Technical Efficiency and Adoption of Soil Conservation in El Salvador and Honduras

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Abstract

A household-level switching regression model is implemented to examine potential selectivity bias for rural households under high and low levels of investments in soil conservation in El Salvador and Honduras. In the presence of selectivity bias, separate stochastic production frontiers are estimated for low and high adopters. The main results indicate that households with higher levels of investments in soil conservation show higher average TE than those with a lower level of investments. Constrains in the rural land and credit markets are likely explanations for these differences. The results also indicate that for farms with lower levels of investments in soil conservation access to credit is a significant factor explaining the sources of inefficiency. Conversely, households with higher levels of investments have the highest partial output elasticity for land, the highest levels of TE and the smallest farms. These results are consistent with the presence of a failure in the land market which would limit access to land to the more efficient producers.

JEL classification: d24; q12; o13; c21

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1. Introduction

Soil erosion is a major contributor to watershed degradation in Central America stemming in large part from environmentally unsustainable farming practices. This can have significant negative effects on farm-productivity and rural-income along with adverse social and environmental consequences (Conroy, 1996). Local governments with the support of international donors have undertaken several programs during the last two decades as an effort to improve environmental conditions and to reduce poverty among hillside producers. Two of these programs, which are the focus of this study, are the Environmental Program for El Salvador (PAES) and the Natural Resource Management Program in Honduras (CAJON). Both programs, which have recently concluded, were aimed at conserving renewable natural resources in the upper watershed of the Lempa River in El Salvador and in the Cajón watershed in Honduras. An underlying objective of these programs was to improve the socioeconomic conditions of the rural population in their areas of influence by promoting the adoption of soil conservation techniques and more diversified cropping patterns.

The rates of adoption and the factors influencing farmers' decision to adopt the new technologies vary sharply among beneficiary farmers (Cocchi, 2004). This variation provides an opportunity to measure the magnitude of the expected gains in productivity resulting from different levels of investments in soil conservation. Consequently, the main goal of this paper is to study technical efficiency (TE) levels for rural-hillside households under two different levels (high and low) of investments in soil conservation. The rest of this paper is divided into three additional sections. The next section describes the empirical model and the data set. The subsequent section presents and discusses the main results while the last section provides some concluding remarks.

2. Model and data

To pursue our goal it will be necessary to estimate separate production functions for farms under different level of investment in soil conservation. Freeman *et al* (1998) indicate that this estimation could be feasible if the levels of investments vary randomly among the studied farms. However, Pattanayak and Mercer (1998) indicate that this might not be the case in this kind of analysis since the adoption of a new technology is a voluntary choice exercised by the household. Thus, the estimation of separate production functions based on an arbitrary classifying of the farms could generate a self-selection problem. Specifically, Maddala (1983) explains that by creating the various groups the observations in each might no longer be randomly selected from the population if the data in each group depend on the variables affecting the adoption of the technology under analysis.

To account for the potential self-selection bias that may arise in the models to be estimated in this study, a switching regression model (SRM) is implemented. In general terms, a SRM corrects for this bias by introducing a set of self-selectivity variables into the productivity model. In doing so, the first step in this model is to determine the factors influencing farmers' decisions to invest in soil conservation. Following Freeman *et al* (1998) the level of investment in soil conservation can be described by a criterion function, which is postulated to be associated with exogenous household socioeconomic variables as follows:

$$I_i = \delta' Z_i + u_{0i} \quad \textbf{(1)}$$

where subscript *i* denotes farm-households, *I* is the level of investment in soil conservation, Z is a vector of exogenous variables, δ are the unknown parameters and u_o is the disturbance term. Here two investment levels are proposed -high and low- with the sample mean as the breakpoint. By doing so, the dependent variable is now dichotomous (I = 1 for a high level of investment and 0 otherwise) and the parameters in equation (1) can be estimated using a probit model.

The second step in the SRM is to estimate separate production functions for the two groups of farmers. These production functions can be expressed as:

$$Y_{1i} = \beta_1^{'} X_{1i} + u_{1i} \qquad \text{if } I = \text{HIGH} \qquad (2)$$

$$Y_{2i} = \beta_2^{'} X_{2i} + u_{2i} \qquad \text{if } I = \text{LOW} \qquad (3)$$

where Y_1 and Y_2 represent output levels for farm-households with high and low levels of investments in soil conservation, respectively, X_1 and X_2 are input vectors, β_1 and β_2 are the unknown parameters, and u_1 and u_2 are random disturbance terms.

Maddala (1983) indicates that OLS estimates of β_1 and β_2 will yield biased parameters because the expected values of the error terms, conditional on the sample selection criterion, are non-zero. Furthermore, he argues that the random disturbances, u_0, u_1 and u_2 (equations 1, 2 and 3, respectively) have a trivariate normal distribution with zero mean and non-singular covariance matrix. Thus, to obtain unbiased estimators these equations should be estimated simultaneously via maximum likelihood (ML). To simplify this estimation, Lee (1978) suggests a two-step approach where self-selectivity is treated as a missing variable problem. In doing so, the expected values of the truncated error terms $\left(u_1 \middle| I = 1\right)$ and $\left(u_2 \middle| I = 0\right)$ are equal to:

$$\left(u_1 \middle| I = 1\right) = \mathrm{E}\left(u_1 \middle| u_0 > -Z'\delta\right) = \sigma_{10} \frac{\phi(Z_i^{'}\delta)}{\Phi(Z_i^{'}\delta)} \equiv \sigma_{10} W_1 \qquad (4)$$

$$\left(u_2 \middle| I = 0\right) = \mathrm{E}\left(u_2 \middle| u_0 \leq -Z'\delta\right) = \sigma_{20} \frac{-\phi(Z_i'\delta)}{1-\Phi(Z_i'\delta)} \equiv \sigma_{20} W_2 \tag{5}$$

where Z and δ are, respectively, the vector of exogenous variables and the estimated parameters from equation (1), and the expressions ϕ and Φ are, the probability density and the cumulative distribution functions, respectively.

By introducing W_1 and W_2 (self-selectivity variables) into equations (2) and (3), respectively, the new residuals will present zero conditional mean. So, the estimation of the corrected equation will yield unbiased estimators. However, Freeman *et al* (1998) show that by including the self-selectivity variables we introduce heteroscedasticity and they suggest estimating the corrected equations using Weighted Least Square (WLS) to obtain efficient parameters.

Sriboonchitta and Wibonnpongse (2004) contend that the methodology described above can also be used to modify the stochastic production frontier (SPF) model in order to estimate TE while avoiding self-selectivity bias. Thus, the SPF the using SRM can be repesented as:

$$Y_{1i} = \beta_1' X_{1i} + \sigma_{10} W_{1i} + v_{1i} - u_{1i} \qquad \text{if } I = \text{HIGH} \tag{6}$$

$$Y_{2i} = \beta_2' X_{2i} + \sigma_{20} W_{2i} + v_{2i} - u_{2i} \qquad \text{if } I = \text{LOW} \tag{7}$$

where v_i, is a random variable reflecting stochastic shocks entering into the frontier, and u_i captures the technical inefficiency relative to the stochastic frontier. The ML estimation of equations (6) and (7) will produce consistent parameter for the SPFs.

To evaluate the sources of inefficiency we implement the Battese and Coelli (1995) approach by incorporating the following expression in the frontier model:

$$\mu_i = \alpha_0 + \sum_{n=1}^{m} \alpha_n F_{ni} + e_i \tag{8}$$

where F_{ni} is a vector of household-specific variables, α_n are unknown parameters and e are unobservable random variables, assumed to be independently distributed.

The data used to estimate these models come from a random sample of 530 project beneficiaries from PAES and 210 from CAJON for the agricultural year 2001-02. The PAES project is divided into three (1, 2 and 3) to reflect the fact that it was implemented by three different companies. After deleting all surveys with missing or incomplete data the final data set includes 639 observations. Table 1 presents the variables and their means.

3. Results

Three different SPFs were estimated using the *translog* functional form where all variables are normalized by their geometric mean. At the point of approximation, the three models satisfy monotonicity and convexity. The HIGH and LOW models include the self-selectivity variables W_1 and W_2 estimated from the results obtained in the fist-stage regression. The Lee *et al* (1980) procedure was implemented to account for heteroscedasticity and to calculate the correct asymptotic covariance matrix and standard errors. The SPF for the entire sample (ALL) is included for comparison purposes. Due to space limitation this discussion will focus only on the second-stage equations shown in Table 3.

The values for σ^2 and γ are reported at the end of Table 3. The null hypothesis that γ = 0 is rejected in all cases which suggests that TE is indeed stochastic. Moreover, the value for γ is statistically significant and ranges from 0.672 to 0.832 indicating that inefficiency is highly significant. The parameters for the selectivity variables W_1 and W_2 are statistically significant, which supports the estimation of the SPF using the SRM. Fuglie and Bosch (1995) suggest that the signs of the parameters for W_1 and W_2 (i.e., σ_{10} and σ_{20}) have important economic interpretations. Assuming expected profit maximization, if σ_{10} and σ_{20} display the same sign, as is the case here, households with higher levels of adoption also have higher total output. Thus, these results indicate that soil conservation is compatible with improvements in total production among the households in the sample.

The SPF results indicate that more than half of the estimated coefficients are significant at least at the 10% level and that the estimated production elasticities follow similar patterns in the three models. Table 3 shows that, at the geometric mean of the data, FAMILY LABOR and PURCHASED INPUTS contribute the most to total household production. The parameters for the three variables used to measure the effect of labor are consistently positive. Nevertheless, the statistical significance of these parameters varies among the three models. For instance, the parameters for FAMILY LABOR and ADULTS are statistically different from zero in all cases. However, the parameter for HIRED LABOR is significant only in model LOW.

Farm size presents positive but small effects in all estimated models. Indeed, the partial elasticity for LAND in model HIGH is 0.144, indicating that a 10% rise in total cultivated area could increase total household production by 1.44%. Lastly, all project variables display positive coefficients suggesting that farmers associated with PAES (1, 2 and 3) have higher levels of productivity than those working with CAJON.

At the point of approximation, the function coefficient is equal to 0.87, 0.82 and 0.75 for models HIGH, ALL and LOW, respectively, suggesting the presence of decreasing returns to scale (DRTS). Chavas *et al* (2005) indicate that in household-level analyses, the presence of DRTS implies that household resources are 'too large' for the technology implemented. Given that the farms under analysis are small in terms of land area, the source of DRTS is most likely due to a relatively high number of adults per household, a problem that might be offset by promoting off-farm employment opportunities (Chavas *et al*, 2005).

The empirical results also show that the average levels of TE are 0.83, 0.77 and 0.74 for models HIGH, ALL and LOW, respectively. Based on paired *t*-tests, the differences among these means are statistically different from zero suggesting that households with higher levels of investment in soil conservation exhibit, on average, higher TE as well. These results also reveal considerable inefficiency, where, on average, households could reduce the level of inputs from 17% to 26% and still generate the same level of earnings.

Table 3 also presents the determinants of TE for each of the models estimated. Following common practice, the interpretation of the parameters is performed with respect to their effect on efficiency. As expected, EDUCATION and FREQUENCY display positive and statistically significant effects in all three models. Gorton and Davidova (2004) suggest that improvements in human capital enhance household efficiency by offering peasants the necessary means to achieve more with the available resources and the existing technology.

Female-headed households exhibit lower TE than male-headed households in the three models. Similar outcomes have been reported by González (2004), and López and Valdés (2000), and different hypothesis have been proposed to explain this result. For instance, López and Valdés (2000) suggest that this finding does not necessarily mean that females are less efficient but may be related to the different kinds of production activities performed by male and females in Central America. González (2004) argues that gender inequalities, prevalent in rural Latin America, limit the access of women to information, land, capital and other inputs and this can adversely affect TE. This difference could also be explained by unmeasured non-economic activities performed by females in the household, since in less developed areas, female household-heads are not only in charge of their family business but they also take care of many other needs (child care, cooking, cleaning, etc).

CREDIT presents a positive effect on household efficiency but it is statistically significant only in the model LOW. The literature shows mixed results with regards to the effect of credit assistance on productivity (Deininger *et al,* 2004; Binam *et al,* 2003). Nonetheless, the outcomes of this analysis suggest that households with low levels of investment in soil conservation may be credit constrained. Therefore, extension programs should take advantage of this situation and focus credit assistance on this group of households where credit presents a positive and significant effect for productivity improvement.

Finally, the coefficient for OWNERSHIP is negative in all models but statistically significant only in the HIGH model. This suggests that TE decreases with land ownership, contradicting the neoclassical notion that land ownership is an economic incentive for farmers to improve their production technologies. Nevertheless, this seemingly contradictory finding has been reported in other studies (e.g., Binam *et al*, 2003; Byiringiro and Reardon, 1996). Deininger *et al* (2003) claim that this result could be explained by the prevalence of imperfect rural land markets, which may restrict access to land to farmers, including those that may be the most technically efficient in a given geographical area.

4. Conclusions

The purpose of this study was to assess the connection between the adoption of soil conservation practices and household TE by comparing two types of farm-households in hillside regions of Honduras and El Salvador. A switching regression approach was used to test if there is a systematic difference between households with high and low levels of investment in soil conservation. The empirical analysis corroborates previous assumptions that a systematic difference exists between the two groups.

The second-step analysis reveals that producers with higher levels of investments in soil conservation also exhibit higher TE. These producers also have the smallest farms and present the highest partial elasticity of production with respect to total cultivated land. These results suggest the presence of a market failure in the land market in the areas under analysis. Deininger *et al* (2003) claim that market failures in less-favorable areas denies access to land to many efficient rural producers. A workable approach to handle these market failures could be to strengthen the rental land market and to offer farmers the necessary financial support so that they can afford to rent additional land.

Conversely, farms with lower levels of investment in soil conservation display the highest elasticities for purchased inputs and hired labor. In addition, access to credit is found to correlate with inefficiency, suggesting the presence of credit constraints. Thus, resource management programs should consider targeting credit programs to these households as a strategy for development and productivity improvement as well as for helping farmers to undertake the initial investments to adopt soil conservation techniques. Improved access to financial resources will also allow this group of farmers to acquire more inputs and to hire external labor.

All three models show positive and significant effects of education and extension on technical efficiency. These results are not surprising since the average level of formal education among the sampled households is only 3.6 years. Furthermore, the analysis reveals substantial inefficiency for household production in El Salvador and Honduras, indicating considerable potential for profitability improvement. Thus, emphasis on improving farmers’ human capital by supporting agricultural training, extension and educational programs seems warranted.

Table 1. Variable Definition and Means

VARIABLES	DEFINITION	ALL	HIGH	LOW
Practices	Percentage of total land with soil conservation practices	0.5	0.7	0.3
Age	Age of the household head	48.0	46.4	49.5
Education	Average level of education for household's members ≥10 years old	3.6	3.7	3.3
Gender	1 if the household head is a man (*dummy*)	0.9	0.9	0.9
Family Size	Number of people in the household	5.3	5.4	5.2
Land	Total number of Manzanas devoted to agricultural production	5.9	2.8	8.8
Slope	1 if the average slope is greater than 15% (*dummy*)	0.6	0.6	0.6
Ownership	1 if the household owns more than 50% of the farm (*dummy*)	0.7	0.8	0.6
Frequency	Number of visits by an extensionist to the farm	2.0	1.9	2.1
Years	Number of years involve with the projects	3.1	3.1	3.1
Credit	1 if the household uses financial credit (*dummy*)	0.3	0.3	0.2
Perception	1 if farmer is aware of the erosion problem in the area	0.81	0.93	0.69
Participation	1 if the household head participate in an organization (*dummy*)	0.6	0.6	0.6
H. Income	Total household income (US$)	2,110.6	2,347.9	1,860.4
Off-Farm Income	Wage labor in off-farm activities (US$)	541.0	517.4	565.9
Purchased Inputs	Total expenditure in variable inputs (US$)	657.8	799.9	507.9
Family Labor	Total family labor (working days)	43.5	47.1	39.7
Hired Labor	Total hired labor (US$)	20.3	24.6	15.6
Adults	Number of people in the household over the age of 15	3.0	2.8	3.5
PAES 1	Household with PAES 1 (*dummy*)	148	97	58
PAES 2	Household with PAES 2 (*dummy*)	162	83	79
PAES 3	Household with PAES 3 (*dummy*)	155	64	84
CAJON	Household with CAJON (*dummy*)	174	84	90
No. of Households		**639**	**328**	**311**

Table 2. Second-Stage Stochastic Production Frontiers

Variable[1]		ALL		HIGH		LOW	
		Coef.	SD	Coef.	SD	Coef.	SD
Constant		-3.045***	*0.492*	-4.208***	*0.547*	-3.018***	*0.325*
Land		0.078*	*0.054*	0.144*	*0.080*	0.047*	*0.027*
Purchased Inputs		0.244***	*0.098*	0.243***	*0.098*	0.254***	*0.111*
Family Labor		0.312***	*0.048*	0.326***	*0.062*	0.228**	*0.108*
Hired Labor		0.109	*0.079*	0.076	*0.077*	0.144*	*0.080*
Adults		0.078*	*0.028*	0.089**	*0.038*	0.081**	*0.040*
Slope		0.009	*0.009*	0.011	*0.014*	0.005	*0.012*
W_1		--	--	0.163*	*0.094*	--	--
W_2		--	--	--	--	0.218*	*0.136*
PAES 1		0.301***	*0.082*	0.323***	*0.078*	0.277***	*0.083*
PAES 2		0.316***	*0.094*	0.322***	*0.071*	0.297***	*0.112*
PAES 3		0.228**	*0.108*	0.291**	*0.153*	0.111**	*0.055*
Quadratic and interaction terms excluded due to space limitations							
Inefficiency Model							
Constant		-2.985*	1.268	-2.794***	*0.757*	1.781*	*0.988*
Age		0.007	0.012	0.002	*0.003*	0.005	*0.007*
Education		-0.412***	0.175	-0.715**	*0.340*	-0.301**	*0.126*
Gender		-0.996**	0.504	0.708**	*0.317*	-0.729**	*0.365*
Frequency		-0.439*	0.237	-0.312*	*0.162*	0.201**	*0.088*
Years		0.104	0.154	0.031	*0.038*	0.036	*0.050*
Credit		-0.215	0.447	-0.211	*0.196*	-0.227*	*0.134*
Ownership		0.701	0.558	0.598*	*0.311*	0.111	*0.120*
Participation		-0.235	0.344	-0.122	*0.136*	-0.076	*0.210*
Sigma-squared	σ^2	0.621***	*0.128*	0.842***	*0.111*	0.595***	*0.066*
Gamma	γ	0.805***	*0.051*	0.672***	*0.071*	0.832***	*0.048*
log-likelihood		-540.85		-675.36		-715.89	
Mean TE		***0.77***		***0.83***		***0.74***	
Returns to Scale		***0.82***		***0.87***		***0.75***	

* 10% level of significance, ** 5% level of significance, ***1% level of significance.

[1] The dependent variable is total household income, measured in US dollars.

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