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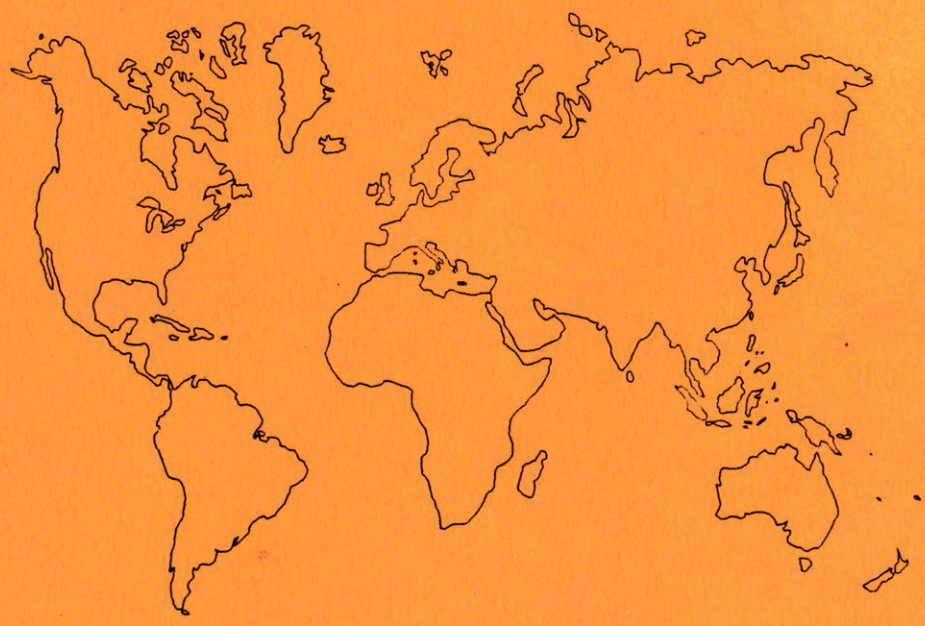
HUMAN AND SOCIAL CAPITAL CHARACTERISTICS NEAR THE FRONTIER OF PRODUCTION TECHNOLOGY

By
Michael J. Martin and Timothy G. Taylor

IW97-17 December 1997

INTERNATIONAL WORKING PAPER SERIES



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Human and Social Capital Characteristics Near the Frontier of Production Technology

by

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&
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Key Words: Human Capital, Social Capital, Stochastic Frontier, Technical Efficiency, Central America, Honduras

Summary: This paper presents insights into how human and social capital factors improve production efficiency in impoverished rural areas. A stochastic frontier production function is estimated for over 400 Honduran maize producers. Deubreu-Farrell technical and allocative measures are calculated relative to the observed "best practice" production frontier. Group means compare efficiencies by various socioeconomic characteristics that are intuitively related to production, but have not yet been examined. Efficiency is positively related to proportion of output marketed, education, health and experience. Personal extension assistance also improves efficiency, and farmers with no extension assistance are noticeably inefficient. Religion shows mixed effects on efficiency.

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Human and Social Capital Characteristics Near the Frontier of Production Technology

1. INTRODUCTION

Traditional farmers have been widely recognized as being poor but efficient producers and resource allocators.[1] In Central America and other developing regions, changes in production environments and improvements in technology have disrupted traditional practice equilibria. Sufficient time is rarely available to reallocate resources so that new equilibria are reached. Indeed, production environments often change so rapidly that new changes occur before the old ones can be fully adopted. Thus, the equilibrated "full efficiency" state achieved in traditional agriculture (Schultz, 1964) almost always lies beyond the reach of farm producers, emphasizing the need to augment human capital to "deal with disequilibria" (Schultz, 1975).

Human capital determinants of technology adoption have been examined extensively (See Birkhaeuaser, Evenson and Feder, 1991). However, empirical analyses of technology adoption generally illustrate fragmentary aspects of the return to human capital investments. The real return to human and social capital investments emerges in production efficiency which is more challenging to determine because it requires more extensive data than technology adoption studies.[2]

The theoretical bases of how human capital affects productivity is intuitive. Empirically, however, human capital consists of investments that are elusive to quantitative estimation. Years of schooling is easily measured, but education is not. Site visits of extension agents can be enumerated, but extension services vary in type and intensity. Social capital investments such as civic involvement and religious affiliation are identifiable, but the level of involvement that would influence one's economic behavior cannot be precisely measured. Perhaps the most difficult to measure, and the most important, is health, which is arguably integrally linked with all other human and social capital investments and may have its biggest impact in infancy and early childhood, before one engages in economic activities. For these and other reasons, empirical measures of human and social capital thus

yield no reliable *elasticities*, but they often provide valuable directional results against which the theory may be examined and differences compared.

The question this paper asks is: Is there a difference in average technical and allocative efficiencies among groups of producers with differing levels of human and social capital? To address the question, technical and allocative efficiencies are estimated for Honduran maize producers vis à vis a stochastic frontier production function. Efficiency levels relative to the observed maximum frontier are then compared for producers characterized by various human and social capital factors.

The following section discusses statistical methodologies used to estimate "Debreu-Farrell" efficiencies (Debreu, 1951; Farrell, 1957). The second section reviews human and social capital variables and data. The third section presents and discusses differences in means of those efficiencies grouped by personal and household characteristics, physical capital, social capital, extension methods and experience.

2. Technical and Allocative Efficiency

The most widely used efficiency measures are rooted in the writings of Debreu (1951) and Farrell (1957). Unlike input-output ratios which yield relative measures of efficiency, technical efficiencies proposed by Debreu and Farrell represent a deviation from an observed maximum. Technical efficiencies capture how well a given producer performs relative to the "best practice" or "frontier" production function, which is defined as the maximum level of output obtainable from a given set of inputs.

Technical efficiency illustrates the economy with which producers are utilizing selected inputs to produce outputs. It is a performance measure of the process of transforming input into output and is devoid of price or market information. Allocative efficiency, on the other hand, is a measure of a producer's success in selecting optimum input mixes relative to the a given set of prices and the frontier

production technology. Rational producers endeavor to choose the types and quantities of inputs that minimize the cost of production. Both forms of efficiency measure behavior that may be influenced by human and social capital investments. Input utilization and selection require decisions that may be improved by education, training, experience or other human and social capital investments.

Figure 1. illustrates technical and allocative efficiencies. The unit isoquant for the frontier production function utilizing inputs x_1 and x_2 is represented by I^o. For any input combination along I^o, a reduction in any one input would require an increase in another input to maintain the same level of output.[3] A technically efficient producer is represented by B, which lies on the production frontier. Point A represents an inefficient producer who utilizes more inputs than B to produce the same level of unit output. According to the production potential demonstrated by the frontier, the producer at point A can reduce input use without any reduction in the unit level of output represented by I^o, The technical efficiency measure is then:

$$TE = OB/OA^4.$$

TE is less than or equal to one because $OB \leq OA$. TE approaches unity as the input-output transformation process increases in efficiency (OB approaches OA).

The concept of allocative efficiency, a measure of cost minimizing performance, is also depicted in Figure 1. C/p_1 C/p_2 is the budget line the producer faces given the total cost of production (C) and input prices p_1 and p_2. In order to minimize costs, production must be set at a level where the ratio of input prices equals the marginal rate of technical substitution, or point E on Figure 1. Allocative efficiency is measured by the distance separating the price line and the efficient isoquant:

$$AE = OC/OB.$$

AE is less than or equal to unity because $OC \leq OB$. AE also approaches unity as the marginal rate of technical substitution equalizes with the price line (OC approaches OB). Allocative inefficiency results in costs that are in excess of the necessary minimum. Even though a producer represented by point B

is technically efficient, the input combination used at B does not minimize costs. Input combinations at B incur greater costs than the combination at E to produce the same level of output.

2.ESTIMATION AND DATA

(a) The frontier production function

Frontier production functions have been used extensively in examining production efficiency.[5] Prior to the emergence of frontier functions, the conventional model that was estimated took the form

$$\mathbf{q} = q(\mathbf{x},\tau) - e$$

where is $q(\mathbf{x},\tau)$ the production function, $\mathbf{q}$ is output and $\mathbf{x}$ is a vector of input s, τ represents technology and e is the random error. OLS necessarily assumes the expected value of the disturbance term, e, is zero. However, neoclassical production theory defines the production function as the *maximum* output obtainable from a given set of inputs. In the absence of random error, $e \geq 0$ because observed levels of output cannot exceed the theoretical maximum.

Initial frontier estimations attributed all deviations from the frontier to inefficiency, disregarding random shocks. The "stochastic frontier" (Aigner Lovell and Schmidt, 1977; Battese and Corra, 1977; and Meeusen and van den Broeck, 1977) allows for random deviation from the frontier owed to measurement error or events beyond the control of the producer. The error term of the production function in the stochastic frontier is comprised of two components:

$$e = (v - u)$$

where v has a symmetric distribution which captures random effects and exogenous shocks across firms; and the one-sided error, $u \geq 0$, captures technical efficiency of a firm relative to the stochastic frontier. Thus the estimated frontier accounts for stochastic characteristics that are likely to affect any production system, isolating systematic effects in the measurement of technical inefficiency.

Although Aigner et al. (1977) characterized the variances of u and v within the residual e, they

were not able to break the residual into its two components for *each observation*. Decomposition of the variances for each observation is possible, however, if the conditional distribution $(u_i | e_i)$ is assumed (Jondrow, Lovell, Materov and Schmidt, 1982).

(b) Obtaining efficiency measures vis à vis the frontier

This paper presents technical and allocative efficiencies for each producer and compares those efficiencies by various socioeconomic groups. Technical efficiencies are obtained as:

$$TE = \frac{q(x,\tau)}{q^*(x,\tau)} = \{\exp\}u \leq 1$$

where $q^*(\mathbf{x},\tau)$ is optimum level of output for given inputs as determined by the estimated frontier. Allocative efficiency is obtained from technical efficiency and from the minimum and actual costs incurred.[6]

$$AE = \frac{c^*(q^*,w)}{TE * c(q,w)} \leq 1$$

where $c(q,\mathbf{w})$ is actual cost incurred to produce q at input prices $\mathbf{w}$, and $c^*(q^*,\mathbf{w})$[7] is the minimum level of cost incurred to produce $q^*(\mathbf{x},\tau)$.

(c) Data and study area

All producers surveyed in this study belonged to cooperatives that participated in an agricultural extension experiment sponsored by the Honduran Integrated Pest Management Project (Spanish acronym MIPH) at the Pan American Agriculture School in Zamorano, Honduras. The extension program developed and disseminated information on integrated pest management techniques, as well as a full range of production assistance. MIPH randomly assigned participating cooperatives to

receive one of four different training techniques. One group received printed material only, one group received printed material and lectures, one group received lectures only and a final group received lectures accompanied by electronic visual aids. One group was set aside with no training to serve as a control group against which extension efforts could be measured.

Production and demographic data were gathered in Honduras during one production cycle in 1988-89. Surveys were conducted in Olancho and El Paraíso, contiguous regions in eastern Honduras which share similar climate, terrain and cultural characteristics. 408 individual producers belonging to 27 cooperatives participated in the study. Data on individual and collective maize production systems were used to estimate stochastic frontier production parameters. The model and estimated parameters are displayed in the appendix.

3. EFFICIENCY BY SOCIOECONOMIC CHARACTERISTICS

(a) Human and social capital determinants

Education has been the main focus of human capital studies for its quantitative potential (usually years of schooling) and for its useful policy implications. Education is almost always measured by the number of school years completed. The manner in which education affects efficiency can be obscured by heterogeneous forms of schooling and the exclusion of social interaction variables which may be more influential than education (Birkhaeuser et al., 1991). Better educated farmers tend to have better access to extension and credit agents and officials of organizations that have the resources to facilitate technology adoption. Fortunately, producers surveyed for this study are members of Honduran agrarian reform cooperatives who arguably form a homogeneous group with respect to education, social networking and outside opportunities. Almost all were poor rural laborers who recognized the similar conditions of their rural counterparts and formed political alliances based on those similar conditions.

Health is perhaps the most important human capital factor which influences productivity both directly and, through its effect on learning, indirectly. It is difficult to empirically measure the effect of health on productivity or work performance. Detailed physical examinations or health histories are costly, and even those cannot capture the range of early-age malnourishment which may explain the persistence of poor production performance and the inability to absorb other forms of human capital investments. Most studies thus far have assumed measures of current physical stature, such as height and weight or limb circumference, reflect nutritional background.[8] Those variables are used in this study as they are intuitively related to the health condition critical to the rigorous physical labor of agricultural production.

Training and work experience, apart from education, are important means of improving the broadly defined human capital component of knowledge. Recent studies on how training influences productivity, especially from developed countries, suggest a high pay-off from worker training.[9] Most studies in developing countries use site visits or the number of regional extension agents as proxies and thus assume that extension services are homogeneous and preclude the potential for information to be acquired from other sources (Birkhaeuser, Evenson and Feder, 1991). The data gathered for this study attempt to avoid problems arising from differences in extension assistance. All producers that participated in this study received training through their cooperatives from MIPH. Producers could have learned directly from extension materials, or from other coop members who received the same specific training techniques. It is unlikely that producers would have learned from a source outside the extension service or the cooperative as cooperatives serve as the dominant communication venue for most members.

Social capital may also clarify the uncertainty arising from "social networking" variables excluded from most studies. Social capital, recently treated in political science literature (Putnam, 1993; Helliwell and Putnam, 1995), may account for some of the influence on efficiency differences

obscured by education because it provides communication venues through which new technological ideas may be transmitted. However, the influence of social capital on technology adoption and efficiency in agricultural sectors of developing countries has been given little attention in the economics literature. Social capital has been measured by civic involvement, satisfaction with government or even recreational gatherings such as "bowling leagues" (Putnam, 1993 and 1995). Social capital in this paper is considered to be a congregating force, such as religion, games or music, that elicits communication and thus may encourage the transfer of efficiency-enhancing information.

(b) Efficiency comparisons

Most stochastic frontier studies incorporate socioeconomic variables[10] in a "second step" procedure by calculating correlation coefficients with efficiency estimates, or by regressing socioeconomic variables on efficiency estimates. However, statistical regressions and correlation coefficients are intended to estimate statistical parameters with observed data. Technical efficiencies calculated from an observed stochastic frontier are statistical in nature and cannot be considered data. The estimation of slope parameters with a dependent variable consisting not of data but statistics has no theoretical foundation. Moreover, the second step regressors themselves are often human capital or institutional proxies that approximate the variables they represent. Nonetheless, comparing efficiencies of farmers that lie close to the frontier vis à vis farmers who lie further away from the frontier provides useful and reliable directional insights. This can be accomplished by comparing averages of farmers grouped by socioeconomic characteristics with simple t-tests.

The tables below display differences in mean efficiencies for producers grouped by several demographic categories. Corresponding t-statistics evaluating the significance of the means differences are presented below each difference. Allocative efficiencies are calculated for two wage rates. In the first, the price of labor is the total cost of all labor divided by the total number of labor days, both free and paid, devoted to a given parcel. The other imputes the standard wage of five *lempiras* for all

labor.

Tables 1 - 5 display the differences in means for various groups of farmers. Many of the variables fall into one of two mutually exclusive categories (e.g. a respondent was either literate or not). For ordered categorical variables, comparisons were made for groups above and below the average (e.g. efficiency scores were compared for the group that had more than the average number of school years with the group that had less than the average number of school years).

4. THE RESULTS

(a) Personal and household characteristics

Table 1 shows efficiency differences based on various demographic characteristics. The most striking result emerges in the proportion of output sold. Farmers who market on average proportionately more output are more technically and allocatively efficient than farmers who market less. This result indicates that "hillside farmer" programs, which are designed to improve efficiency and environmental protection and which are popular among policy makers, will have limited impact because most hillside farmers are near-subsistence producers. These efficiency results also conform to technology adoption studies on Honduran Agriculture (Martin and Taylor, 1995; Martin, 1996).

By contrast, producers who supplement their income with outside work register a significantly positive difference in allocative efficiency, but only when the full wage is imputed. This illustrates how the potential for outside labor opportunities increases the opportunity cost of labor. The Labor/land ratio differences are negative and statistically significant for allocative efficiency when the full wage rate is imputed, indicating that farmers with relatively little access to personal land have a low opportunity cost of labor. Both of these results are consistent with economic intuition.

Another significant difference that emerges in terms of technical efficiency in Table 1 is observed between those individuals above the age of 50 and their younger counterparts. The negative

sign indicates that older men tend to be less efficient. Given the rigors of fieldwork, one can understand how younger men would hold an advantage at hard labor. Allocative efficiency is also greater for farmers under the age of 30. That the negative values for older men and the positive values for younger men reduce in significance when the standard wage is imputed suggests that older men have a higher opportunity cost for their labor in individual production than younger men. Perhaps this result could be explained by the life-cycle hypothesis in that younger men are saving and older men are dissaving.

A positive and statistically significant difference in allocative efficiencies is demonstrated between farmers who are literate vis à vis those who are illiterate. Producers with above average primary schooling and cognitive capacity[11] also demonstrate higher allocative efficiencies, indicating that more intelligent, better educated farmers are more capable of adjusting input mixes to take advantage of relative input price differences. These results corroborate previous human capital studies and further underscore the payoff that is achieved from human capital investments.

Farmers with larger than average families are less allocatively efficient than farmers with smaller than average families, but only when the wage for free labor is zero. Larger families are not significantly less allocatively efficient when the standard wage is imputed, indicating that larger families have a higher opportunity cost for labor than smaller families. This result may seem curious in light of the conventional belief that rural children in developing societies are used extensively in farm production. However, children in Honduras now attend school on a routine basis, perhaps because farm families recognize the opportunity costs of not educating children. Larger families would not only be deprived of family labor in such instances, but may have to hire additional labor to ensure an adequate food supply.

(b) Physical capital

Table 2 shows the differences in efficiency over varying health factors. Larger farmers are

more technically and allocatively efficient than smaller farmers, as demonstrated by weight, arm circumference and leg circumference. It stands to reason that larger farmers would be more technically efficient, given the arduous labor involved in agricultural production.

The fact that larger farmers are also more allocatively efficient as well may stem from the fact that smaller farmers often suffered malnourishment at a young age, which impaired mental capacity. Eye sight is the only other factor to register a significant result, and only for allocative efficiency. It too may be correlated with greater mental faculty. These measures are indirect measures of how child malnourishment negatively influences mental faculties, but they are consistent with studies that show better health and nutrition improve educational performance (Leslie and Jamison, 1990; Levinger 1992; Myers 1992; Pollitt 1990).

(c) Social capital

Table 3 displays efficiency differences across various social capital factors. For each group or activity, the social capital variables are all binary. The observation is one if the respondent participated in a given social activity, zero if the respondent did not. Catholics appear statistically more allocatively efficient than non-Catholics, perhaps because base communities offer a forum for interaction. Religion is a prominent form of social capital, the primary initiative behind the establishment of many cooperatives and a congregating force in rural Honduras. It may be noted that in the Olancho region where data were gathered, two Catholic priests and over a dozen *campesino* activists motivated by a socially focused liberation theology lost their lives in disputes with large land owners. It is possible that traumatic episodes may have moved land reform beneficiaries to value and efficiently utilize their resources because those resources were acquired at high cost.

Evangelicals are statistically and significantly less technically and allocatively efficient than non-evangelicals. Their allocative inefficiencies become stronger and more significant when the standard wage is imputed. The low efficiencies of Evangelicals cannot be explained by theology;

productivity and thriftiness are often promoted in Evangelical churches. However, one speculative interpretation lies in the emotional states of individuals compelled to follow Evangelical callings. Many people resort to Evangelical supplications because they are enduring emotional trauma, such as alcoholism or divorce, that a socially based theology does not respond to. Alcoholism is a serious problem in rural Honduras, but efforts to investigate it through field surveying made respondents nervous and jeopardized the acquisition of more important information.

(d) Extension methods

Efficiency differences as they relate to various forms of extension methods are displayed in Table 4. Producers who received a lecture unaccompanied by pamphlets or visual aids (*Lecture only*) register higher technical and allocative efficiencies. All other significant results are negative, suggesting that supplementary teaching aids are generally counterproductive tools in extension efforts. However, different training methods have been shown to be more effective in influencing the efficiency of producers who have relatively higher levels of education (Martin 1996).

The control group shows negative and significant allocative efficiencies, which indicates that those cooperatives that did not receive any extension assistance were significantly less adept at adjusting input mixes to an optimum. The MIPH program emphasized appropriate input selection and use in response to aggressive marketing strategies by input supply firms. The strong negative results of the control group relative to other groups that received some form of extension training illustrates the transformation that is underway in the rural economy and the importance of training to enable producers to "deal with disequilibria" (Schultz, 1975).

(e) Experience

Finally, Table 5 shows efficiency differences for farmers with above and below average levels of experience (as measured by years of input use). Experience with herbicides and insecticides appears most helpful in improving efficiency. To some extent, no single input should be considered apart from

the others in that hybrid seeds require fertilizer and pesticides to maximize potential; it is a *package*. However, pesticides constitute the most complicated component of the package. Producers considered them as medicine or nutrients and, according to extension agents, often applied them in an injudicious manner. Improper pesticide application could override benefits derived from hybrids and fertilizer, thus permitting the only difference in experience to be manifested in pesticides.

5. Conclusion

This paper empirically examined the role human and social capital play in influencing the efficiency of basic grain producers in Honduras. Group means of technical and allocative efficiencies derived from a stochastic frontier production function were compared. The groups were categorized by five groups of socioeconomic characteristics of maize producers: personal and household characteristics, physical capital, social capital, extension and experience.

The most prominent characteristic associated with higher efficiency appears to be the proportion of output sold. Producers appear to be more efficient the more they commercialize their output. This result conforms with the influence of commercialization on technology adoption and emphasizes the fact that farmers respond to market signals. However, it does not bode well for hillside farmer programs popular among development planners in Central America. Efficiency enhancing modifications do not appear to justify the return on investment for farmers with small land parcels.

Human capital investments demonstrate a positive impact on production efficiency. Health, as measured by height, weight and limb circumference, show positive influences on both technical and allocative efficiency. Primary schooling and literacy exhibit a positive influence efficiency that conforms with previous human capital research. Age shows an inverse relationship with efficiency that is understandable in light of the labor involved in maize production.

One form of extension, lecture only, demonstrates a positive relationship with technical and

allocative efficiency. Other forms were negatively related with efficiency or insignificant. Perhaps most interestingly, the control group, which received no extension assistance, was notably allocatively inefficient, evidencing the importance of human capital in coping with changing production environments.

Experience with the nontraditional inputs of hybrid seeds and fertilizers bares little correspondence with the efficiency of maize production. However, experience with herbicides and insecticides, the application of which is more complicated and which has a "magical" appeal among many farmers, appears to enhance efficiency. The greater efficiency associated with pesticide experience may stem from the relative importance of pesticides to production technology packages. Improper pesticide use could override the proper use of fertilizer and hybrid seeds.

The only significant results emerging from the social capital factors are that Catholic farmers appear more efficient than non-Catholic farmers and Evangelical farmers were less efficient than non-evangelicals. This may be attributed to the fact that base community organizations provide communication networks, or that evangelicals appeal to people suffering emotional trauma - such as alcoholism or divorce - that weaken their capacity to produce.

This paper presented several directional insights into how human and social capital factors improve production efficiency in impoverished and changing rural areas. Many of the factors are intuitively related to production performance, but have not yet been examined. Generally, the human capital of education, training, health and experience, as well as social capital, are shown to be investments which have tangible returns on efficiency.

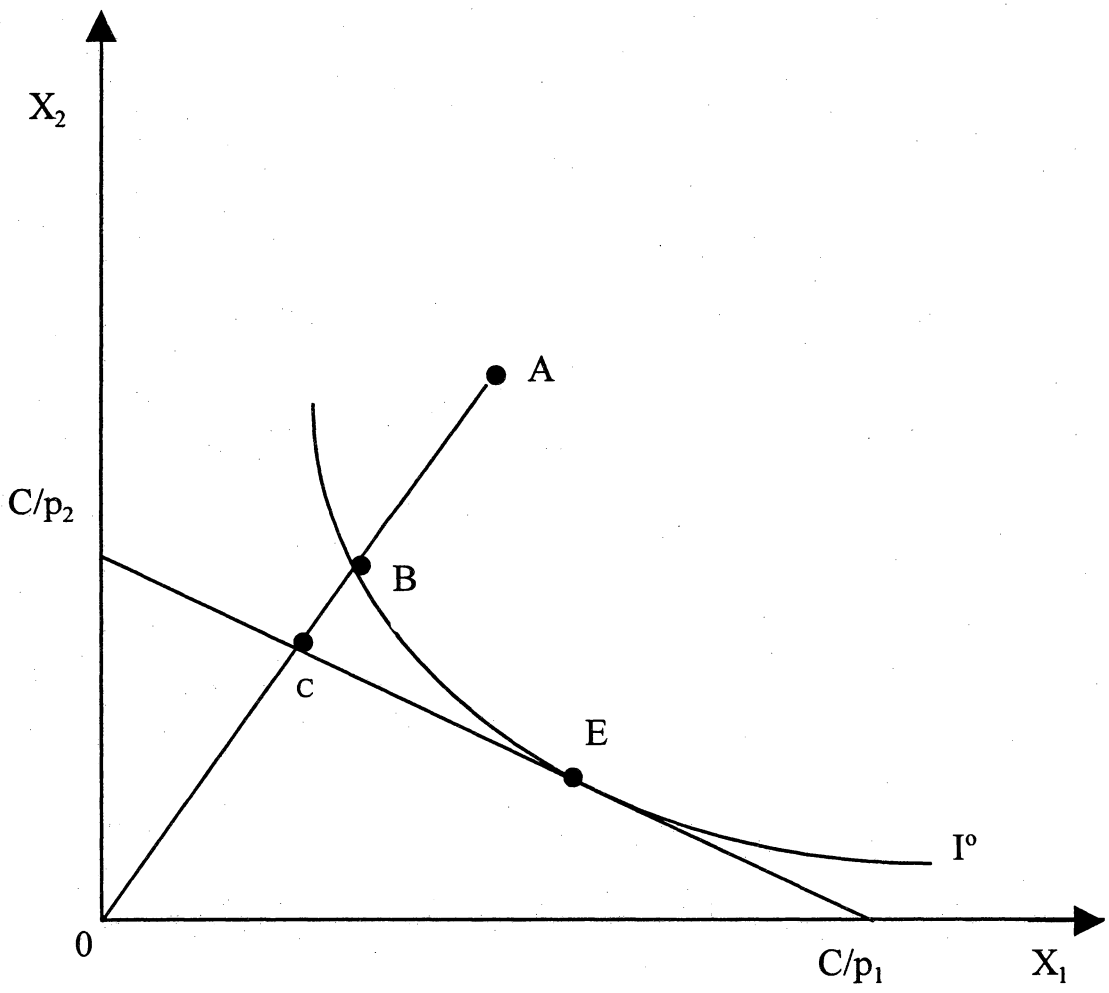
X_2
A
C/p_2
B
C
E
I^o
0
C/p_1
X_1

Table 1 Personal and household characteristics

	Technical Efficiency		Allocative Efficiency		Allocative Efficiency	
			Imputed free labor wage = 0		Imputed free labor wage = 5	
	Half-normal	Exponential	Half-normal	Exponential	Half-normal	Exponential
Primary Schooling	0.018	0.018	0.036	0.042	0.017	0.017
	(1.14)	(1.15)	(2.43***)	(2.49***)	(1.18)	(1.07)
Attended literacy class	0.006	0.006	0.017	0.019	0.012	0.014
	(0.41)	(0.4)	(1.12)	(1.16)	(0.84)	(0.91)
Literate	0.009	0.008	0.032	0.034	0.018	0.015
	(0.58)	(0.55)	(2.2**)	(2.06**)	(1.25)	(0.97)
Cognitive capacity	0.018	0.018	0.019	0.022	0.016	0.018
	(1.16)	(1.17)	(1.29*)	(1.35*)	(1.14)	(1.16)
Age over 50	-0.033	-0.033	-0.039	-0.040	-0.029	-0.024
	(-2.02**)	(-1.98**)	(-2.43***)	(-2.19**)	(-1.88**)	(-1.46*)
Age under 30	0.012	0.012	0.051	0.060	0.023	0.025
	(0.51)	(0.53)	(2.35***)	(2.44***)	(1.12)	(1.1)
Proportion output sold	0.0510	0.0506	0.0803	0.0909	0.0501	0.0536
	(3.41***)	(3.36***)	(5.66***)	(5.69***)	(3.59***)	(3.56***)
Outside work	0.036	0.035	0.022	0.020	0.047	0.052
	(1.42*)	(1.41*)	(0.9)	(0.73)	(2**)	(2.07**)
Labor/Land	0.013	0.013	-0.010	-0.014	-0.029	-0.040
	(0.85)	(0.83)	(-0.64)	(-0.85)	(-2.06**)	(-2.61***)
Married	0.012	0.011	-0.005	-0.007	0.004	0.003
	(0.54)	(0.51)	(-0.24)	(-0.31)	(0.17)	(0.14)
Family	-0.009	-0.009	-0.028	-0.034	-0.012	-0.014
	(-0.6)	(-0.58)	(-1.91**)	(-2.08**)	(-0.89)	(-0.95)

t statistics are in parentheses

* Significant at the .1 probability level.

** Significant at the .05 probability level.

*** Significant at the .01 probability level.

Table 2 Physical capital

	Technical Efficiency		Allocative Efficiency		Allocative Efficiency	
			Imputed free labor wage = 0		Imputed free labor wage = 5	
	Half-normal	Exponential	Half-normal	Exponential	Half-normal	Exponential
Eye sight	-0.001	-0.001	0.034	0.038	0.005	0.002
	(-0.07)	(-0.07)	(2.26**)	(2.31**)	(0.37)	(0.13)
Height	-0.003	-0.004	0.013	0.009	0.007	0.001
	(-0.19)	(-0.25)	(0.88)	(0.54)	(0.46)	(0.09)
Weight	0.028	0.028	0.027	0.026	0.032	0.032
	(1.85**)	(1.83**)	(1.84**)	(1.56*)	(2.28**)	(2.11**)
Arm circumference	0.027	0.027	0.020	0.023	0.020	0.023
	(1.78**)	(1.82**)	(1.36*)	(1.37*)	(1.44*)	(1.51*)
Leg circumference	0.029	0.030	0.029	0.032	0.022	0.022
	(1.93**)	(1.95**)	(1.98**)	(1.92**)	(1.58*)	(1.47*)

t statistics are in parentheses
* Significant at the .1 probability level.
** Significant at the .05 probability level.
*** Significant at the .01 probability level.

Table 3 Social capital

	Technical Efficiency		Allocative Efficiency		Allocative Efficiency	
			Imputed free labor wage = 0		Imputed free labor wage = 5	
	Half-normal	Exponential	Half-normal	Exponential	Half-normal	Exponential
Catholic	0.012 (0.81)	0.012 (0.76)	0.029 (1.95**)	0.031 (1.87**)	0.028 (2.01**)	0.030 (1.96**)
Evangelical	-0.047 (-1.71**)	-0.045 (-1.65**)	-0.039 (-1.45*)	-0.034 (-1.14)	-0.053 (-2.08**)	-0.050 (-1.83**)
Soccer	-0.009 (-0.42)	-0.009 (-0.44)	-0.007 (-0.34)	-0.012 (-0.5)	-0.012 (-0.62)	-0.018 (-0.82)
Dice	-0.165 (-2.25**)	-0.168 (-2.28**)	-0.054 (-0.76)	-0.061 (-0.76)	-0.049 (-0.71)	-0.048 (-0.65)
Cards	0.002 (0.07)	0.001 (0.06)	-0.017 (-0.78)	-0.020 (-0.8)	0.003 (0.16)	0.005 (0.21)
Billiards	0.031 (0.91)	0.032 (0.91)	0.040 (1.2)	0.042 (1.12)	0.039 (1.22)	0.042 (1.21)
Music	-0.019 (-0.57)	-0.018 (-0.53)	-0.017 (-0.52)	-0.017 (-0.46)	0.008 (0.26)	0.018 (0.53)

t statistics are in parentheses

* Significant at the .1 probability level.

** Significant at the .05 probability level.

*** Significant at the .01 probability level.

Table 4 Extension methods

	Technical Efficiency		Allocative Efficiency		Allocative Efficiency	
			Imputed free labor wage = 0		Imputed free labor wage = 5	
	Half-normal	Exponential	Half-normal	Exponential	Half-normal	Exponential
Lecture only	0.033 (1.84**)	0.035 (1.95**)	0.077 (4.47***)	0.097 (5.03***)	0.089 (5.43***)	0.112 (6.46***)
Publication only	0.015 (0.65)	0.017 (0.74)	0.002 (0.08)	0.012 (0.45)	-0.032 (-1.47*)	-0.034 (-1.44*)
Lecture and publication	0.009 (0.53)	0.010 (0.59)	-0.025 (-1.52*)	-0.029 (-1.57*)	-0.037 (-2.35***)	-0.044 (-2.56***)
Lecture and visual aids	-0.035 (-1.94**)	-0.038 (-2.12**)	-0.015 (-0.84)	-0.024 (-1.23)	0.009 (0.53)	0.006 (0.3)
Control group	-0.019 (-0.98)	-0.020 (-1.06)	-0.038 (-2.06**)	-0.050 (-2.44***)	-0.040 (-2.28**)	-0.053 (-2.79***)

t statistics are in parentheses

* Significant at the .1 probability level.

** Significant at the .05 probability level.

*** Significant at the .01 probability level.

Table 5 Experience

	Technical Efficiency		Allocative Efficiency		Allocative Efficiency	
			Imputed free labor wage = 0		Imputed free labor wage = 5	
	Half-normal	Exponential	Half-normal	Exponential	Half-normal	Exponential
Hybrid seeds	-0.003 (-0.17)	-0.002 (-0.15)	0.012 (0.84)	0.017 (1.04)	0.016 (1.14)	0.022 (1.46*)
Herbicides	0.032 (2.13**)	0.032 (2.14**)	0.023 (1.58*)	0.027 (1.67**)	0.039 (2.82***)	0.047 (3.14***)
Insecticides	0.020 (1.34*)	0.020 (1.31*)	0.023 (1.58*)	0.026 (1.57*)	0.036 (2.6***)	0.042 (2.82***)
Fertilizer	0.004 (0.24)	0.003 (0.2)	0.006 (0.42)	0.006 (0.38)	0.024 (1.7**)	0.028 (1.88**)

t statistics are in parentheses

* Significant at the .1 probability level.

** Significant at the .05 probability level.

*** Significant at the .01 probability level.

Table A1. Variables

Variable	Coefficient
Technology (A)	Constant
Land	Land measured in *manzanas*[*]
Labor	Labor measured in work days
Seed	Seed measured in pounds
Fertilizer	Fertilizer measured in quintals
Herbicide	Herbicide measured in pounds
Landprep	Total cost of land preparation
Collectivity	Degree of collective work arrangements[**]
Paraíso Region	= 1 if producer is from the region of El Paraŷso, 0 otherwise.
Lecture	= 1 if group received extension lectures without additional teaching aids, 0 otherwise
Publication	= 1 if group received printed extension publications and no personal lecture, 0 otherwise
Lectureaid	= 1 if group received lectures accompanied by electronic visual aids, 0 otherwise
Lecturepub	= 1 if group received both lectures and printed extension publications, 0 otherwise

[*]*Manzana* = 0.705 hectare
[**]Parcels used completely in the collective mode are scored as one, those planted prior to parcelization are scored as one half, and those for which the only collective activity land preparation are scored as one fourth. Completely individual production is registered as zero.

Table A2 Maize Production Functions

Variable	OLS	Frontier	
		Half-Normal	Exponential
Constant	2.295*** (9.938)	2.806*** (14.49)	2.800*** (15.74)
Land	0.464*** (7.028)	0.556*** (10.78)	0.559*** (11.36)
Labor	0.129*** (3.287)	0.122*** (4.317)	0.123*** (4.557)
Seed	0.175*** (3.010)	0.116*** (2.690)	0.115*** (2.732)
Fertilizer	0.035*** (2.889)	0.023*** (2.540)	0.022*** (2.511)
Herbicide	0.016** (2.222)	0.011* (1.693)	0.010* (1.688)
Land Preparation	0.044*** (2.533)	0.049*** (3.738)	0.050*** (3.929)
Collectivity	0.112*** (6.900)	0.085*** (5.997)	0.086*** (6.258)
Paraiso Region	0.151*** (3.691)	0.099*** (2.872)	0.095*** (2.854)
Lecture	0.052 (0.861)	0.020 (0.336)	0.015 (0.271)
Publication	0.212*** (3.065)	0.129** (2.088)	0.125** (2.089)
Lecturemold	0.039 (0.67)	0.095* (1.717)	0.097* (1.830)
Lecturepub	0.171*** (2.756)	0.131** (2.209)	0.127** (2.230)
μ/σ_u		2.856 (0.704)	
σ_u/σ_v		5.098** (2.124)	
$\sqrt{\sigma^2_v+\sigma^2_u}$		1.031** (1.961)	
φ			3.524*** (12.57)
σ_v			0.198*** (11.54)

t-statistics are in parentheses.

* Significant at the .1 probability level.

** Significant at the .05 probability level.

*** Significant at the .01 probability level.

R-squared:0.877 Adjusted R-squared:0.873	Log-Likelihood: -11, 7.0200 Variance components: $\sigma^2(v) = 0.03935$ $\sigma^2(u) = 1.02273$	Log-Likelihood: -114.7641 Variance components: $\sigma^2(v) = 0.03907$ $\sigma^2(u) = 0.08053$

APPENDIX

STOCHASTIC FRONTIER

The Cobb-Douglas model is selected as the functional form:

$$q = A \prod_{i=1}^{k} x_i^{\beta_i} \prod_{i=1}^{m} h_i^{\alpha_i} \prod_{i=1}^{n} o_i^{\gamma_i} u = q^* u, \qquad 0 \le u \le 1$$

where q is a producer's output, A is a given level of technology, x_i represents the set of i = 1...n inputs and the β_i's are the corresponding input coefficients. The standard production function estimates output q, solely as a function of physical inputs x_i. However, Jensen and Meckling (1979) suggested an extended form of the production function which recognized that production did not occur in a physical vacuum. Knowledge h_i (human capital) and "organizational forms" o_i also influence the level of output by their parameters α_i and γ_i respectively. The systematic element on the right-hand side, u_i, represents the one-sided efficiency disturbance, and q^* frontier output. The variables used to estimate the model are listed in Table A1.

Maximum likelihood estimates are presented in Table A2. The half-normal and exponential distributions are assumed for the one-sided error. Technical and allocative efficiencies are displayed in Tables 1 - 5.

Endnotes

1.Theodore Schultz has written extensively on the importance of human capital and the agricultural sector in economic development. For a review of human capital, see T.J. Schultz, 1993 and T.P. Schultz, 1992.

2.See Jamison and Lau (1982) and Bravo-Ureta and Pinheiro, 1993 for reviews.

3.This conforms to Koopmans' (1951) definition of efficiency. The Debreu-Farrell technical efficiency is a "radial" measure in that, if the isoquant is weakly convex, producers located on the portion of the isoquant where the slope is zero or infinite are considered to be technically efficient. The Debreu-Farrell definition of technical efficiency is thus not as restrictive as that proposed by Koopmans. Clearly, more efficiency is attainable if reducing one input results in no reduction of output, a necessary condition for Koopmans, but not for Debreu_Farrell. However, while slack may pose some problems for mathematical programming estimates, it does not hamper econometric techniques because functional forms (e.g. Cobb-Douglas) preclude slack.

4. In vector notation $\|B\|/\|A\|$ where $\|X\| = (\Sigma x_i^2)^{1/2}$, $\forall i$.

5.For an excellent review of frontier techniques and applications, see Fried, Lovell and Schmidt (1993).

6. Farrell proposed a composite measure of economic efficiency (EE) which is the product of TE and AE. EE is the ratio of the minimum cost required to produce a given level of output to the actual cost incurred.

7.It is not necessary to statistically estimate the cost function, as it can be analytically derived from the production function. The cost function is a dual representation of the production technology (Shepard, 1970), thus coefficients from the frontier production function can be incorporated into the frontier cost function, $c^*(q,w)$ (Kopp and Diewert, 1982).

8.Iminck et. al. 1982; Moock and Leslie, 1986; and Jamison, 1986.

9.For developing countries see Jamison and Lau (1982); Shapiro and Müller (1977); Behrman et al. (1985); and Kalirajan and Shand (1985). For developed countries see Mincer (1989); and Vaughan (1989).

10.Stochastic frontiers have been used in LDC's to measure the effectiveness of credit programs (Ekanayake, 1987; and Taylor, Drummond and Gomez, 1986). Several studies examined extension programs (Kalirajin and Shand, 1985; Kalirajan, 1984; Kalirajan and Finn, 1983; and Bravo-Ureta and Evenson, 1994) and education (Kalirajan, 1990; and Pinheiro, 1992). The stochastic frontier has also been used to identify firm and managerial characteristics that influence efficiency (Seale, 1990).

11.As measured by Raven's colored matrices test.

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