**Farm Size, Productivity, and Economic Efficiency:
Accounting for Differences in Efficiency of Farms by Size in Honduras**

Daniel O. Gilligan[1]
Agricultural and Resource Economics Department
University of Maryland
2200 Symons Hall
College Park, MD 20742

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Abstract

The farm size—productivity relationship is tested using nonparametric efficiency measures based on distance functions. This approach to efficiency measurement is less restrictive and more informative than alternative methods. For a group of Honduran farms, diminishing returns to scale render smaller farms more economically efficient overall, despite the relative technical efficiency of larger farms.

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One of the most debated findings in international agricultural development is that of an inverse relationship between farm size and agricultural productivity. This result, which has been supported by studies in a number of developing countries,[2] provides an efficiency argument in favor of land reform. However, the relevant comparison regarding the desirability of land reform is not whether smaller farms have higher average productivity (yield or value of output per hectare) but whether they demonstrate greater overall economic efficiency. Recent studies have compared farms by size using more complete measures of efficiency such as total factor productivity (TFP) or quasi-rent (Binswanger, Deininger and Feder). In this paper, efficiency measures based on distance functions introduced by Shephard (1953) are used to test the relationship of farm size to economic efficiency for farms in coffee-growing regions of Honduras. Using Data Envelopment Analysis (DEA), economic efficiency for each farm is disaggregated into measures of scale and technical efficiency using only input and output quantity data. These measures are used to determine how the relative share of each source of inefficiency differs across farms by size.

Using DEA, relative technical inefficiency is measured as the distance of the observed input-output bundle for a given farm from a multi-input/multi-output production frontier constructed from data on all observed farms, under assumptions on returns to scale. If price and time series data were available, it would be possible to develop a complete characterization of the sources of economic efficiency by including measures of allocative efficiency and technical change in the analysis. The latter measures are not included here due to data limitations.

In addition to enabling a fuller characterization of the sources of economic efficiency, DEA offers several benefits over other methods of measuring efficiency for the purpose of testing the farm size—efficiency relationship. From DEA, measures of returns to scale and technical efficiency can be developed using only data on input and output quantities, whereas technical efficiency measured by TFP or profit function estimation relies on price data that is often unreliable. Production function based approaches suffer from infamous inconsistency of parameter estimates due to endogeneity of inputs and also require restrictions for functional form. Distance functions, on the other hand, rely on the construction of production frontiers that does not require a choice of functional form.

Using data on a sample of Honduran farms, measures of relative technical efficiency calculated under differing assumptions on returns to scale were used to test the farm size—efficiency relationship. Results show that farm size is inversely related to an aggregate measure of scale and technical efficiency. However, after controlling for the presence of decreasing returns to scale, larger farms are more technically efficient. A decomposition of efficiency measures into scale and technical efficiency indexes confirms econometric results demonstrating that scale diseconomies dominate the relative technical efficiency of larger farms, implying that overall economic efficiency would be improved by reductions in farm size. This result supports efficiency-based arguments for land reform in these regions of Honduras.

Estimating the farm size and productivity relationship: the benchmark result

A popular formulation used to test the relationship between farm size and a measure of (average) productivity is based on the simple model

(1) $$y = \alpha + \beta \ln A + \varepsilon$$

where y is the value (or quantity) of farm output per hectare, lnA is the natural logarithm of farm area planted, and ε is a classical disturbance term.[3] A negative value of β in this specification represents an inverse relationship between farm size and productivity. Later studies included other regressors to control for the effects of household versus hired labor (Taslim; Frisvold), land quality (Carter; Bhalla; Bhalla and Roy; Benjamin), and availability of credit (Berry and Cline).

A version of the model in equation (1) was estimated using the data from Honduras to provide a benchmark for later results. The results of this regression are reproduced in Table 1. The dependent variable is the value of crop output per unit area. Right-hand-side variables include farm area operated, an index of land quality (described in detail below), person-days of household labor employed, person-days of wage labor employed, and total credit used for all farm operations. The parameter estimates in Table 1 are representative of similar models in other studies. Based on this measure of average productivity, smaller farms are significantly more productive than larger farms.

Table 1: *The Inverse Farm Size—Productivity Relationship*

Dependent Variable:	Value of output per unit area	
R^2	0.2546	
Adjusted R^2	0.2453	
Variable	Estimate	t-statistic
Intercept	737.147	2.500
ln(area)	-374.930	-8.520
land quality	440.169	3.805
Household labor	0.516	1.565
hired labor	1.147	7.829
total credit	0.005	1.399

Data Envelopment Analysis and Distance Functions as Efficiency Measures

DEA has been used in management science to evaluate *ex post* the efficiency of achieving an objective from a given level of inputs (Banker, Charnes, and Cooper). Its applications in the economics profession build on the work of Debreu, Koopman (1951, 1957) and Farrell. DEA employs linear programming techniques to measure efficiency as the distance of each firm from a nonparametric production frontier constructed from convex combinations of observed input-output combinations.

Let $x \in \Re_{+}^{N}$ be a vector of inputs and $y \in \Re_{+}^{M}$ be a vector of outputs. Feasible input-output combinations are represented by the production possibilities set, $T \subset \Re_{+}^{N} \times \Re_{+}^{M}$,

(2) $$T = \{(x, y):\ x \text{ can produce } y\}.$$ [4]

Using this notation, the input distance function is defined by

(3) $$D_I(x, y) = \sup\left\{\beta : \left(\frac{x}{\beta}, y\right) \in T\right\}.$$

For a given input-output vector (x, y), the input distance function is the maximum (technically, the supremum) proportional reduction of all inputs that still enables the production of output vector *y*. The input distance function is a decreasing measure of efficiency that is bounded by one $(D_I(x, y) \geq 1)$. It maintains all of the properties of the technology. Similarly, Shephard's (1953) output distance function is defined as the minimum proportional expansion of all outputs such that the output combination can still be produced from the original input vector,

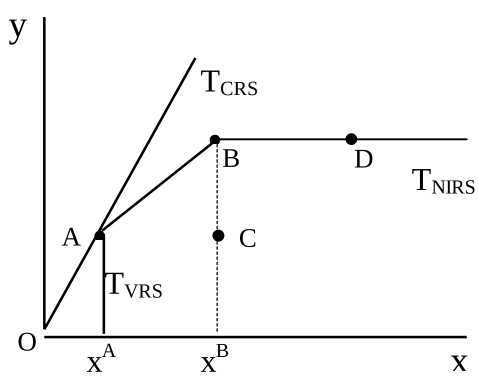
(4) $$D_O(y, x) = \inf\left\{\alpha: \left(x, \frac{y}{\alpha}\right) \in T\right\}.$$

By definition, the output distance function is an increasing measure of efficiency lying between zero and one, where a value of one represents technical output efficiency.

Empirical calculation of the input and output distance functions requires solution of a nonlinear programming problem. Fortunately, an easier approach is available. The reciprocals of the input and output distance functions are equal, respectively, to Farrell's measures of input and output efficiency defined by $F_I(x, y) = \inf\{\theta:\ (\theta\, \mathrm{x}, \mathrm{y}) \in T\}$ and $F_O(y, x) = \sup\{\gamma : (\mathrm{x}, \gamma\, \mathrm{y}) \in T\}$ where $F_I(x, y) \leq 1$ and $\mathrm{F}_O(x, y) \geq 1$. These measures are easily obtained as solutions to linear programming problems.[5]

Following Färe, Grosskopf, Norris, and Zhang, the construction of the reference technology for measuring technical efficiency under various assumptions on returns to scale is illustrated in Figure 1 for a scalar input and output. Consider four farms with input-output combinations at A, B, C, and D. Under constant returns to scale, the technology is bounded above by ray OA. Under non-increasing returns, the convex combination of the production of y across farms can be no greater than the largest quantity of y produced by any single farm, leading to a frontier given by OABD. Under variable returns, the input use of farm j is restricted to be no less than the smallest quantity of inputs used by any farm. This leads to the possibility of increasing returns to scale, causing the frontier to lie no closer to the y axis than at point A. The frontier becomes x^AABD. Note that, under variable returns to scale, the values of the input and output distance functions for farm C are the ratios Ox^B/Ox^A and x^BC/x^BB, respectively.

Figure 1
Construction of the Reference Technology and Returns to Scale



Farrell efficiency measures were calculated for each farm under alternative assumptions on returns to scale for the Honduran data using linear programming. The input and output distance functions are recovered by taking the reciprocal of the corresponding Farrell efficiency measure. As noted by Färe, Grosskopf, and Lovell, because the constant returns to scale assumption is more restrictive than an assumption of nonincreasing returns to scale, distance functions calculated under constant returns (C) can be no more efficient than those subject to nonincreasing returns (N). The variable returns to scale assumption (V) is less restrictive still. This leads to an ordering of the input distance function measures for the *jth* farm:

(5) $$D_I\left(x^j, y^j \middle| C\right) \geq D_I\left(x^j, y^j \middle| N\right) \geq D_I\left(x^j, y^j \middle| V\right) \geq 1 .$$

Similarly, consideration of the output distance function under alternative assumptions on returns to scale yields the efficiency ranking

(6) $$0 < D_O(y^j, x^j | C) \leq D_O(y^j, x^j | N) \leq D_O(y^j, x^j | V) \leq 1 .$$

A limitation of the input and output distance functions as measures of efficiency is that a farm can be input efficient and output inefficient, or vice versa, in the absence of constant returns to scale. This paradox is illustrated in Figure 1. The farm producing the input-output combination at point D is output efficient, but B is more input efficient. In fact, only farms operating on the section of the frontier between points A and B are truly technically efficient with respect to the variable returns to scale technology. This problem is resolved by introducing the *transformation function*, defined as the difference of the output and input distance functions:

(7) $$t(y^j, x^j) = D_O(y^j, x^j) - D_I(x^j, y^j) .$$

By definition, $t(y^j, x^j) \le 0$ always holds; the transformation function is an increasing measure of efficiency for which technically efficient farms are characterized by $t(y^j, x^j) = 0$. At point D in Figure 1, $D_O(y^D, x^D) = 1$ and $D_I(x^D, y^D) > 1$, resulting in $t(y^D, x^D) < 0$. Generally, the efficiency ranking of transformation functions under differing assumptions on returns to scale is

(8) $$t(y^j, x^j|C) \le t(y^j, x^j|N) \le t(y^j, x^j|V) \le 0 .$$

Färe, Grosskopf, and Lovell suggest an informative decomposition of the most restrictive constant returns to scale technical efficiency measure into components based on scale efficiencies and the least restrictive variable returns to scale technical efficiency measure. Using the Farrell input measures because they lie between zero and one, the input scale efficiency measure is defined $\bar{S}_I(x^j, y^j) = F_I(x^j, y^j|C) / F_I(x^j, y^j|V)$, j = 1,...,J . The *jth* farm is input scale efficient if it is equally efficient with respect to constant and variable returns technologies $(\bar{S}_I(x^j, y^j) = 1)$. For example, in Figure 1, a farm at point C is input scale efficient. Any farms producing above (below) point C on the line x^BB would achieve scale efficiency gains by reducing (increasing) its scale of operation to point C. These farms are operating on the decreasing (increasing) returns portion of the total cost curve.

The construction of this measure enables the decomposition of the constant returns input Farrell measure into sources of input scale and technical efficiency under variable returns to scale,

(9) $$F_I(x^j, y^j|C) = F_I(x^j, y^j|V) \times \bar{S}_I(x^j, y^j), \quad j = 1,...,J .$$

A similar decomposition for output measures is based on the output distance function because it enables construction of indexes. Output scale efficiency is defined as $\bar{S}_O(y^j, x^j) = D_O(y^j, x^j|C) / D_O(y^j, x^j|V)$, j = 1,...,J . The corresponding decomposition of the constant returns output distance function is

(10) $$D_O(y^j, x^j|C) = D_O(y^j, x^j|V) \times \bar{S}_O(y^j, x^j), \quad j = 1,...,J .$$

These decompositions assist in interpreting the farm size—efficiency relationship below.

The Data

The tests of the relationship of farm-size to economic efficiency are based on a sample of 409 farms in the Comayagua and Santa Barbara regions of Honduras in 1993-94. The survey questionnaire includes considerable detail on inputs and outputs by farm, including labor data disaggregated by type (household vs. hired) and by crop. A subjective variable for land quality is also available. The Farrell efficiency measures were calculated using data on the eight outputs and 30 inputs listed in Table 2.

Table 2: *Variables used in calculation of Farrell efficiency measures*

Outputs	Coffee, corn1, corn2, beans, rice, sugar, bananas, fallow land
Inputs	Area, household labor and hired labor (each for 5 crop categories), urea fertilizer, formula fertilizer, herbicides, wooden plow, iron plow, fumigator, water pump, oxen, tractors, horses, well with pump, well without pump, terrace, patio, cellar, granary, coffee sink, pulp remover (manual and mechanical)

In these regions of Honduras, coffee, corn, and beans are the most important crops, together accounting for more than 96 percent of the value of production in the farms surveyed. Corn1 and corn2 are, respectively, the main corn crop and a second crop grown later in the year.

The area variable is the farm area operated by the farmer in *manzanas* in 1993.[6] The average farm size is 25 manzanas, or approximately 17.5 hectares. Area includes land owned plus land sharecropped from other farmers and land leased in minus land sharecropped to other farmers and land leased out. There are ten series of labor data representing the number of person-days per year of household or hired labor devoted to five crop categories: coffee, corn1, corn2, beans and other crops. Among the other inputs are variable inputs such as urea, formula, and herbicides applied to all crops as well as many capital inputs. The data on plows, fumigators, water pumps, oxen, tractors and horses are the numbers of each of these owned by the farmer. The data for all other capital inputs is the discounted present value of the input, under the assumption that the productivity of the flow of services of these inputs in a year is proportional to the market value (discounted present value of the original price) of the factor. Since any proportionality constant will fall out of the linear programming models, this measure is well defined.[7]

An important issue for efficiency measurement using the Honduran data is the treatment of the labor data. Farmers were asked to recall the number of person-days of both household and hired labor devoted to the four largest crops in the region (coffee, corn1, corn2, and beans) as well as to all other crops combined. If labor is perfectly substitutable across crops, transformation functions could be calculated using labor data aggregated across crops but not laborer-type (household vs. hired). The corresponding efficiency measure, say $t^S(y,x)$ (dropping the superscript on farms), includes a vector of 22 rather than 30 inputs due to the aggregation of labor. An alternative approach is to calculate the transformation functions including all outputs, non-labor inputs, and disaggregated labor in the same linear programming problem. This eliminates the assumption of perfect substitutability and instead assumes that various *kinds* of labor (e.g., household labor devoted to coffee) could be applied to each crop. This leads to an efficiency measure based on all 30 inputs, say $t^D(y,x)$. A third approach assigns each crop-specific labor source to its particular use under the assumption that production is input-nonjoint with respect to labor. However, because crop-specific data is not available for non-labor inputs, separate efficiency measures must be constructed for each crop based only on the labor devoted to that crop plus *all* other inputs. The Farrell efficiency measures for the technology as a whole are then the minimum (maximum) of the Farrell input (output) efficiency measures for each crop. Label the corresponding transformation functions $t^M(y,x)$. This measure takes advantage of the availability of information on the allocation of labor to each crop but overstates the use of non-labor inputs.

The least restrictive of these measures is the second one, for which labor is disaggregated. Also, the assumption of perfect substitutability of labor under the first approach is less restrictive than that of input nonjoint technology. This yields the following ordering of the transformation functions with respect to labor treatment, where technically efficient farms receive an efficiency measure of zero,

(11) $$t^M(y,x) \le t^S(y,x) \le t^D(y,x) \le 0 .$$

Results

The transformation functions were generated from Farrell efficiency measures calculated alternately under the various combinations of assumptions on returns to scale and labor substitutability. Summary statistics for these efficiency measures are provided in Table 3. Notice that the transformation functions satisfy the ordering in (8) regarding returns to scale and in (11) with regard to labor substitutability. Although only mean values are displayed, these orderings hold for each observation on the various efficiency measures.

Table 3: *Summary Statistics for the Transformation Function Under Assumptions Regarding Labor Substitutability and Returns to Scale*

Efficiency Measures and Returns to Scale	(1) Labor Perfectly Substitutable Between Crops ($t^S(y,x)$)		(2) Disaggregated Labor, All Outputs ($t^D(y,x)$)		(3) Disaggregated Labor, Crop-by-Crop ($t^M(y,x)$)	
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
t(y,x|V)	-1.759	5.343	-1.404	4.941	-2.331	5.727
t(y,x|N)	-2.238	8.743	-1.716	6.435	-28.186	131.778
t(y,x|C)	-4.466	14.268	-3.965	13.080	--	--

Returns to Scale

Hypothesis tests developed by Banker (1996) for use with data envelopment analysis were performed to test for returns to scale in the Honduran data. Banker developed two test statistics for the Farrell output efficiency measure based on the assumption that $F_O(y,x)$ and $F_O(y,x)-1$ have an exponential and half-normal distribution, respectively. Using these tests, the null hypothesis of constant returns to scale was rejected for the sample as a whole, as well as for three sub-samples of the farms ranked by farm size. Following these results, a test of non-decreasing returns against the alternative of decreasing returns was constructed. Non-decreasing returns to scale was rejected for all groupings of farms by size. The results of the latter tests are provided in Table 4.

Table 4: *Hypothesis Tests for Returns to Scale for All Farms and by Farm Size*

	Exponential Distribution		Half Normal Distribution	
H_0: NDRS; H_1: DRS	Test Stat.	Critical F	Test Stat.	Critical F
All 409 Farms	5.718	1.122	15.815	1.177
Smallest third (<3.5 ha.)	1.836	1.221	1.905	1.327
Middle third (3.5-10.5 ha.)	5.435	1.221	24.228	1.327
Largest third (>11 ha.)	36.786	1.221	1253.265	1.326

The finding of decreasing returns to scale is not surprising for this type of coffee-centered agriculture. However, it has strong implications for the relationship of farm size to economic efficiency. On the basis of scale economies alone, smaller farms are more efficient over the entire range of farm sizes, even among farms smaller than 3.5 hectares. To determine whether or not smaller farms are also more technically efficient requires estimation of the relationship of farm size to efficiency in a model similar to equation (1) in which productivity is replaced with measures of technical efficiency as the dependent variable. Ultimately, it will be possible to compare the relative magnitude of the sources of efficiency by farm size based on the decompositions in (9) and (10).

Testing the Farm Size—Efficiency Relationship

The transformation functions were used as efficiency measures to estimate a revised version of the model in equation (1)

(12) $$E = \alpha + \beta \ln A + \gamma \ln LQUAL + v$$

where E represents a measure of relative technical efficiency, $\ln A$ is the natural logarithm of farm size, $LQUAL$ is the natural logarithm of an index of land quality and v is the disturbance term. When the endogenous variable is a distance function-based efficiency measure, it is no longer necessary to include exogenous variables to account for the use of other inputs such as labor or credit since labor enters directly into the efficiency index calculation and access to credit is implicitly captured by inclusion of inputs generally purchased with credit (fertilizer, herbicides, land, etc.). The only explanatory variable required in model (12) in addition to farm size is the logarithm of the index of land quality. Farmers were asked to rank the quality of each parcel of land on their farm as either good, average, or bad. These responses were given a cardinal representation (3, 2, or 1, respectively) and a land quality index was created as the area-weighted sums of these rankings. Because the land quality variable is a highly subjective measure, it was not included as an input in the calculation of the distance functions so that its effect on the estimation of the farm size—efficiency relationship could be judged independently.

Because the transformation function is an increasing measure of efficiency, an inverse relationship between farm size and technical efficiency results in a negative coefficient on farm size, β. Since farms of higher average land quality should appear more efficient when land quality is omitted from the efficiency index, we expect the coefficient on land quality, γ, to be positive. The model in (12) was estimated as a Tobit model because the efficiency measures are censored above at zero. Hypothesis tests that the values of the coefficients are significantly different from zero for the Tobit model are based on the derivation of a chi-square statistic.

Combining Scale and Technical Efficiency

The finding of decreasing returns to scale suggests on its own that productivity gains could be achieved by reducing farm size. Based on the decomposition of efficiency measures provided in (9) and (10), it is instructive to estimate an initial set of regressions using the transformation function restricted to constant returns to scale as the dependent variable, since this measure ($t(y, x \mid C) = 0$) represents overall scale and technical efficiency. The model in (12) was estimated using the first two alternative assumptions on labor substitutability.[8] Results are provided in Table 5.

Table 5: *Tobit Results on Effect of Farm Size on Economic Efficiency Under Constant RTS*

Dep. Var.: t(y,x|C)						
Labor Assumption:	Perfect substitutability across crops			Disaggregated Labor		
Variable	Estimate	Std Err	Pr>Chi	Estimate	Std Err	Pr>Chi
Intercept	1.7569	(3.2402)	0.2940	1.8544	(3.0638)	0.5450
Ln(AREA)	-2.0726	(0.6024)	0.0006	-2.2979	(0.5729)	0.0001
Ln(LQUAL)	2.2521	(3.4625)	0.5154	3.9098	(3.2863)	0.2341
N=409, Noncensored Values:	302			286		

Results from Table 5 show strong support for the inverse farm size—efficiency relationship. Under both assumptions on labor substitutability, the measure of technical efficiency subject to constant returns to scale is decreasing in farm size. Land quality is positively related to technical efficiency, as expected, although the parameter estimates are not significant.

Technical Efficiency Under Nonincreasing Returns to Scale

Model (12) was also estimated for technical efficiency measures calculated under nonincreasing returns to scale, the closest definition of the transformation function consistent with observed decreasing returns. In this case, the transformation function provides a pure measure of technical efficiency. Results are presented in Table 6.

The striking result from Table 6 is that for both efficiency measures farm size is positively related to technical efficiency. The reversal of the sign on the farm size coefficient suggests that larger farms are more technically efficient relative to the observed decreasing returns to scale technology, despite the greater overall economic efficiency of smaller farms when scale diseconomies are captured in the efficiency measure. The finding of greater relative technical efficiency of larger farms must be interpreted with some care. It may be driven in part by the presence of decreasing returns to scale, which causes the frontier of the reference technology to be concave. Because the frontier is constructed using convex combinations of observed input-output bundles, with decreasing returns to scale a large number of farms will lie on the frontier, and large farms are likely to be important in determining the shape of the frontier.

Table 6: *Tobit Results on Effect of Farm Size On Economic Efficiency Under Nonincreasing RTS*

Dep. Var.: t(y,x|N) **Labor Assumption:**	Perfect substitutability across crops			Disaggregated Labor		
Variable	Estimate	Std Err	Pr>Chi	Estimate	Std Err	Pr>Chi
Intercept	-4.3266	(3.0601)	0.1575	-3.2607	(2.6538)	0.2192
Ln(AREA)	2.1505	(0.5989)	0.0003	1.5078	(0.5210)	0.0038
Ln(LQUAL)	7.2337	(3.3182)	0.0293	8.5545	(2.9157)	0.0033
N=409, Noncensored Values:	177			144		

However, the result that larger farms are more technically efficient relative to the decreasing returns technology is not surprising. A number of unobserved factors could contribute to this result. For example, the largest ten percent of farms in this sample (ranked by area operated) farm more than 38 hectares. The returns to management could be significant on these larger farms. Also, credit market imperfections or information asymmetries may make it easier for larger farms to obtain credit for example.

Decomposing Economic Efficiency

The decomposition presented in (9) and (10) can be used to obtain a broader understanding of the farm size—efficiency relationship. Because the technology exhibits decreasing returns to scale, larger farms are known to be relatively input and output scale inefficient, although they are relatively technically efficient. This is verified using the input and output scale efficiency measures defined above. Average efficiency indexes are provided in Table 7 for the input Farrell measure and the output distance function according to (9) and (10) respectively. Both measures indicate that, on average, excessive scale of operation is a greater source of inefficiency than technical inefficiency. Using this decomposition, the share of inefficiency due to pure technical inefficiency, measured by $F_I\left(x^j, y^j \middle| V\right)$ and $D_O\left(y^j, x^j \middle| V\right)$ and scale inefficiency measured by $\bar{S}_I\left(x^j, y^j\right)$ and $\bar{S}_O\left(y^j, x^j\right)$ was derived for all farms and for groupings of farms by size. Overall, diseconomies of scale account for 58% of input inefficiency and 70% of output inefficiency. When these measures are considered by size of farm, earlier findings regarding scale and technical efficiency by farm size are confirmed. In the input measure, a greater share of inefficiency is explained by technical inefficiencies for the smallest farms, while inefficiency on the largest farms is largely due to scale diseconomies. For the output measure, scale inefficiency dominates for farms of all sizes, although it is a far greater source of inefficiency on the largest farms.

Table 7: *Input and Output, Technical and Scale Inefficiency Decomposition by Farm Size*

	$F_I(C)$	$F_I(V)$	S_I	$D_O(C)$	$D_O(V)$	S_O
Avg. Efficiency Index: (N=409)	0.5924	0.8090	0.7323	0.5843	0.8643	0.6761
Inefficiency Shares:						
All 409 Farms		41.64%	58.36%		29.53%	70.47%
Smallest third (<3.5 ha.)		55.79	44.21		48.65	51.35
Middle third (3.5-10.5 ha.)		45.16	54.84		31.13	68.87
Largest third (>11 ha.)		29.21	70.79		14.24	85.76

Conclusions

The tools of Data Envelopment Analysis are used to create efficiency measures of scale and technical efficiency based on distance functions. Broader measures of economic efficiency are preferred to average productivity measures (such as yield) for determining an economic argument for land reform. Scale and technical efficiency measures based on the distance function are subject to less error than alternative measures that require production function estimation or use of unreliable price data.

For the sample of Honduran farms, measures of economic efficiency that incorporate scale and technical efficiency are negatively related to farm size. A decomposition of this measure and econometric results demonstrate that, relative to the observed decreasing returns technology, larger farms are more technically efficient. However, scale inefficiency dominates the relative technical efficiency of larger farms. These results support arguments for land reform based on efficiency grounds for this sample of Honduran farms.

[2] See, for example, Sen (1962, 1964); Bardhan; Berry and Cline; Carter; and Rosenzweig and Binswanger.
[3] See, for example, Berry and Cline or Binswanger and Rosenzweig for a review of the literature.
[4] See Chambers. The production possibilities set is assumed to satisfy basic properties outlined by Shephard (1970).
[5] See Färe, Grosskopf, and Lovell for an introduction to the calculation of Farrell efficiency measures.
[6] One manzana equals 0.7 hectares.
[7] The patio, cellar, sink, and pulp remover inputs are all used in initial stages of processing coffee for sale.

[8] Because the transformation functions derived using crop-specific distance functions under the assumption of input-nonjoint production (col. 3 of Table 3) were extremely inefficient when calculated under the observed decreasing returns technology, this measure was not included in the regression analysis.

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