van den Broeck (1977) developed a translog frontier production function. This procedure also allows for the calculation of the technical efficiency of each firm in the sample. It has the advantage that its error term includes the measurement error or

TABLE 3
Summary Statistics: Slave Farms

Variable Name	Units of Measurement	Mean (St. Deviation)	Minimum Value	Maximum Value
Home Manufacturers	Dollars	273.46 (245.18)	0.00	1050.00
Grain	Bushels	912.88 (867.32)	0.00	4310.00
Cotton	Bales	20.40 (28.87)	0.00	136.00
Wool	Pounds	16.12 (36.51)	0.00	200.00
Peas and Beans	Bushels	75.58 (108.92)	0.00	500.00
Potatoes	Bushels	166.20 (147.39)	0.00	500.00
Butter and Cheese	Pounds	124.46 (130.08)	0.00	500.00
Hay	Tons	1.58 (3.25)	0.00	18.00
Molasses	Pounds	15.80 (83.55)	0.00	560.00
Beeswax and Honey	Pounds	26.14 (65.91)	0.00	350.00
Labor	Numbers	9.34 (8.78)	0.83	49.48
Capital	Dollars	316.17 (328.16)	23.64	1642.86
Land	Acres	670.36 (754.20)	105.00	3680.00

unrecognized factors discussed in the previous paragraph. However, this approach has two shortcomings. First, it imposes some sort of functional form on both the production function and the error structure. This implies that specification error could exist. Second, it does not allow for multiple outputs. Caves, Christensen, and Diewert (1982) have developed a translog cost function which allows for multiple outputs. However, this requires information regarding input prices and costs which are not needed by the nonstochastic production frontier model.

As stated previously, the analysis of this paper seems to show that non-slave farms were overall more technically efficient than slave farms. In addition, non-slave farms were more scale efficient but less purely technically efficient than slave farms. In order to statistically test these propositions a number of simple tests were performed: an analysis of variance, a means test, the median test, and the Kruskal-Wallis one way analysis of variance based on ranks. The latter three are nonparametric tests and do not require the assumption of normality. The analysis of variance compares the variation of efficiency measures within slave and non-slave farms with the variance between these two groups. The means test compares the average efficiency measures for the slave versus non-slave farms. The median test compares the efficiency of slave and non-slave farms based on their central tendency as defined by the median. The Kruskal-Wallis test compares the distributions of the efficiency measures for slave and non-slave farms.

The test statistics for each of the three efficiency measures are presented in Table Five. As can be seen, almost all the results indicate that the various measures of efficiency are significantly different for slave and non-slave farms. Only the median test for the pure technical efficiency measures, W, is not significant.

TABLE 4
Summary Statistics: Non-Slave Farms

Variable Name	Units of Measurement	Mean (St. Deviation)	Minimum Value	Maximum Value
Home Manufacturers	Dollars	125.02 (88.68)	0.00	410.00
Grain	Bushels	275.24 (246.28)	0.00	1635.00
Cotton	Bales	2.73 (4.89)	0.00	28.00
Wool	Pounds	14.30 (49.81)	0.00	400.00
Peas and Beans	Bushels	16.57 (60.50)	0.00	500.00
Potatoes	Bushels	60.53 (91.52)	0.00	600.00
Butter and Cheese	Pounds	75.85 (75.02)	0.00	400.00
Hay	Tons	0.52 (1.19)	0.00	5.00
Molasses	Pounds	7.32 (30.14)	0.00	200.00
Beeswax and Honey	Pounds	24.13 (57.23)	0.00	290.00
Labor	Numbers	1.78 (1.50)	0.17	12.13
Capital	Dollars	81.69 (96.99)	1.50	612.07
Land	Acres	188.61 (190.61)	5.00	1360.00

In summary, in terms of overall technical efficiency, the non-slave farms were more efficient. When overall technical efficiency is disaggregated into its two components, it is found that non-slave farms are much more scale efficient than slave farms. However, slave farms would seem to be more purely technically efficient. In addition, most of the output lost on slave farms as a result of not operating on the frontier was lost due to scale inefficiency. In addition when K and W* are compared for slave farms, one finds that of the 48 slave farms in the sample, 42 were operating at decreasing returns to scale. With

TABLE 5
Statistical Tests: Slave and Non-Slave

Efficiency Measure	Analysis of Variance F (Prob > F)	Means Test Z (Prob > |Z|)	Median Test X^2 (Prob > X^2)	Kruskal-Wallis Test X^2 (Prob > X^2)
K(x, y)	7.41 (.0075)	2.74 (.0073)	3.41 (.0649)	6.98 (.0082)
S(x, y)	50.95 (.0001)	6.45 (.0001)	26.71 (.0001)	36.13 (.0001)
W(x, y)	5.84 (.0172)	2.63 (.0096)	2.18 (.1398)	3.39 (.0657)

respect to non-slave farms, most of the output lost was due to pure technical inefficiency and of the 74 non-slave farms, only 21 were operating at decreasing returns to scale.

These results indicate that the relative profitability of slavery was not the result of superior technical efficiency (Productivity) relative to non-slave farms. Given the previous discussion by David and Temin and Wright it would seem likely that the profitability of slave agriculture was related to crop composition. Applying national average price data[10] to the figures for ouput in Tables Four and Five, one finds that free farms on average derived 25% of their revenue from home manufactures, 34% from grain, 25% from cotton, and 14% from all other crops. Slave farms, on the other hand, derived 49% of their revenue from cotton, 29% from grain, 14% from home manufacturing, and 8% from all other crops. This indicates important differences in crop composition.

Before leaving this section two final issues need to be addressed. Fogel and Engerman argued that the superiority of slave agriculture stemmed from the fact that large scale plantations were more efficient than both small scale free and slave farms. Fogel and Engerman measured the size of the slave farm by the number of slaves used. In order to test this proposition with respect to slave farms, correlation analysis was used to determine whether there was a significant relationship between overall technical, scale, and pure technical efficiency and size of slave farm measured either in terms of number of slaves or acres of cultivated land. Specifically, Pearson correlation coefficients were calculated and the results are presented in Table Six (the numbers in parentheses represent significance levels and the numbers above them are the correlation coefficients). With respect to size measured in acres, there is no significant relationship with any of the efficiency measures. With respect to number of slaves, the correlation with overall technical efficiency is negative and not statistically significant. The correlation with pure technical efficiency is positive and significant while the scale efficiency measure is negatively correlated and also significant. In summary, there seems to be no significant relationship between size, measured either in acres of land or number of slaves, and overall technical efficiency.

Finally, it should be noted that the results presented in this paper are further supported by additional work carried out by the authors utilizing samples different from that utilized here. Specifically, in work using a stochastic production frontier approach to measure efficiency (1988) and utilizing a sample of 2080 farms, no correlation between efficiency and number of slaves was found to exist.

IV

The purpose of this paper was to reexamine some issues initially raised by Fogel and Engerman. Using a relatively simple measure of technical efficiency, they concluded that within Southern agriculture in 1860, slave farms were more efficient than non-slave farms.

In this paper a more sophisticated measure of technical efficiency was used. It involved constructing a non-parametric frontier technology using data drawn from a sample of Southern farms. Each farm's performance was then compared to the frontier in order to develop a measure of each farm's overall technical efficiency. Then technical efficiency was disaggregated into its two components: pure technical and scale. Thus the type of technical inefficiency could be determined as well as its overall relative importance.

TABLE 6
Correlation Analysis

	Overall Technical Efficiency	Scale Efficiency	Pure Technical Efficiency
Land	−0.15 (0.31)	−0.21 (0.16)	0.03 (0.86)
Labor	−0.10 (.48)	−0.27 (.05)	0.29 (.04)

The application of the above methodology resulted in conclusions significantly different from that derived by Fogel and Engerman. Specifically, non-slave farms were found to be overall more technically efficient than slave farms. In addition, the main source of inefficiency differed between the two types of farms. The slave farms lost potential output mainly due to scale inefficiency, operating, for the most part, at decreasing returns to scale. Alternatively for non-slave farms output was lost mainly as a result of pure technical inefficiency.

Given previous criticisms of Fogel and Engerman's work by David and Temin and Wright, the results of the current study indicate that the relative profitability of slavery was certainly not due to the superior technical efficiency of slave labor. Instead, it points to the fact that differences in crop composition may account for the relative profitability of slave farms. Specifically, slave farms tended to specialize in cotton production while non-slave farms produced relatively less cotton and more grain and home manufactures. The crop diversification seen in non-slave farms is of course not surprising since most of these farms were small family operations which were much more subsistance oriented than the larger plantations. Thus crop selection can be explained by the riskiness for small farms of growing cotton at the expense of food crops.

FOOTNOTES

1. A good survey of such techniques can be found in Førsund, Lovell, and Schmidt (1980).
2. See Fogel and Engerman (1971) and Fogel and Engerman (1974).
3. This is documented in Schaefer (1983).
4. This was pointed out by one of the anonymous reviewers.
5. See Afriat (1972).
6. The data utilized in this paper were made available by the Inter-University Consortium for Political and Social Research. The data for the 1860 Cotton Sample were originally collected by William N. Parker and Robert E. Gallman under a grant from the National Science Foundation. Neither the original collectors of the data nor the consortium bear any responsibility for the analyses or interpretations presented here.
7. A more detailed discussion of the data is available from the authors upon request.
8. The means for our sample and the Parker-Gallman sample were compared and a t-statistic was calculated to determine if there was a statistically significant difference. The means for cotton, dairy products, hay, and capital appear to be different. For the rest of the variables, the means do not appear to differ. A more detailed discussion is available from the authors.
9. The relationship $K = S \cdot W$ holds only for individual farms and not for the sample means of K, S, and W.
10. These prices were taken from Towne and Rasmussen (1960).

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