Natural Resource Conservation and Technical Efficiency from Small-scale Farmers in Central Chile

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Selected Paper prepared for presentation at the International Association of Agricultural Economists (IAAE) Triennial Conference, Foz do Iguaçu, Brazil, 18-24 August, 2012.

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Abstract

This study estimates a stochastic production frontier to measure technical efficiency (TE) using farm-level survey data for a random sample of small-scale farmers in Central Chile. Socioeconomic and productive information was collected in season 2005/06 through a survey of 319 farmers in the Province of Linares. An important issue in the paper is the effect of adoption of soil and water conservation practices on productivity. The results reveal a positive relationship between the adoption of soil and water conservation and farm-level TE. The results also indicate that improvements in TE, when associated with conservation practices, not only lead to higher output and thus improvements in net returns, but also contribute to environmental sustainability. Moreover, the analysis reveals a positive relationship between TE and human capital variables such as education and agricultural extension.

Keywords: soil and water conservation, stochastic frontiers, technical efficiency, sustainability.

1. Introduction

Eighty percent of the world's agricultural land is moderately to slightly eroded, and another 10% is severely eroded. Losses of topsoil due to erosion are especially high in Central Africa, Central America, and Asia, where losses of 30–to 40 tons of soil per hectare per year are common (Bekele and Drake, 2003).. The causes of the loss of agricultural soil are varied and complex. They include variables such as environmental conditions, the kinds of crops grown, and the techniques of production (Muchena *et al*., 2005). In Central America, most soil erosion is due to poor agricultural practices by low-income farmers - part of a vicious cycle of poverty and environmental degradation (Solís *et al.*, 2006; Solís and Bravo-Ureta, 2005). In Chile, 63% of the soil is affected by the processes of desertification, and 50% of the soil shows signs of erosion (Francke, 1997). An average of

47 tons of soil are lost per hectare annually (Saintraint and Sloot, 1993).

Because of the severity of the environmental degradation worldwide, many developing countries have formulated strategies for the conservation of natural resources. Although these strategies are not always well implemented (Amsalu and de Graaff, 2007), conservation practices can have a positive impact in the productivity of some crops (Gupta and Seth, 2007) and in farm income (Bravo-Ureta *et al*., 2006).

Several researchers have focused on the analysis of socioeconomic and productive factors that influence the adoption of conservation practices of natural resources in various areas of the world (Asafu-Adjaye, 2008; Cramb *et al.*, 2007; Pender and Kerr, 1998; Caviglia-Harris, 2002; and others). However, there are few studies on the relationship between the adoption of conservation practices and productivity. This relationship is relevant—especially in developing countries—in the formulation of public policies for improved agricultural productivity, resource conservation, and farm income.

The aim of this research is to examine technical efficiency (TE) in a sample of small farmers of the Province of Linares, Chile, with emphasis in the relation between TE and soil and water conservation (SWC) practices. This paper continues with a review of literature, followed by the methodological framework, a description of the data, and the empirical model. We then discuss the results and conclude with a summary of our findings.

2. Productivity and conservation: a literature review

Since Farrell´s work (1957) followed by Aigner, Lovell, and Schmidt (1977) and Meeusen and Van den Broeck (1977), the stochastic frontier analysis has become a fundamental tool to study productivity. The popularity of this approach is demonstrated in several survey papers including Battese (1992), Bravo-Ureta and Pinheiro (1993), Munroe (2001), Bravo-Ureta et al. (2007), and Moreira and Bravo-Ureta (2010).

According to Nishimizu and Page (1982), productivity increases stem from technological change (TC) and technical efficiency (TE), where the latter can be interpreted as a relative measurement of managerial ability, and the former is associated with technology adoption (Bravo-Ureta et al., 2007). Thus, increases in TE stem from improvements in the decisions made by the producer, whereas increases in TC are related to investments in research, development, and technology (Ahmad and Bravo-Ureta 1996).

Regarding the sources of efficiency, Coelli and Battese (1996), and Bravo-Ureta and Pinheiro (1993) have identified a set of variables that can influence TE. Gorton and Davidova (2004) suggest that these variables should be classified in two major groups: (1) human capital; and (2) structural factors. Human capital is captured in variables such as education, extension, experience, family size, age, and gender. Structural factors are reflected in variables such as access to credit, land tenure, farm size, off-farm income, and environmental variables (Solís et al., 2009).

The relationship between TE, conservation practices and the degradation of natural resources has been analyzed in a limited number of studies. In Mexico, Pascual (2005) used an index of soil fertility as an input in the production function and found positive effects of soil fertility on the production of maize. He also found that an increase in TE associated with the intensification in the use of fertilizer and land significantly reduced the erosion related with "*slash and burn*" practices. In Rwanda, Byiringiro and Reardon (1996) showed a positive and significant effect of conservation practices on land productivity. Solís et al. (2007) found a positive relationship between the adoption of soil conservation practices and TE on small farms in Honduras and El Salvador. Helfand and Levine (2004), and Mahadevan (2008) found that the adoption of soil conservation practices significantly reduced inefficiency. Finally Lohr and Park (2007) found that soil quality is positively associated with farm efficiency.

3. Methodological framework

To determinate TE at the farm level, a Stochastic Production Frontier (SPF) was used, following Battese and Coelli (1995):

$$Y_i = \exp(x_i\beta + v_i - u_i) \qquad [1]$$

where *Y* is the production value of the *i*th farmer, *x* are the inputs, *ß* is a vector of unknown parameters and $v - u = \varepsilon$ is the error term. The term *v* is a two sided random error with a normal distribution ($v \sim N[0, \sigma_v^2]$) which captures the stochastic effect of factors beyond the farmer's control (e.g., climate, natural disasters) and statistical noise. The term *u* is a one sided ($u \geq 0$) component that captures the TE of the producer; in other words, *u* measures the gap between the observed production and its maximum value given by the frontier. This error can follow a semi-normal, exponential, or gamma distribution (Aigner, Lovell and Schmidt, 1977; Greene 1980; Meeusen and Van den Broeck, 1977). A high value of u implies a high degree of technical inefficiency; conversely, a value of zero implies that the farm is completely efficient. According to Battese and Coelli (1992), the TE of the ith farm is given by:

$$TE_i = \exp(-u_i) \qquad [2]$$

where u is the efficiency term specified in [1]. TE for each farm is calculated using the conditional mean of $e^{(-u)}$, given the compound error term for the stochastic frontier model (Jondrow et al., 1982; Battese and Coelli, 1988). According to the maximum-likelihood method developed by Battese and Coelli (1995), it is possible to estimate both the parameters of the production frontier and the variables that explain technical inefficiency (z_j). Thus, technical inefficiency is defined as:

$$u_j = \delta_0 + \sum_{n=1}^{k} \delta_n z_{nj} + e_j \qquad [3]$$

where u_j is technical inefficiency, z_{nj} are farm-variables that affect efficiency and δ_n are unknown parameters to be estimated.

Data and area under study

The study area covers 9,590 farms in the micro-basins of the rivers Putagán, Achibueno, Ancoa, and Longaví, tributaries of the Rio Maule in the Province of Linares, Chile. Of these farms, 86% are small producers. During September and December of 2005, a survey was conducted that involved 319 interviews, representing 3.89% of the farmers in the study area, in 32 water communities (CdA). The surveys with missing information were excluded from the analysis, leaving 307 valid surveys. A typical small-scale farmer cultivates 0.5–1.0 hectare of fruit trees (raspberries), which provides most of the household’s cash income, and 2.0–4.5 hectares of mixed crops—wheat, corn, beans, and some vegetables. In some cases, part of the farm is dedicated to pasture for cattle. Management practices include conventional tillage and two or three fertilizer applications per season. Crop stubble is usually burned, causing a reduction in soil quality, which in turn forces an increase in inputs and leads to soil degradation. Less commonly, the stubble is incorporated in the soil or used for compost.

The Empirical model

The empirical model assumes an SPF with a modified translog functional (TL) form:

$$\ln y_i = \beta_0 + \sum_{i=1}^{5} \beta_i \ln x_i + \sum_{i=1}^{5}\sum_{j=1}^{5} \beta_{ij} \ln x_i \ln x_j + \sum_{k=1}^{2} D_k + v_i - u_i \qquad [4]$$

where y_i represents the value of the agricultural production of the *i*th farm, which includes the cash crop and self-consumption; x_1 is the number of hectares worked by the farmer; x_2 represents the costs of purchased inputs (seeds, fertilizers, pesticides); x_3 is the value of family labor; x_4 is the cost of hired labor (services of machinery and workers); x_5 is an index of soil and water conservation practices (ICAS); D_k are dichotomous variables that indicate the major crops (fruit trees, pasture and annual crops where the latter is the omitted category); β are the parameters to be estimated; and v and u are as defined previously.

Table 1 shows a description of the variables used in the TL model. On average, the annual value of agricultural production is MM$4.9 (in Chilean pesos[1]); the standard deviation of MM$6.9 indicating a considerable variation between the farms. The average farm has 6.3 hectares and spends MM$ 0.9 on purchased inputs (seeds, fertilizers and pesticides). The average cost of hired labor, which includes wages and the rental of machinery, is MM$0.5. The average value of family labor is MM$1.9, or roughly 5,000 Chilean pesos per day per person.

Soil and water conservation index (ICAS)

Several studies have focused on the construction of sustainability indexes that are

[1] 1 US$ = 507.8 Chilean pesos

closely related to conservation practices. Taylor et al. (1993) constructed an index of sustainability at the farm level based on a scoring system that considers the following factors: (a) plague control; (b) disease control; (c) weed control; (d) maintenance of soil fertility; and (e) erosion control. Gómez et al. (1996) used a similar index, but they incorporated economic aspects, such as crop yield and profitability. Rigby et al. (2001) constructed an index of sustainability based on (a) seed origin; (b) soil fertility; (c) disease control; (d) weed control; and (e) crop management. They assigned higher scores to practices that minimize the use of external inputs.

Regarding the relation between TE and the conservation of natural resources, Solís et al. (2009) include as sources of inefficiency diverse soil conservation practices and incorporate the ratio between the area of land treated with soil conservation measures and total cultivated area. Helfand and Levine (2004) include some soil conservation practices in their inefficiency model, while Mahadevan (2008) classifies soil conservation practices from the least effective (set at 1) up to the most effective (set at 5). Finally, Lohr and Park (2007) incorporate an index in the production function that measures the on-farm inputs to improve soil structure and quality.

In agreement with the classification presented by Mahadevan (2008) and the index offered by Rigby et al. (2001), in this study we elaborated an index (ICAS) based on the number of SWC practices used. The practices have been weighted by criteria suggested by a panel of five experts. This panel classified the SWC practices according to their level of impact in the conservation of natural resources. As a result, ICAS is defined as:

$$ICAS_i = \left(\sum_{j=1}^{n} SSA * p_{sj} \right) + \left(\sum_{j=1}^{n} SWA * p_{wj} \right) \qquad [5]$$

where $ICAS_i$ is the index of SWC practices of the *i*th farmer, *SSA* is the number of soil conservation practices, and p_{sj} is the weight of the *j*th practice. *SWA* is the number of water conservation practices and p_{wj} is the weight of the *j*th practice. Table 2 describes each of these SWC practices and the weight suggested by the panel of experts.

Previous investigations suggest that the adoption of SWC practices is an endogenous variable that can be correlated with the error term of equation [4] (Jones, 2002;

Langpap, 2004). Therefore, an instrumental variable is used, similar to that implemented by Ríos and Shively (2006) and Solís et al. (2009), to correct for possible endogeneity. Results from using the value of ICAS directly in the production model are compared with the predicted values obtained from a Tobit regression model (see Appendix A). Table 3 shows the descriptive statistics of the number of SWC practices adopted by the farmers, the actual ICAS, and the predicted ICAS. Out of a possible 10 SWC practices, farmers adopted 3.21 on average. The average ICAS was 2.36, and the expected average ICAS was 2.33.

4. Results and Discussion

Table 4 shows the estimations of the SPF model. Model I includes the actual ICAS value, whereas Model II uses the predicted values. The TL functional form was selected based on previous analysis where the Cobb–Douglas (CD) was rejected in favor of the more flexible specification. All variables are normalized by their geometric mean (GM); thus, the first order coefficients can be interpreted as partial elasticities of production evaluated at the GM. The parameter γ is significant at the 1% level for both models (I and II), with a value of 0.71 for Model I and 0.79 for Model II.

In addition, the null hypothesis that $\gamma = 0$ is rejected, confirming that technical inefficiency must be considered and that the stochastic model is superior to the model that would result from estimation using ordinary least squares (OLS). Using the Durbin–Wu–Hausman test (Davidson and MacKinnon, 1993), it was verified that the variable ICAS is endogenous. Thus, Model II is the preferred specification.

For Model I, all first order parameters are positive and statistically significant at the 10% level. The highest value is for the parameter for Land at 0.584. The parameter for ICAS, when the direct value of this variable is used, is 0.058. The results for Model II indicate that all first order parameters are positive and significant, with the exception of the one for ICAS (expected value), though its sign is positive. The parameters for the dichotomous variables Fruit Trees and Pasture are positive and significant, which suggests that land devoted to fruit trees and pasture is more productive than land used for the production of mixed crops.

The function coefficients of Models I and II, without including ICAS, at the geometric mean, are 0.982 and 0.950, respectively. If we include the ICAS parameter, both models yield a function coefficient slightly higher than 1, which shows increasing returns to scale. This finding is consistent with the fact that all the units in the sample are relatively small (Moreira, 2006). Bozoglu and Ceyhan (2007) reported increasing returns to scale (1.51) with an average farm size of 4.47 ha. However, decreasing returns to scale have been reported in studies where the farm size is relatively small (Rahman and Hasan, 2008; Wadud and White, 2000). Chavas et al. (2005) argue that decreasing returns to scale imply that the quantity of some inputs, such as family labor, is greater than what is needed, given the current technology.

Technical Efficiency

Table 5 shows the values of TE for Models I and II, which average 80.3% and 79.7%, respectively. This result indicates that several farms might significantly reduce their level of inputs and still obtain the same level of productivity. Table 5 also shows that approximately 83% of the producers attained TEs of 70% or higher. The average TE value is consistent with other studies focused in Latin America. Solís et al. (2009) reported a TE of 78%, and Bravo-Ureta et al. (2007), using SPF models, also found a TE of 78%.

The test of the null hypothesis test supported Model II, the analysis that follows focuses on the results obtained from that model. Table 4 shows the parameters of the variables that explain inefficiency. Following the usual practice, the interpretation is in terms of TE (instead of inefficiency). The positive sign for Age, a variable used as a proxy for human capital reflected by experience, indicates that older farmers are more efficient, but the parameter is not significant. The results in the literature relating Age and TE are inconsistent. On one hand, Erhabor and Emokako (2007) established that young farmers are more efficient. On the other hand, Munroe (2001) and Amaza et al. (2006) found a positive relationship between Age and TE. In Turkey, Bozoglu and Ceyhan (2007) incorporated Age as a determinant of TE in the cultivation of vegetables. The results indicated a negative association between the farmer's age and TE. However, years of experience in raising vegetables was positively associated with TE.

The parameters for Education and Extension show a positive relationship between these variables and TE. Abdulai and Huffman (2000) also found that education has a positive and significant effect on TE, and suggested that an efficient response to changes in market prices requires management skills which are acquired through education and access to information. Similar results were found by Stefanou and Saxena (1988). Likewise, Gorton and Davidova (2004) and Kalirajan and Shand (1985) suggested that education and extension have a positive relationship with TE, especially for low-income farmers.

The variable Extension shows a positive and significant relationship with TE, according to Adamassie (1999) and Seyoum et al. (1998). The finding of Binam (2004) that the relationship was not significant was explained by the poor performance of extension programs in the area studied. Similar results were found by Feder et al. (2004). The parameter for Participation indicates that l social interactions with local community organizations are negatively associated with TE. This result can be explained by the fact that the social activities are not related to agriculture. Finally, the parameter for the variable Training indicates a positive relationship with the TE, though it is not significant.

Table 6 presents a cluster classification where the association variable is the level of TE. Farmers with a high level of income and large amounts of cultivated land appear to have the highest TE. Some studies suggest that an inverse relation exists between farm size and TE (Tadesse and Krishnamoorthy, 1997; Munroe, 2001) and this can be explained by inadequate management of inputs or by failures in credit and labor markets (Solís et al., 2009). On the other hand, Coelli and Batesse (1996) and Ahmad et al. (2002) report a positive association between land and TE. As Gorton and Davidova (2004) have suggested, the role of farm size should be analyzed together with human capital and agro-ecological conditions. These authors add that efficiency in the management of small plots depends on the availability of extension and technological education. In this study, the groups with the highest levels of TE (see groups 1 and 2, in Table 6) had not only better access to technical assistance, but also better access to credit. Similar results have been reported by Binam et al. (2004), Adamassie (1999), and Seyoum et al (1998).

Table 7 exhibits the relationship between area cultivated, TE, ICAS, and the number of cash crops. The results clearly show a positive relation between TE and area cultivated, adoption of conservation practices, and number of cash crops. Table 8 shows the relation between ICAS and TE. In general, 51.5% of the farmers have an ICAS between 2 and 4. Only 5.5% of the farmers do not adopt any SWC practices (ICAS = 0), and for this group, the mean TE is 76%. For the 12% of the farmers with an ICAS between 0 and 1, TE is

78%. The TE of these two groups differs significantly from that of farmers who have an ICAS greater than 4. The latter group represents 11.2% of the sample. Thus, this analysis reveals a positive association between TE and ICAS; that is to say, the adoption of conservation practices is significantly associated with both technical efficiency and environmental conservation. These results are similar to those of Solís et al. (2009), who hypothesized that economic and environmental sustainability can be complementary aims.

5. Conclusions

This study uses a SPF model to measure TE in a sample of small farms in Central Chile. In order to evaluate the relation between TE and conservation practices, we have included an index of conservation (ICAS) in our model. A positive association between TE and ICAS was observed, which shows that improved levels of efficiency not only represent an economic benefit for the producer, but also contribute to environmental sustainability. The estimated models showed significant levels of inefficiency, a result that suggests the potential for increasing production using the current level of inputs and available technology.

The empirical results also show that human capital, in terms of education and experience, is a crucial factor associated with higher levels of managerial performance measured by TE. (Mundlak, 1961; Ahmad and Bravo-Ureta 1996). Other authors conclude that the knowledge and practice of soil conservation measures significantly help to reduce inefficiency (Helfand and Levine, 2004; Mahadevan, 2008). Nevertheless, since it is not clear to what extent the lack of managerial ability is responsible for inefficiency, it is not desirable at this point to include variables related to conservation in the inefficiency model.

Widespread adoption of the SWC practices considered in this investigation could have a long-term effect on the productivity of farms in Chile, at least in part through their effect on erosion control. Additional work is needed to analyze the long-term relation between TE and conservation practices, so that policies can be formulated that effectively support improvements in farm income, productivity, and natural resource management.

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Table 1. Description and definition of the variables used in the model SPF

Variables	***unit***	***Definition***	***Mean***	***S.D.***
Agricultural PV	MM$	Value of agricultural production (including cash crop and consumption)	4.9	6.9
Land	Ha	hectares worked	6.3	7.8
Purchased input	MM$	Expense in seeds, fertilizers and pesticides	0.9	1.7
Hired Labor	MM$	Value of labor and hired machinery services	0.5	0.7
Familiy Labor	MM$	Value of family labor		
Fruit trees	%	Dummy variable that indicates if the principal use of the land is fruit trees; 0 otherwise	1.9	0.8
Pasture	%	Dummy variable that indicates if the principal use of the land is for pasture, 0 otherwise	23.7	-
Crops[1]	%	Dummy variable if the principal use of the land is for mixed crops, 0 otherwise	4.2	-
		Years of age of the farmer	72.1	-
Age	years	Years of education of the farmer	57.1	14.1
Education	years	Variable that indicates if the producer has	6.3	3.7
Extension	%	technical assistance, 0 otherwise	32.8	-
Participation index	years	Index between 0-1, the higher the index the greater participation in social activities	0.4	0.2
Training	%	Dummy variable that indicates if the producer participated in training, 0 otherwise	11.7	-

1. ommited variable

Table 2. Conservation practices and weights used in this study

	Average Score [1]	***Category***	***Weight***
Soil			
Fallow	2.7	low	0.38
Crop rotation	6.3	high	0.90
Cover crop	6.0	high	0.86
Stubble	5.7	high	0.81
Cut and pasture carrying	5.3	medium	0.76
Cover with stubble	5.7	high	0.81
Compost	6.3	high	0.90
Mulch	6.0	high	0.86
Manure	5.0	medium	0.71
Improved cultivation	6.0	high	0.86
Improved pastures	5.5	medium	0.79
Water Resources			
Elimination of weeds in the channels	4.7	low	0.67
Cleaning sediments in the channels	4.7	low	0.67
Improvements in water conduction	6.7	high	0.95
New channels in-farm	6.0	high	0.86
Stone walls	4.0	low	0.57
Drip irrigation	6.7	high	0.95

1. Average score obtained from the expert panel (on a scale of 1 to 7).

Table 3. Descriptive statistics of ICAS

	Average	*D.E.*	*Minimum*	*Maximum*
Number of Practices [1]	3.21	1.72	0	10
ICAS[2]	2.36	1.32	0	7.81
ICAS (EV)[3]	2.33	0.79	0.82	4.19

1. SWC practices
2. Weighted number of practices
3. Predicted value from a Tobit model

Table 4. Translog parameters for two stochastic production frontiers

Variables	***Model I***		***Model II***	
Constant (β_0)	0.125**	*0.060*	0.139**	*0.067*
Land (β_1)	0.584***	*0.043*	0.584***	*0.052*
Inputs (β_2)	0.196***	*0.036*	0.168***	*0.034*
Hired Labor (β_3)	0.131***	*0.020*	0.128***	*0.022*
Family Labor (β_4)	0.071***	*0.020*	0.070***	*0.019*
ICAS (β_5)	0.058*	*0.035*	-	-
ICAS (VE) ($\beta_{5'}$)	-	-	0.174	*0.150*
Fruit trees (β_7)	0.247***	*0.080*	0.264***	*0.080*
Pasture (β_8)	0.745***	*0.250*	0.711***	*0.275*
Land * Inputs	-0.062***	*0.021*	-0.065**	*0.030*
Land * Hired Labor	0.016	*0.014*	0.022	*0.020*
Land * Family Labor	-0.029	*0.024*	0.034	*0.032*
Land * ICAS	0.007	*0.021*	-	-
Land * ICAS (VE)	-	-	-0.069	*0.088*
Inputs * Hired Labor	0.017***	*0.004*	0.014***	*0.004*
Inputs * Family Labor	0.048***	*0.016*	0.051***	*0.014*
Inputs * ICAS	0.041***	*0.014*	-	-
Inputs * ICAS (VE)	-	-	0.150*	*0.079*
Hired Labor * Labor Familiar	-0.036**	*0.015*	-0.049***	*0.015*
Hired Labor * ICAS	-0.042***	*0.017*	-	-
Hired Labor * ICAS (VE)	-	-	-0.046	*0.056*
Family Labor * ICAS	0.017	*0.011*	-	
Family Labor * ICAS (VE)	-	-	-0.060	*0.066*
InefficiencyModel:				
Constant (Z0)	3.450	*2.343*	-	-
Age (Z1)	-0.068	*0.061*	-0.038	*0.024*
Education (Z2)	-0.223	*0.208*	-0.134*	*0.077*
Extension (Z3)	-1.080	*0.869*	-2.788*	*1.711*
Participation (Z4)	0.611	*0.816*	1.949*	*1.160*
Training (Z5)	-1.413	*1.335*	-1.654	*1.229*
Returns to scale[a]	0.982		0.950	
Log. FMV	-236.80		-242.68	
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.75**	*0.445*	1.06***	*0.321*
$\gamma = \sigma_u^2 / \sigma^2$	0.71***	*0.175*	0.79***	*0.073*
TE	80.32		79.65	

* p < 0.1; **p < 0.05; ***p <0.01.

\- variables not included.

a. Without considering the parameter of ICAS

VE: estimated through Tobit regression model.

FMV: maximum likelihood function.

Table 5. Distribution of TE.

Interval TE	*% of farm in intervals*	
	Model I	***Model II***
20-29	0.7	0.3
30-39	0.3	0.7
40-49	2.9	1.6
50-59	3.9	2.0
60-69	7.2	9.1
70-79	26.4	24.8
80-89	47.9	54.7
>90	10.7	6.8
Average TE	80.3	79.7

Table 6. Clusters of technical efficiency for Model II

	Group 1 N= 150	Group 2 N= 107	Group 3 N= 39	Group 4 N= 11
Qualitative variables [1]				
TE average (%)	86.7 a	78.5 b	65.8 c	43.1 d
Value of production (ln)	15.2 a	14.4 ab	13.8 b	12.5 c
Land cultivated (ln ha)	1.29 a	0.94 ab	0.91 ab	0.53 c
Cash crop	1.7 a	1.5 ab	1.2 ab	0.9 c
Education (years)	6.6 a	5.8 a	5.8 a	5.6 a
Qualitative variables				
Extension	59%	11%	3%	0%
Access to credit	58%	44%	23%	27%
Off-farm work	34%	44%	53%	55%

a. The number of groups was estimated using the dendrogram methodology, and then there was a separation of k-means.
1. For quantitative variables, the different letters in the same row indicate significant differences according to Tukey and Duncan ($p \leq 0.05$)

Table 7. Farm size, TE, and ICAS

Cultivated land (hectares)	n	TE Average	ICAS	Cash Crop
0.10 – 0.75	65	76.4	1.43	0.66
0.76 – 2.55	61	80.0	2.08	1.14
2.56 – 5.95	58	80.2	2.54	1.80
5.96 – 10.0	71	80.7	2.87	1.96
10.1 – 60.0	52	81.2	2.93	2.11

Table 8. Technical Efficiency by ICAS

ICAS	n	%	Model I	Model II
0	17	5.5	0.77	0.76*
>0 – 1	37	12.0	0.77*	0.78*
>1 – 2	62	20.2	0.81	0.80
>2 – 3	94	30.6	0.80	0.79
>3 – 4	63	20.5	0.81	0.81
>4	34	11.2	0.83	0.82

* Statistically different with the ICAS group > 4.

Appendix A. Tobit Model Estimation

Variable	***Coefficient***	***Standard Error***
Farm Size	0.025***	*0.006*
Soil Quality	-0.101	*0.148*
Self-consumption	-0.615***	*0.231*
Raspberry	-0.672***	*0.206*
Access to Credit	0.521***	*0.147*
Incentives	0.612**	*0.281*
CdeA	0.411***	*0.150*
Constant	1.685***	*0.166*
Log-Likelihood	-469.13	
N	307	
Pseudo R^2	0.11	

* p < 0.1; **p < 0.05; ***p <0.01.

Correlations:

	ICAS
Expected value of ICAS	0.521**

** Correlation significant at 5%.