Efficiency of Small Landholders in Eastern Paraguay

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The relative efficiency levels of 283 rural households from three regions in eastern Paraguay are measured using a nonparametric approach. Technical, allocative, and scale efficiency measures are calculated both at national and regional levels, and factors that may affect the efficiency levels are analyzed econometrically. The three regions selected for this study represent distinct production systems and socio-economic conditions: production of traditional crops or extensive livestock operations; a dynamic region with massive in-migration where capitalized farms produce soybeans and wheat; and an older region, integrated with urban areas, where depleted and highly fragmented land has forced households to rely on nonagricultural sources of income. Nonparametric results show high levels of technical efficiency across all three regions, but low levels of allocative and scale efficicency. Because policies to increase scale efficiency are politically unpalatable, the factors affecting allocative efficiency are explored. Significant factors include employment opportunities, land titling, and access to credit, markets, and extension services.

Key words: allocative efficiency, land, nonparametric approach, Paraguay, scale efficiency, technical efficiency

Introduction

In Paraguay, agriculture has become the leading economic sector, generating more than 25% of the country's GDP, employing nearly half of the "economically active population,"[1] and accounting for 95% of total exports (de Villalobos and Howe). Previous sector growth can be explained almost entirely by the increase in the amount of land allocated to export crops. These export crops are concentrated in two products: cotton, a traditional crop grown by smaller farms, and soybeans, a more recent crop, generally grown by large, highly capitalized farms on the eastern frontier. Cotton accounts for more than one-third of total exports, and 70% is produced on farms with fewer than 20 hectares (Carter, Luz, and Galeano). Yet, land is highly concentrated in Paraguay: 40% of the production units have access to only 1% of the country's land, while 1% of the farms control 75% of the total land (Censo Agropecuario Nacional).

Despite the importance of small farms, their situation has been steadily deteriorating. International prices for Paraguay's export crops have decreased drastically, and weather conditions have been unfavorable. Given increasingly scarce employment

[1] "Economically active population" is defined as individuals 12 years of age or older.

opportunities, the rural sector has become a "poverty refuge" of subsistence agriculture. With a high population growth rate and most of the country's labor force involved in rural activities, access to land, particularly in Paraguay's eastern region, has become increasingly critical. At the same time, the supply of state lands used in the colonizing programs has been depleted. Furthermore, despite growing demand for land reform, redistribution programs have been strongly opposed by the country's most powerful economic groups, who dominate the government.

Collectively, the relevance of the small farmers in the country's economy, the poor economic performance of the sector over the last decade, the dwindling supply of state lands, and the high population growth rate have made farm productivity growth a major policy issue (Nikiphoroff and Villagra; Bravo-Ureta and Evenson). Given that further expansion of agricultural lands is limited and land reform is politically unlikely, the only means left to improve the well-being of small producers is to increase the efficiency of their existing operations.

This study examines the efficiency level of small farms in Paraguay's eastern region to identify potential for improving efficiency. Smallholders' relative technical, allocative, and scale efficiency levels are calculated using a computationally improved nonparametric approach. In a second stage, hypotheses concerning which factors are associated with inefficiencies are tested in an econometric model. These results are then used to assess the potential to improve smallholders' efficiency and to consider what types of policies would have the greatest impact.

Measuring Efficiency

Economic efficiency is defined in terms of the behavioral goals of the production units and, for a given scale, is disaggregated into two elements: technical efficiency, the physical component, and allocative efficiency, the monetary component.[2] The technical efficiency (TE) index is defined as the minimum factor by which a vector of inputs can be rescaled and still allow the production of a given vector of outputs (Debreu; Farrell).

The allocative efficiency (AE) index measures a production unit's ability to choose the input combination that minimizes cost given the best available technology. AE is the ratio between the minimum cost required to produce a certain level of output and the unit's production costs if it were technically efficient.[3] Because allocative efficiency implies substituting or intensifying the use of certain inputs based on their prices, inefficiencies may stem from unobserved prices (e.g., undervalued management or labor time), from incorrectly perceived prices, or from lack of accurate and timely information (Aguilar).

Both technical and allocative efficiency measures are calculated for a given scale. A third type of efficiency which is relevant in the long run is the scale efficiency (SE) index, which indicates whether the unit is producing at the output level minimizing its average cost.

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[2] There is some inconsistency with the names given in the literature. For instance, Paris refers to allocative efficiency and economic efficiency as economic efficiency and overall efficiency, respectively; and Lovell speaks of productive efficiency when referring to economic efficiency. This study adopts the terms as defined by Chavas and Aliber.

[3] Alternatively, allocative efficiency could be calculated as the ability of the economic unit to maximize profit given the best available technology. Clearly, different coefficients will result depending upon the criteria used. For this study, cost minimization is assumed.

These efficiency indices can be calculated using either parametric or nonparametric techniques. An innovative computational method is developed in this analysis to measure efficiency using a nonparametric approach. The nonparametric method provides advantages over a parametric statistical approach. First, it does not impose a specific structure on the technology because it does not require assumptions about the functional form or the distribution of the error terms of the frontier production function. Second, it allows the use of disaggregated data. There is no need to force a high degree of aggregation of inputs (x) and outputs (y) or to run separate models for each product to obtain adequate degrees of freedom. The latter property is particularly convenient for investigating multi-product farms, which are common among small producers in developing countries, because the amount of input allocated to each output does not need to be specified. If disaggregated data were used in an econometric analysis, the zero observations on certain inputs or outputs for some households would have to be dealt with in the context of a limited dependent variable model for factor demand and output supply systems, which complicates estimation considerably. However, the gain in flexibility associated with nonparametric techniques is accompanied by the disadvantage that statistical tests cannot be conducted (Färe, Grosskopf, and Lovell). In addition, the nonparametric approach provides only an upper bound to the true efficiency measures because all deviation from the production frontier is attributed to inefficiency.

Following Chavas and Aliber, a technical efficiency measure is calculated for each of the z households. The technical efficiency for production unit h (TE^h) is found by comparing unit h with combinations of all other production units and establishing the minimum proportion of inputs that would allow unit h to produce the level of output actually being produced by h. Each household's technical efficiency is derived from a separate problem because each household faces a different set of constraints. However, given that each household's problem is independent, the z efficiency measures can be calculated in a single problem. It is possible to aggregate the constraints and replace the objective function with one minimizing the *sum* of the technical efficiency coefficients TE^h. Minimizing the sum of the coefficients guarantees each household's coefficient is also minimized.

The computationally efficient program to determine each household's technical efficiency measure, TE^h, is specified as:

(1)
$$\min_{\lambda_t^h, TE^h} \sum_{h=1}^{z} TE^h$$

$$\text{s.t.:} \quad \sum_{t=1}^{z} \lambda_t^h y_s^t \geq y_s^h \qquad \text{for } s = 1, \ldots, m; \ h = 1, \ldots, z,$$

$$\sum_{t=1}^{z} \lambda_t^h x_g^t \leq TE^h x_g^h \qquad \text{for } g = 1, \ldots, n; \ h = 1, \ldots, z,$$

$$\sum_{t=1}^{z} \lambda_t^h = 1 \qquad \text{for } h = 1, \ldots, z,$$

$$\lambda_t^h \geq 0 \qquad \text{for } t = 1, \ldots, z; \ h = 1, \ldots, z,$$

$$TE^h \geq 0 \qquad \text{for } h = 1, \ldots, z,$$

where there are m outputs and n inputs, y_s^h is the sth output of unit h, and x_g^h is the gth input of unit h. The combination of units against which unit h is compared is given by the vector λ^h, where each element of vector $\lambda^h = (\lambda_1^h, ..., \lambda_h^h, ..., \lambda_z^h)'$ is the weight of each of the z units in the combination. The weighted outputs and inputs of those units against which unit h is compared are given by $\Sigma_t \lambda_t^h y_s^t$ and $\Sigma_t \lambda_t^h x_g^t$, respectively, where y_s^t denotes the production of output s for each of the $t = 1, ..., z$ units, and x_g^t denotes the endowments of input g for each of the $t = 1, ..., z$ units. The first set of constraints guarantees, for each output, the amount produced by the combination of production units is at least as much as unit h's output. The second group of constraints requires that, combining production units in the same manner, the inputs used do not exceed unit h's inputs. The third constraint guarantees unit h's production frontier is weakly concave. If unit h is efficient, $TE^h = 1$. The lower TE^h is, the greater the reduction in inputs which would permit the same production of output—i.e., the more technically inefficient unit h is.

In order to calculate the allocative efficiency index, it is necessary to find the minimum cost, given input prices, output levels, and technology. As in the case of technical efficiency measures, the z individual linear programs used to calculate the minimum costs for each of the z households are combined into a single computationally efficient linear program:

$$(2) \qquad \min_{\mathbf{x}^*, \lambda^h} \sum_{h=1}^{z} \mathbf{w}^{h'} \mathbf{x}^{*h}$$

$$\text{s.t.:} \quad \sum_{t=1}^{z} \lambda_t^h y_s^t \geq y_s^h \qquad \text{for } s = 1, ..., m; \ h = 1, ..., z,$$

$$\sum_{t=1}^{z} \lambda_t^h x_g^t \leq x_g^{*h} \qquad \text{for } g = 1, ..., n; \ h = 1, ..., z,$$

$$\sum_{t=1}^{z} \lambda_t^h = 1 \qquad \text{for } h = 1, ..., z,$$

$$\lambda_t^h \geq 0 \qquad \text{for } t = 1, ..., z; \ h = 1, ..., z,$$

where $\mathbf{w}^h$ is an n-vector of input prices, $\mathbf{x}^{*h}$ is the least-cost input combination for household h, and $\mathbf{w}^{h'}\mathbf{x}^{*h}$ is the minimum cost that would allow household h to produce the same output level given the available technology. Having obtained the minimum cost for each of the z households, the allocative efficiency measure for household h (AE^h) is given by the ratio of the minimum cost obtained above, and farm h's costs if they had been technically efficient:

$$(3) \qquad AE^h = C^{*h}(\mathbf{w}^h, \mathbf{y}^h) / (TE^h \mathbf{w}^{h'} \mathbf{x}^{*h}).$$

Finally, scale efficiency measures are derived from the cost function. The scale efficiency measure is the ratio of the minimum average cost and the average cost. The production unit will be scale-efficient only when the average cost for its output level coincides with the minimum average cost. Chavas and Aliber show that the SE index for each household can be simplified to the ratio of the minimum cost function evaluated at constant and variable returns-to-scale technologies, respectively. The minimum cost under variable returns-to-scale technology is obtained by solving the linear program

in (2). The convexity constraints in (2) are eliminated to calculate the minimum cost under constant returns to scale.

Correlates of Inefficiency

This study of efficiency adopts what Bravo-Ureta and Evenson call a "two-step procedure." The first step consists of measuring efficiency levels. The second identifies factors correlated with inefficiency for policy analysis. Both parametric and nonparametric techniques have been used in a variety of studies to determine what factors are linked with agricultural production inefficiency.

Large farmers have been found to be technically or economically more efficient than small farmers (Hallam and Machado; Kaiser; Aly et al.; Garcia, Sonka, and Yoo; Bailey et al.; Sharma, Leung, and Zaleski). However, Chavas and Aliber observed economies of scale for small farmers, but Bravo-Ureta and Evenson were unable to find any relationship between efficiency and farm size in Paraguay using a parametric approach.

In their investigation of land tenure arrangements, Lee and Somwaru concluded share-rent tenants were the most technically efficient, while owner operators were the most economically efficient. Other factors found to be correlated with efficiency are credit, education, age, availability of off-farm labor opportunities, availability of extension services, and access to technology (Bagi; Taylor, Drummond, and Gomes; Azhar; Chavas and Aliber; Bravo-Ureta and Evenson; Kalaitzandonakes; Parikh, Ali, and Shah; Sharma, Leung, and Zaleski; Tzouvelekas, Pantzios, and Fotopoulos).

Description of the Data

In 1991, through a joint effort by the University of Wisconsin's Land Tenure Center (LTC) and the Centro Paraguayo de Estudios Sociológicos (CPES), 300 rural households in Paraguay were surveyed. The LTC-CPES survey was based on a multi-stage sampling procedure from three areas of eastern Paraguay, where most of the country's agricultural production and land scarcity problems are concentrated. Following Galeano, three different zones are represented in the sample:

- The Minifundia zone, southeast of the capital, Asunción, includes traditional settlements of very small plots. Over decades of constant use and poor land management, these small plots have lost most of their fertility, thereby forcing the majority of the population to rely on off-farm income. The Minifundia zone has the highest road density and lies closest to the country's largest cities.

- The Colonization zone, located north of Asunción, was developed due to the agricultural policies of the 1960s. It has better quality soils and fewer land conflicts. However, this region lacks infrastructure, especially paved roads, and is not fully integrated into the rest of the country.

- The Frontier zone, along the southeast border, has the best land, the highest rainfall, and a large immigrant population who are attracted not only by the quality of the land but also by low land prices relative to neighboring countries. This area is characterized by larger farms and modern technology.

The final sample frame was stratified by the land endowment of the households (0–5, 5–10, 10–20, 20–50, and >50 hectares). Due to the small percentage of existing large farms, this group was oversampled.[4] The survey design does not allow for the distinction between some on-farm and off-farm activities, such as labor allocation and machinery use. Consequently, this study analyzes the efficiency of households, not of farms. Specifically, the analysis considers how families use *all* their resources to produce a set of outputs, including off-farm production. Because of the nonparametric methodology, it is not necessary to assign inputs to outputs.

To account for households with different production structures, each household's detailed information is aggregated into nine inputs ($n = 9$) and nine outputs ($m = 9$) using a Tornqvist index. This calculation requires the use of monetary values and, to avoid price biases, the data used for measuring technical efficiency were valued at national average prices. However, *compañía*-level[5] prices from a concurrent survey are used to calculate costs for allocative efficiency measures.

Descriptive statistics for all inputs and outputs are presented in table 1. The nine inputs are defined as follows. Family labor (*FAMLABOR*) is measured in adult equivalents. It is differentiated from hired labor because household members are believed to be more strongly motivated and they can perform supervisory roles (Feder). Weights used for different age groups were adapted from Deere and de Janvry's criteria for Peruvian peasants: ages 4–5 = 0.1, ages 6–8 = 0.3, ages 9–12 = 0.5, ages 13–17 = 0.8, ages 18–59 = 1.0, ages 60–65 = 0.8, ages 66–75 = 0.5, and ages 76–80 = 0.3. Although the survey did not ask about the work of children under age 12, to account for mandatory school attendance, they were assumed to work on the farm one-third time. Permanent off-farm workers (*OPPLABOR*), measured in US$, are a proxy for the opportunity cost of the labor for those household members. Hired labor (*HIRLABOR*) is measured as the household's total expenditure in hiring permanent and temporary farm labor.

Animals (*ANIMAL*) represent the flow value[6] of the average number of oxen, cows, heifers, bulls, sheep, pigs, and beehives reported by each household.[7] Land (*LAND*) represents the flow value of the land operated by the households. To adjust for quality, the land is classified into cropland, pasture, woodlands or uncleared plots, and land that cannot be used for production. The different categories of land are aggregated using relative prices for each type of land obtained from interviews with real estate agents in each region.

Short-term implements (*SRIMPVAL*) are those farm implements with a life cycle of one year or less, medium-term implements (*MRIMPVAL*) have a life span of two to six years, and long-term implements (*LRIMPVAL*) have an expected life of seven years or more. The values of medium- and long-term implements are calculated as their flow value plus their depreciation rate based on their useful life. Miscellaneous inputs (*INPUT*) represent the monetary value of all other inputs used by the household.

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[4] The descriptive statistics presented are weighted to correct for the over-representation of the large farms in the sample.

[5] *Compañías* are political subdivisions in rural areas and vary in population from perhaps 50 to 200 families (Reh).

[6] The interest rate used to estimate the flow values was obtained by deducting the inflation rate from the deposit interest rate offered by commercial banks in Paraguay for six-month certificates of deposit, for the period July 1990 to June 1991 (Banco Central del Paraguay).

[7] Because animals are not perfect substitutes for one another, the original model classified animals into three groups: traction, dairy, and others. However, they were regrouped by value into one category for this study because the results did not vary significantly.

Table 1. Descriptive Statistics of Inputs and Outputs Used to Calculate Efficiency, by Eastern Paraguay Agricultural Production Zone

Variables	Colonization Zone		Frontier Zone		Minifundia Zone	
	Obser-vations [a]	Mean (Std. Dev.)	Obser-vations [a]	Mean (Std. Dev.)	Obser-vations [a]	Mean (Std. Dev.)
INPUTS:						
FAMLABOR (adults)	75	3.44 (1.86)	117	3.86 (2.97)	91	2.88 (1.47)
OPPLABOR ($)	4	1,756.84 (1,260.62)	6	1,458.83 (1,545.41)	7	440.76 (716.34)
HIRLABOR ($)	42	395.58 (361.87)	92	882.34 (1,586.31)	38	283.95 (466.17)
ANIMAL ($)	62	2,398.14 (3,144.22)	103	3,000.13 (3,635.37)	85	2,039.14 (1,764.81)
LAND (Ha equivalent)	75	11.04 (9.03)	117	18.52 (17.40)	91	7.31 (5.88)
SRIMPVAL ($)	15	56.67 (11.02)	17	45.69 (31.62)	17	69.45 (34.34)
MRIMPVAL ($)	55	123.51 (51.81)	94	172.73 (507.75)	34	95.76 (51.12)
LRIMPVAL ($)	41	1,015.29 (738.17)	80	14,588.68 (19,675.69)	64	1,312.40 (3,860.79)
INPUT ($)	73	288.46 (532.72)	112	1,475.15 (2,895.97)	88	436.02 (1,192.50)
OUTPUTS:						
COTTON ($)	68	2,558.75 (3,008.13)	64	2,097.34 (2,796.11)	66	624.64 (566.37)
SOYBEANS ($)	0	—	75	5,299.89 (5,742.26)	1	64.39
CROPS ($)	75	18,174.23 (87,407.16)	115	26,682.17 (141,220.67)	90	23,952.80 (134,816.53)
INCLABOR ($)	24	897.91 (1,573.35)	71	896.80 (1,496.21)	53	932.04 (1,864.51)
INCEXTRA ($)	8	13,231.26 (19,183.43)	9	379,704.60 (1,137,382.83)	73	4,436.13 (19,805.99)
INCPRCRO ($)	9	1,296.87 (1,579.40)	6	531.16 (476.95)	1	40.53
INCANIM ($)	33	451.09 (617.46)	72	498.48 (668.54)	74	456.12 (456.15)
INCPRANI ($)	22	53,140.77 (174,811.26)	29	474.88 (649.55)	41	364.42 (561.40)
INCOTHER ($)	1	21.26	0	—	3	57.65 (20.68)

[a] Statistics for inputs and outputs are based only on nonzero observations for each variable.

Nine outputs are used in the analysis: cotton (*COTTON*); soybeans (*SOYBEANS*); other crops (*CROPS*), measured as the monetary value of the amount harvested by the household; labor sold (*INCLABOR*), which includes the total income earned by household members working, permanently or temporarily, outside the farm; extractive products (*INCEXTRA*), representing the sale of firewood, charcoal, bricks, and posts; products derived from crops (*INCPRCRO*), which include the production of *miel negra* (Paraguayan molasses), mint, petitgrain essence, and starch; animals (*INCANIM*), representing the

sale of animals and meat; products derived from animals (*INCPRANI*), including the sale of milk, eggs, cheese, and honey; and other income (*INCOTHER*), which includes machinery rental and handicraft sales.

Data for Econometric Estimation of Correlates of Allocative Efficiency

To explore potential sources of inefficiency in the second step of the analysis, the following variables are considered: farm size, land ownership, household labor availability, education, farm experience, access to formal and informal credit, share of off-farm income, and location.

LAND, measured in hectares, represents the total land controlled by the household. It is expected that larger farms would have economies of scale due to better access to markets and lower transactions costs. Land ownership (*%TITLED*) represents the percentage of *LAND* for which the household has a title. Ownership is expected to positively affect efficiency because households with legal land rights have the option of selling their land, they have increased investment opportunities (Feder et al.; Carter and Olinto), and they can use land as collateral for credit (Binswanger and Rosenzweig).

The number of adults from 18 to 60 years of age in the household (*ADULTS*) is a proxy for the family labor available to work on the farm. Family labor is believed to be more motivated than hired labor, can undertake supervisory roles, and can engage in off-farm employment. Hence, *ADULTS* is expected to have a positive influence on efficiency. *EDUCAT* is the number of years of formal education completed by the household head (these data were obtained from a 1994 survey as reported by Carter and Olinto). Education is believed to be positively linked to better allocation decisions, but the effect is likely to be significant only when an exogenous change in technology or in market conditions occurs (Azhar). *YEARS* refers to the number of years the head of household has worked on that farm. Experience is expected to be positively related to allocative efficiency. However, the effect of experience might vanish in the Frontier zone given the region's more dynamic economic structure, and the more recent introduction of new crops. One dummy variable (*CNIA2*) is used for the Colonization zone equation to represent unusual characteristics of a particular *compañía*, discussed in the results.

Because access to short-term credit may enable the timely use of the necessary chemical inputs, it is predicted to be related positively to allocative efficiency. Informal credit (*INFCRED*), including loans from local dealers or factories, is widely used, is short term, and makes no distinction between cash or inputs.[8] *INFCRED* takes the value of one if the household had received informal credit, and zero otherwise.

SHOFFINC, income from off-farm labor, is an important complement to the total income of the household. A significant positive relationship of *SHOFFINC* with allocative efficiency levels implies diversification of income improves resource allocation and efficiency. A negative relationship between *SHOFFINC* and allocative efficiency may suggest that households diversify as a risk strategy, rather than to improve efficiency.

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[8] In contrast, formal credit includes loans from state agencies, in particular from the Banco Nacional de Fomento and from the Crédito Agrícola de Habilitación, or from cooperatives. Formal credit was not widely used by the farms comprising our sample: nine out of 91 farms in the Minifundia zone, 14 out of 75 in the Colonization zone, and 29 out of 117 in the Frontier zone. The paucity of observations prevented using formal credit as an explanatory variable in each of the three regional equations.

Because the data represent a single growing season, credit and income are determined jointly with allocative efficiency; i.e., given the nature of production decisions in Paraguay, credit decisions, income, and allocative efficiency are outcomes that occur concurrently within a single growing season. Therefore, to avoid simultaneity bias, instruments for credit and off-farm income are utilized. Instrumental variable estimates[9] are available upon request from the authors. The remainder of the variables are exogenously determined within a given crop year.

Efficiency Measurements of Paraguayan Farmers

The data set contains information on 283 households ($z = 283$), weighted to reflect the population distribution of farms in eastern Paraguay. A total of 16 observations were excluded from the original sample either because they contained errors or because those households were not interviewed in a second survey conducted in 1994.[10] The efficiency indices are calculated using GAMS software.

National and Regional Efficiency Measures

Technical efficiency measures obtained by comparing each household to all the households in the sample are referred to as the national measures of technical efficiency (NMTE). However, given the differences in climate and soil, each household was also compared only to the households within its own region. Specifically, there were three subsamples (one for each region), with 75, 117, and 91 households in the Colonization, Frontier, and Minifundia zones, respectively. The indices obtained are referred to as regional measures of technical efficiency (RMTE). The NMTE measures allow for comparisons across regions, but the RMTE are more desirable when comparing households within the same region.

Panel A of table 2 presents NMTE and RMTE averaged at country and regional levels. As expected, figures for the regional comparisons are higher than those obtained at the national level because they compare households with similar economic and agroclimatic conditions. The average NMTE for the whole country was 0.84, with a standard deviation of 0.22. Of the 283 households in the sample, 54% were found to be technically efficient.

As seen from table 2, the Minifundia zone presents the greatest degree of variation. The mean RMTE is lowest in this zone (0.91), and the standard deviation (0.19) is the highest. The Minifundia zone also has the lowest percentage of efficient units (74%).

As in the case for the technical efficiency indices, the allocative efficiency measures are obtained by comparing each household with all others in the sample (NMAE) and with those households in the same region (RMAE). These measures are averaged at the country level and for each zone, and are reported in panel B of table 2. It should

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[9] The instrumental variable for off-farm income (*SHOFFINC*) is estimated as a censored regression because it is the percentage of income from off-farm sources, with bounds between zero and 100. Off-farm income is estimated as a function of education, family size (children and adults measured separately), farm size, and location. The instrumental variable for the use of informal credit (*INFCRED*) is estimated as a binomial probit because data on amount were not reliable. Explanatory variables include farm size, title, the instrument for off-farm income, experience, and location.

[10] The educational level of the head of the household is used when analyzing possible sources of inefficiency. That information was not collected by the 1990–91 survey used in this study, but was obtained from a second survey conducted in 1994 (Carter and Olinto).

Table 2. National and Regional Measures of Efficiency, by Eastern Paraguay Agricultural Production Zone

A. TECHNICAL EFFICIENCY

Description	No. of Obser- vations	National Measures (NMTE)			Regional Measures (RMTE)		
		Mean	Standard Deviation	% Efficient	Mean	Standard Deviation	% Efficient
PARAGUAY	283	0.84	0.22	54	0.94	0.14	78
Colonization Zone	75	0.83	0.22	55	0.95	0.11	93
Frontier Zone	117	0.89	0.19	62	0.97	0.11	83
Minifundia Zone	91	0.82	0.25	47	0.91	0.19	74

B. ALLOCATIVE EFFICIENCY

Description	No. of Obser- vations	National Measures (NMAE)			Regional Measures (RMAE)		
		Mean	Standard Deviation	% Efficient	Mean	Standard Deviation	% Efficient
PARAGUAY	283	0.36	0.24	2	0.47	0.27	6
Colonization Zone	75	0.41	0.25	6	0.42	0.28	6
Frontier Zone	117	0.30	0.25	5	0.50	0.26	5
Minifundia Zone	91	0.39	0.21	5	0.49	0.27	12

C. SCALE EFFICIENCY

Description	No. of Obser- vations	Regional Measures (RMSE)		
		Mean	Standard Deviation	% Efficient
PARAGUAY	283	0.61	0.29	10
Colonization Zone	75	0.68	0.28	12
Frontier Zone	117	0.50	0.29	9
Minifundia Zone	91	0.64	0.29	11

be noted that *compañía*-level prices are used to calculate the allocative efficiency measures to reflect regional differences in prices. The allocative efficiency measures are noticeably lower than their corresponding technical efficiency measures.[11] The mean NMAE at the country level is 0.36; that is, even households which become technically efficient could further reduce their costs by 64% through allocative efficiency. Clearly, for policy considerations, particular attention should be paid to allocative efficiency measures because they indicate a broader scope for cost reduction.

As discussed in the data section, the three zones represent different production and socioeconomic environments, and therefore the RMAE are particularly relevant. While the Colonization zone's mean RMAE (0.42) is similar to its NMAE mean (0.41), for the Frontier and Minifundia zones, the RMAE means (0.50 and 0.49, respectively) are considerably higher than their corresponding NMAE means (0.30 and 0.39).

A technically and allocatively efficient household may still be able to lower its costs by adjusting its scale of production to the output level that minimizes average cost.

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[11] While mathematically one would expect TE to increase and AE to decrease with disaggregation, this did not occur in these results. Further disaggregation did not alter the proportion of TE households and, because costs do not change, nor did it alter AE measures.

Given the regional differences in technical and allocative efficiency, scale efficiency is measured only at the regional level (RMSE). The RMSE measures a household's scale efficiency relative to other households in the region. Substantial adjustments in the scale of operation are only feasible in the long run; therefore, the RMSE were estimated assuming all inputs were variable.

The RMSE for household h are aggregated at the regional level, and the statistics are presented in panel C of table 2. With an average scale efficiency index of 0.61 for the country as a whole, households in the sample could potentially experience important reductions in costs by adjusting their scale of production. Even the more precise figures obtained by averaging measures at the regional level indicate potential cost reductions of at least 32%. Moreover, an average of 90% of the production units would benefit from increasing their scale of operation.

Efficiency Measures by Farm Size

Figure 1 provides an illustration of the regional measures of technical efficiency averaged within each land size class. In the Colonization zone, the lowest technical efficiency levels are found in those households with 5 to 20 hectares of land. These results are consistent with the hypothesis that small farmers are unable to work all their land. However, the average RMTE for these two classes is still quite high: 0.93 and 0.92 for the classes with 5–10 and 10–20 hectares, respectively. Most farmers who obtained land through the colonizing programs fall into the category of 10–20 hectares. Within the Frontier zone, there does not appear to be a strong relationship between technical efficiency levels (0.94 to 1.0) and farm size. The slightly lower figure for the 5–10 hectares class may be a consequence of the fact that some farms in this class do not own mechanical implements, yet they are being compared to larger, mechanized farms because they produce similar crops. In the Minifundia zone, however, the RMTE appears to describe a well-defined U-shaped pattern with respect to land size. Households with 10–20 hectares are the least technically efficient of the region, with a mean of 0.78 relative to a regional mean of 0.91.

Households with fewer than five hectares are very efficient in all three regions, with an average technical efficiency of 0.98, 1.0, and 0.95 for the Colonization, Frontier, and Minifundia zones, respectively. The high efficiency levels achieved by this class may be explained, to some extent, by their more diversified production which makes them not fully comparable to other larger production units in the sample.

As observed from figure 2, with small deviations, the allocative efficiency measures do increase with land size. For the Colonization zone, there seems to be a large difference between the allocative efficiency level of households with 20 to 50 hectares—mainly cattle ranches—and the remaining household sizes.

Figure 3 shows the average scale efficiency measures increase with land size in all three regions. However, they peak in the Colonization zone for plots of 20 to 50 hectares. This finding may suggest that land distribution programs in the area should not be designed based on plots of less than 20 hectares. In the Frontier zone, a region in which medium and large farms tend to grow soybeans, a highly mechanized crop, farms smaller than 50 hectares appear scale-inefficient. Finally, in the Minifundia zone, households with more than five hectares are significantly more scale-efficient than those with less land. The higher integration of this region to product and labor markets, and the type of crops grown, may explain the relatively high scale efficiency measures for plots
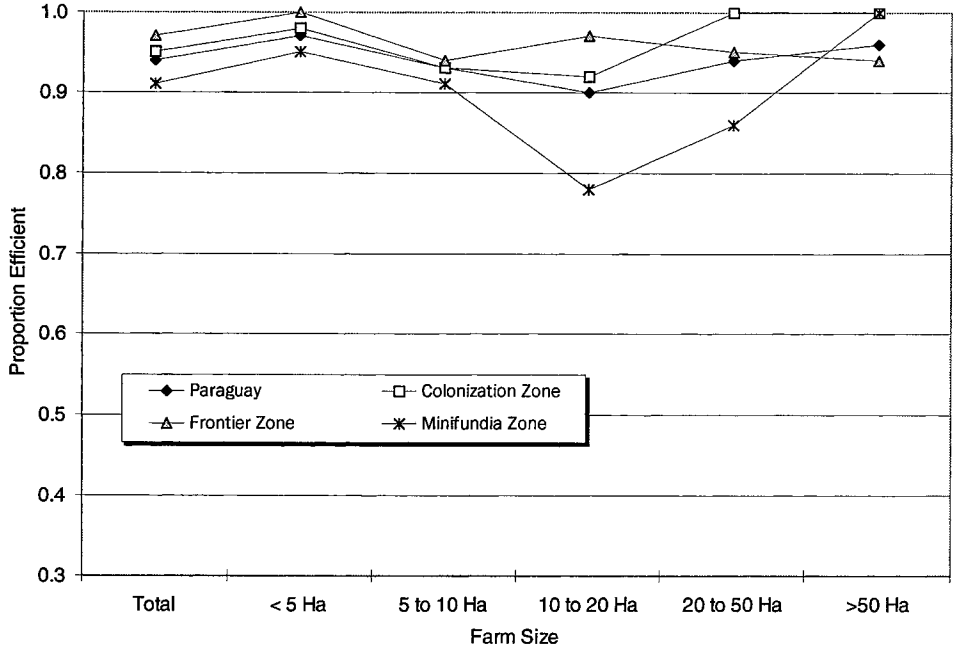
Note: There are only three observations for farms > 50 hectares in the Colonization zone and four in the Minifundia zone. Therefore, statistics should be treated with caution.

Figure 1. Regional measures of technical efficiency (RMTE) by zone and farm size
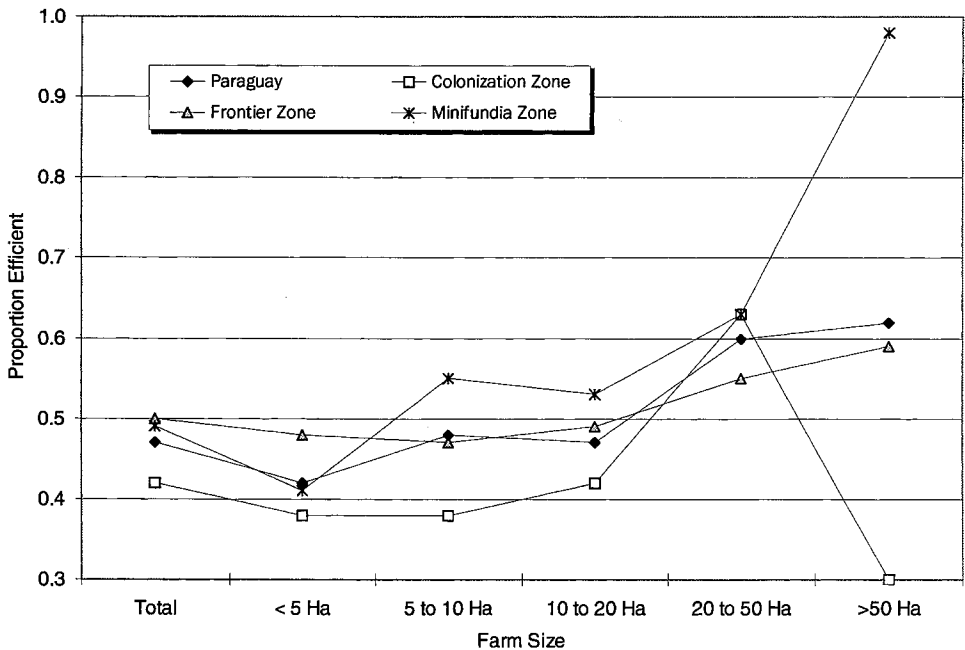
Note: There are only three observations for farms > 50 hectares in the Colonization zone and four in the Minifundia zone. Therefore, statistics should be treated with caution.

Figure 2. Regional measures of allocative efficiency (RMAE) by zone and farm size
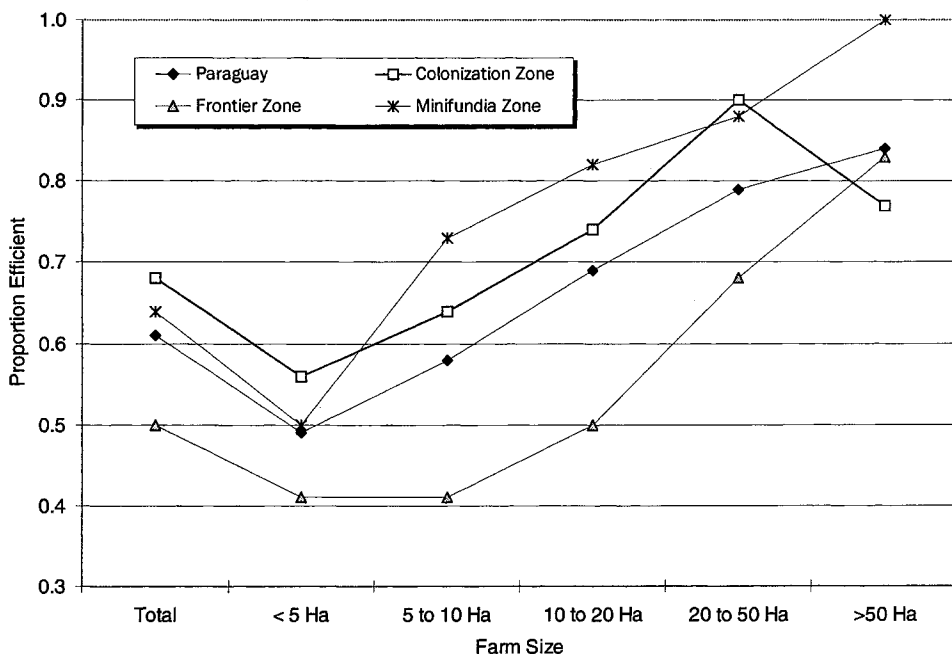
Note: There are only three observations for farms > 50 hectares in the Colonization zone and four in the Minifundia zone. Therefore, statistics should be treated with caution.

Figure 3. Regional measures of scale efficiency (RMSE) by zone and farm size

with more than five hectares. However, given the large number of households in the Minifundia zone with fewer than five hectares, an important scale efficiency problem still remains.

The nonparametric results show relatively high levels of technical efficiency within regions, implying there is little scope for expansion of households' output by improving their technical efficiency, given their endowments and available technology. In addition, the differences found between the national and regional measures strongly suggest any subsequent analysis should be based on the latter, as they capture differences in agricultural and economic conditions among the three regions. The allocative efficiency measures were noticeably lower at both national and regional levels for the three regions, indicating policy efforts should be targeted to improving allocative efficiency. Finally, despite the potential cost reductions suggested by the scale efficiency indices, land redistribution in Paraguay is currently politically unrealistic. Thus, the second step of the analysis explores the variations in allocative efficiency levels by land-holding size, titling, education, experience, access to credit, and share of off-farm income.

Analysis of Allocative Inefficiencies

The dependent variables used in the models are the regional measures of allocative efficiency (RMAE) in percentages. Because RMAE are constrained between zero and 100, Tobit models are used. The vector of explanatory variables contains the previously defined set of variables in linear form, with the exception of *LAND* which is included in

logarithmic form.[12] After applying White's test to all models, heteroskedasticity was found in the Frontier zone equation. A correction procedure for Tobit was run in LIMDEP (Greene) on the Frontier zone equation assuming multiplicative heteroskedasticity related to the logarithm for *LAND*. All equations were estimated using LIMDEP with the maximum-likelihood method and a convergence criterion of 0.001.

Because of the nonlinearity of the Tobit model, each variable's marginal effect on allocative efficiency depends upon the value of all the explanatory variables. The analysis in this section is based on the marginal effects for an average household—i.e., the marginal effects are evaluated at the means of the explanatory variables. Those marginal effects and their corresponding standard errors are reported in table 3.

Three variables are correlated significantly with the allocative efficiency achieved by households in the Colonization zone: farm size, number of adults, and a location-specific dummy variable (table 3).[13] The significantly positive coefficient on the logarithm of *LAND* shows the allocative efficiency of households increases with the number of hectares they control. Differences in allocative efficiency are larger for smaller land-holdings, reflecting differences in access to markets that prevent smallholders from allocating their land efficiently. The magnitude of the marginal effect for land is relatively large; the natural log of farm size increases the probability of being allocatively efficient by over 15%. Converting this back to hectares, a one-hectare increase in farm size increases the probability of being allocatively efficient by 5½%.

Similarly, lack of opportunities in the labor market may lead smallholders to use their own labor inefficiently. Thus, limited access to land, to the resources necessary to work it optimally, and, particularly, limited employment opportunities, explain why *ADULTS* is significantly negative and large in the Colonization zone. An additional adult in the household reduces the probability of being allocatively efficient by over 9%. Interestingly, the dummy variable corresponding to Polento Cué (*CNIA2*) is also significant and very large; households in this *compañía* have a 23% higher probability of being allocatively efficient than households in the rest of the Colonization zone. This *compañía* is where the Department of Agriculture has a large Extension Service office, and there is also better access to financial markets—both of which are expected to increase allocative efficiency.

Only the coefficient for *ADULTS* is significant in the equation for allocative efficiency of households in the Frontier zone.[14] As in the Colonization zone, *ADULTS* is associated negatively with allocative efficiency and of similar magnitude. Employment opportunities are limited in both regions, and agriculture is likely a poverty refuge.

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[12] Quadratic and cubic transformations of the natural logarithm of *LAND* were used as alternatives to the natural logarithm for *LAND* in other Tobit models estimated, but are not reported here.

[13] Off-farm income and experience are not significant; however, pairwise correlation coefficients with allocative efficiency are significantly different from zero (0.26 and 0.29, respectively). This is indicative of multicollinearity. Indeed, off-farm income and experience are not only correlated with each other (0.53), but also with farm size (−0.22 and 0.29, respectively). However, these explanatory variables are not deleted because doing so would introduce bias in the coefficient estimates.

[14] The lack of significance of the other coefficients may reflect a high degree of multicollinearity among the explanatory variables. Pairwise correlation coefficients revealed that size and title are highly correlated (0.55), as are size and off-farm income (−0.71), and title and off-farm income (−0.36). Clearly, multicollinearity masks the relationship between allocative efficiency and the explanatory variables, as indicated by examining their pairwise correlation coefficients; allocative efficiency is correlated with size (0.21), title (0.21), adults (−0.33), and the instrument for off-farm income (−0.20), but not with education (0.09), experience (0.0), or informal credit (−0.06).

Table 3. Tobit Analysis of Allocative Efficiency: Marginal Effects (with standard errors in parentheses)

Explanatory Variables	Colonization Zone	Frontier Zone [a]	Minifundia Zone
Ln(*LAND*)	15.304**	3.633	8.439
	(4.65)	(3.41)	(6.55)
%TITLED	−0.033	0.055	0.127*
	(0.07)	(0.06)	(0.07)
ADULTS	−9.385**	−9.570**	−3.574
	(2.48)	(2.27)	(4.04)
EDUCAT	−1.098	−0.221	0.165
	(0.91)	(1.04)	(0.90)
YEARS	0.239	−0.024	−0.530**
	(0.26)	(0.20)	(0.22)
INFCRED [b]	−14.209	−6.026	−18.022**
	(11.22)	(7.54)	(7.80)
SHOFFINC [b]	0.913	0.361	−0.511
	(1.27)	(0.41)	(0.84)
CONSTANT	37.890**	63.906**	70.398**
	(13.09)	(17.89)	(19.49)
CNIA2	23.239**		
	(11.13)		

Note: Single and double asterisks (*) denote statistical significance at the 10% and 5% levels, respectively.
[a] Corrected for multiplicative heteroskedasticity with natural logarithm of *LAND* using LIMDEP Tobit heteroskedasticity correction (Greene).
[b] Informal credit (*INFCRED*) and income from off-farm labor (*SHOFFINC*) are instrumental variables.

The model estimated for the Minifundia zone shows that *%TITLED, YEARS*, and *INFCRED* are significant. The percentage of land titled (*%TITLED*) is correlated positively with the level of allocative efficiency because in this region land ownership is unstable and titles are necessary to have access to credit. Both factors limit investments made on the farms. The lack of tenure security is enhanced by the greater demand for land, the growing number of squatters, and the extreme fragmentation of land in the region. However, while *%TITLED* is significant, its impact on AE is relatively small.

Experience has a relatively larger impact on the probability of being allocatively efficient. *YEARS* is associated negatively with allocative efficiency; an additional year of experience decreases the probability of being allocatively efficient by about a half a percent. This result is probably reflective of older producers who use traditional methods and are less willing to innovate, alter crop mix, or try other new activities.

Use of informal credit (*INFCRED*) significantly and negatively reduces allocative efficiency. Clearly, reliance on informal credit with high interest rates increases expenses relative to those households that do not use credit or to the very few households with access to formal credit at market rates of interest. Yet, because few households have access to formal credit, those in need of cash to purchase inputs will borrow at high rates of interest. On average, the use of informal credit reduces the probability of AE by 18%.

Conclusions and Policy Recommendations

This study measures the efficiency of small landholders' production in eastern Paraguay using nonparametric techniques. The advantage of the nonparametric method is its flexibility, particularly with respect to representing technology (Färe, Grosskopf, and Lovell; Paris). The nonparametric approach permits disaggregation into input and output categories which clearly are not close substitutes. A parametric statistical approach estimating efficiency measures, on the other hand, would necessarily require greater aggregation of the data used in this study, and hence result in lower efficiency measures. For example, it would not be possible to estimate regional measures by farm size with nine outputs and nine inputs, due to insufficient degrees of freedom.

High levels of technical efficiency were found in all three production regions of eastern Paraguay. This was true whether comparing each household with the whole country (NMTE) or only to others within their region (RMTE). Comparisons of technical efficiency measures across different land size categories reveal households in the smallest land size category of less than five hectares are highly technically efficient given the available technology.

The high levels of technical efficiency found in this study suggest technology is fairly homogeneous across households and that little scope for increasing the individual household's output-to-input ratio is possible unless new technology becomes available in the region.

Regional measures of scale efficiency indicated substantial cost reductions if the scale of operation could be expanded. However, the distribution of those gains varied across regions. In the Minifundia zone, adjustments in the scale of operation could substantially decrease the average cost of production for farms with 10 hectares or less. In the Colonization zone, the gains of expanding the operation were considerable for households with 20 hectares or less. In the Frontier zone, the most mechanized region, farms over 50 hectares were the most scale-efficient. While land redistribution could substantially increase the productivity of agriculture in Paraguay, especially in the Minifundia zone, land reform is politically unlikely to occur.

Thus, mitigating sources of allocative inefficiency has the greatest potential for improving Paraguay's agricultural productivity because little technical inefficiency exists and increasing scale efficiency is politically infeasible. Furthermore, regional measures of allocative efficiency are quite low. With a country average of only 0.47, households' allocative efficiency measures are noticeably lower than the corresponding technical and scale efficiency measures. Therefore, policy efforts should concentrate on factors which could help households achieve more allocative efficiency. In the Colonization zone, households' allocative efficiency levels increase with land size, implying large farms may be able to negotiate higher output prices and lower input prices. This points to policies that encourage small producers to form producer organizations or cooperatives in order to obtain better prices and information and to reduce transactions costs.

In addition, econometric analysis reveals a significant correlation between allocative efficiency and employment opportunities in the Colonization and Frontier zones, indicating that any programs or policies to increase employment in these regions could raise the allocative efficiency of households. The lack of employment opportunities, as suggested by the negative and large relationship between the number of adults in the

household and households' allocative efficiency levels, could be dealt with in two ways. First, it is important to design policies to relax the constraints preventing smaller farms from fully working their land and thereby enhancing the productivity levels of their family labor. Second, nonagricultural employment opportunities should be created.

The econometric analysis also reveals the percentage of titled land is related positively to the allocative efficiency of households in the Minifundia zone, while use of informal credit and years of experience are related negatively. The former implies titling efforts targeted to this region would have a small but significant effect. Further analysis is needed to determine how untitled land affects small farms in the Minifundia zone. These small farmers may perceive their ownership situation as insecure, in which case titling programs may enhance investment and, in turn, improve their efficiency levels. Increasing the availability of credit to this region, which has a high prevalence of very small operators, would appear to have a higher return. The negative relationship between AE and informal credit with its high interest rates implies that programs to increase the availability of credit at market rates would have a large and constructive impact.

Finally, two other variables are significantly related to allocative efficiency in the Colonization zone: location and farm size. The higher allocative efficiency found in Polento Cué (*CNIA2*) is likely related to better access to extension services and marketing channels in that region. The correlation between allocative efficiency and farm size may be due to the restricted access of small farms to input and output markets, to the presence of size-differentiated markets, or to differences in infrastructure that lead to unequal access to markets. Market access by smallholders could be strengthened by marketing policies that enable small farmers to pool and sell their products at higher prices, policies promoting the organization of producers to reduce the number of intermediaries in the input and output markets, and policies increasing farmers' access to credit (Verdecchia; de Villalobos and Howe).

Future research should incorporate uncertainty as well as cultural and behavioral constraints into the analysis. Moreover, it would be very helpful to examine the effects of relevant socioeconomic conditions on efficiency levels over time. Despite these limitations, this study contributes to the empirical literature on agricultural efficiency measures in developing countries, and is useful in guiding policies to improve the economic situation of small farmers in eastern Paraguay. Based on the findings, transfers of currently available technology would have limited impact on improving agricultural productivity in Paraguay, while land reform, land titling, improved access to credit, improved rural employment opportunities, and promotion of producer organizations would have the greatest strategic potential.

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