TECHNICAL EFFICIENCY OF CORN PRODUCTION IN SINALOA, MEXICO.

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Abstract

This study examines the extent to which technical efficiency is related to certain corn producers' characteristics. With data gathered by survey, 229 farms in the Sinaloa valley, Mexico are used to estimate a stochastic frontier model in 2016. The main finding of this work is that membership to a farmers' association has a positive effect on efficiency. There is also a positive relationship between efficiency and formal education, age, property of land and soil analysis. The prevailing level of efficiency among maize producers is .84, implying there is room for improvement with the current technology.

Keywords: *Technical efficiency, Corn production, Stochastic frontier model.*

Introduction.

The variation in technical efficiency in agriculture have been mainly estimated in Asian countries like India (Batesse and Coelli 1995, Ali and Gupta 2011, Bhattacharyya and Pal 2011) and China (Chen and Song 2008, Wang and Rungsuriyawiboon 2010), and in African countries like South Africa (Pauw and Punt 2007) and Kenya (Anderson et al 2008, Kibaara and Kavoi 2012). However, measurements of agricultural technical efficiency in Latin-American countries and especially in Mexico have received notably less attention. For the purpose of this paper, efficiency is defined as the firm's ability to produce the maximum amount of output given a set of inputs and technology.

To the best of our knowledge, no empirical investigation of efficiency of Mexican farmers has been conducted. In addition, there is no literature currently available particularly concerned with evaluating farm specific factors that might be associated with the ability of Mexican farmers to reach the technically efficient frontier in corn production. Therefore, this work estimates the level of technical efficiency/inefficiency of corn producers in the state of Sinaloa. The estimation is done through the analysis of data that contains farm specific input quantities and demographics, using the stochastic frontier model (SFM). Such a model allows us to identify the impact of social, economic, and management practices specific characteristics.

Corn is a symbol of the Mexican culture and the most important agricultural product in the country. It is the base product of the Mexican diet and it is grown all around the country in a variety of agricultural practices embracing subsistence agriculture and irrigated, highly efficient lands. Tortilla, a product elaborated from corn, supplies more than half of the calories and one third of the protein consumed by the population (Trigo and Lechuga 2001).

Mexico is the fifth largest consumer of corn in the world (253 kg/per capita). According to Becerra (2014) for the year 2010, apparent consumption amounted to 30.5 million tons, of which 25% corresponds to imports. This makes Mexico one of the main producers of corn in the world, just behind the United States, China, UE, and Brazil. As noted, local production does not meet national demand; Mexico imports around 10 million tons of corn every year, mainly from the US, its main commercial partner. This suggests that there is room for farmers to allocate more corn production within the domestic market.

In the Sinaloa valley, some farmers have been able to achieve 14 ton/ha, which is above the national average yield of 7.7 ton/ha, this implies that there is potential to increase corn

productivity in the country. It is therefore necessary to estimate the prevailing level of technical efficiency/inefficiency, as well as demographics, socio-economics, and management specific characteristics that impact corn production.

The high levels of productivity of farmers from the state of Sinaloa relative to nationwide average level are particularly interesting, according to official data from the Department of Agriculture (SAGARPA) in 2010, Sinaloa is the main corn producer with a total production of 5.4 million of tons by year (22% of total production). Sinaloa's productivity is remarkable, on average; it produces 7.7 tons per hectare which is more than double of the country's average yield (3.3 ton/ha), and still very superior compared to the world's average productivity (4.6 ton/ha). If we assume all farmers face the same technology and have access to the same inputs, we can ask, what drives efficiency? What are the farm specific characteristics that allow some farmers to achieve the best performance? To address these questions, we test a set of farm specific characteristics using the Stochastic Frontier Model first developed by Aigner, Lovell, and Schmidt (1977) Although we considered a number of such characteristics, we are particularly interested in determining whether belonging to the Confederation of Agricultural Associations of Sinaloa (CAADES) increases farm efficiency.

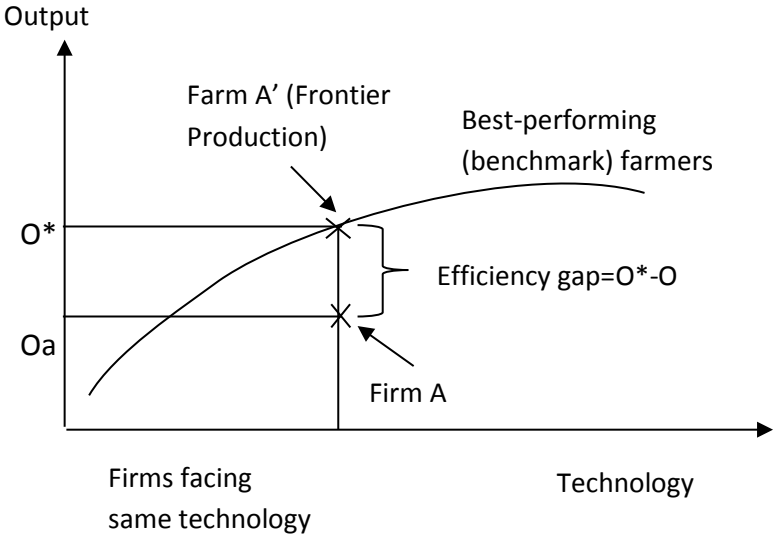
Founded in 1932, CAADES is an agency aimed at increasing farmers' competitiveness independent of farm's type (fruits, grains, vegetables, etc.) and size. Some of its main functions include: giving farmers support and guidance to get access into new-international markets; it also negotiates with input suppliers to get lower input prices for its associates. In addition, it helps farmers in the process of getting financial loans from domestic and international institutions. Finally, CAADES promotes extension knowledge and research and developments. These are just some of the main functions and certainly, one might think that farmers are better off being

members of such agency. However, many farmers in Sinaloa decide not to associate with CAADES. In fact, in the data we use for this study, around 48% of surveyed farmers reported to have links with the agency. This raises the next questions: why do some of the farmers decide not to be a member of CAADES? And, does CAADES really drive farmers' technical efficiency in the Sinaloa valley? To address these research questions we analyze primary data through the estimation of a stochastic frontier efficiency model. Specifically, this study intends to determine if CAADES membership decreases the level of technical inefficiency of corn producers in the Sinaloa valley. Thus, we set the next hypothesis, H_0: CAADES membership help to decrease the level of technical inefficiency of corn producers in the Sinaloa valley.

Empirical Model

The Stochastic Frontier model (SFM) as it appears in the current literature was originally developed by Aigner, Lovell, and Schmidt (1977). In this model, Efficiency (TE) is defined as the firm's ability to produce the maximum amount of output given a set of inputs and technology. Stated in a different way, technical inefficiency refers to the gap between the benchmark firms which maximize operating characteristics and thus lies over the efficient frontier and firms that lie below the efficient frontier. See figure 1 for a visual illustration of this analysis. Thus, in contrast to a regular production function, SFM allows for inefficiency as it does not assume that all farmers are producing the best possible outcome. SFM can be classified into two basics categories: parametric and non-parametric. The main difference between the two categories is that parametric frontier model relies on a specific functional form, whereas non-parametric frontier models do not (Amor and Muller 2010). In this study, we use the parametric approach because of data limitations.

Figure 1. Illustration of Technical Efficiency Gap Based on Best-Performing Farmers



Source: Adapted from Luo and Homburg (2008)

The main advantage of SFM over the traditional ordinary least squares is that the latter yields estimation just on the average firm; whereas the estimation of a SFM will be most heavily influenced by the best performing firms and hence reflect the technology they are using. Also, the frontier function represents a best-practice technology against which the efficiency of firms within an industry can be measured (Coelli 1995). Following Chavez et al (2012), the essential form of the model is:

$$y_i = f(\beta' X_i) + e_i \quad (1).$$

Where y_i is the output of the ith farmer in the sample (i=1,2,…,I), $X_i$is a (1×k) vector of input quantities used by the ith farmer, $\beta$is a (k×1) vector of parameters to be estimated, $f(\beta' X_1)$ is a parametric form of underlying technology, $e_i$is a stochastic error term as denoted by Batesse and Coelli (1995)

$$e_i = v_i - u_i \quad (2).$$

Where $v_i$is the symmetric component, it accounts for random variation in output due to factors outside the farmer's control (rainfall, extreme weather), v_i is two-sided statistical noise component and it is assumed to be independently and identically distributed as $N(0,\ \sigma_v^2)$ independent of u_i. And $u_i$is a non-parametric random variable, associated with technical inefficiency. The asymmetric component u_i is a non-negative random variable and it is assumed to be independently distributed with truncations (at zero) of the normal distribution with mean μ_i and variance, $\sigma_u^2[N(\mu_i,\ \sigma_u^2)]$ (Kumbhakar and Lovell 2002). Following this logic, the mean of technical inefficiency effects, μ_i, can be specified as:

$$\mu_i - \sum \delta_k Z_k \qquad (3).$$

Where $Z_k$is a (1×m) vector of farm-specific variables associated with technical inefficiency, and $\delta_k$is a (m×1) vector of unknown parameters to be estimated.

Thus, the variance of e_i is$\sigma^2 = \sigma_u^2 + \sigma_v^2$, and the standard error is calculated as: $\gamma = \frac{\sigma_u^2}{\sigma_v^2}$, the parameter gamma determines whether a stochastic frontier model is preferred as opposed to a traditional production function model (Kalirajan 1981). If we fail to reject the null $H_0: \gamma = 0$ implies the absence of a stochastic frontier in terms of production.

Under this horizon, TE could be written as:

$$TE_i = \frac{y_i}{f(X_i\beta)exp(v_i)} \qquad (4).$$

This is the ratio of observed output to the maximum possible output given technology characterized by exp$\{v_1\}$. And y_i reaches its maximum of $\left[f\left(X_{i,}\beta\right)exp\{v_i\}\right]$ only when TE_i=1.

If $TE_i < 1$ then we have a gap between the observed output of farmer ith and the maximum possible output characterized by$\{v_1\}$. . We can reframe equation (1) as

$$y_i = f(\beta X_i) exp\{v_i\} exp\{-u_i\} \quad (5).$$

In equation (3) $TE_i = exp\{-u_i\}$ for simplification of the analysis this is the structural form used in this work. Assuming $f(\beta X_{i,})$ behaves as a Cobb-Douglas function, the SFM transforms to

$$Logy_i = \beta_0 + \sum \beta_n LogX_{ni} + v_i - u_i$$

For our purposes, the empirical model takes the form

$$LnY_i = \beta_0 + \beta_1 lnx_1 + \beta_2 lnx_2 + \beta_3 lnx_3 + \beta_4 lnx_4 + \beta_5 lnx_5 + v_i - u_i \quad (6).$$

Where Y_i is the observed output of the ith farm, x_1 is labor, x_2 is money spent on water per hectare, x_3 is quantity of fertilizer, x_4 is capital and x_5 is money spent per hectare during the planting cycle in order to capture those administrative expenditures such as communications and other office duties. And $\beta' s$ are parameters to be estimated. We use the Battese and Coelli (1996) inefficiency model to estimate TE. The model is specified as:

$$u = \delta_0 + \delta_1 z_1 + \delta_2 z_2 + \delta_3 z_3 + \delta_4 z_4 + \delta_5 z_5 + e_1 \quad (7).$$

Here, u is the inefficiency effect, $z_1$is a dummy variable =1 when the ith farmer is a member of CAADES, 0 otherwise, z_2 is farmers' level of education, z_3 is age of farmer, z_4 is a dummy variable =1 when the farmers owns the planting area, 0 otherwise; z_5 is a dummy variable to differentiate farmers that conducted a soil analysis prior to the production process, all variables are fully described in table 1.

Data collection method

The data collected for this project is primary data. It was obtained directly from farmers located in the interest region of Sinaloa via a survey. The "Expo-Agro Sinaloa 2016," is a yearly event celebrated in Culiacan, the largest city of the state that conglomerates buyers and sellers from the agriculture industry. It is a highly visited event by farmers of the region. Expo-Agro Sinaloa is organized to promote economic transactions between farm input suppliers and farmers. Numerous companies utilize this event to introduce their innovations and gain a larger customer base. The event is also recognized as a good forum where agricultural researchers present their work. In early February, 2016 we attended the event and asked farmers to complete our survey.

Two hundred and thirty three farmers were randomly selected and surveyed. They were asked to quantify a full set of inputs in order to capture the production function, as well as some personal characteristics needed to assess the notion of efficiency on the second stage of the SFM. Of the original 233 surveys, 4 questionnaires were eliminated due to unrealistic responses. Thus, we were able to get 229 responses during the field-work. Table 1 presents descriptive statistics for variables in equations (6) and (7) including names of variables, units, means, standard deviations, and minimum and maximum values. It shows that the average yield per hectare is around 11tons using 21 hours of labor per day, 535 kilograms of fertilizer, spending around $3,000 on water per hectare, with an average capital of 12 million. In addition, the average total cost of the planting cycle equals $28200 pesos per hectare.

The farm specific characteristics' variables were employed in technical efficiency analysis. 48% of farmers in the sample are CAADES members. Which is consistent with other studies that show that the ratio of membership in agricultural groups is 40% (Viengpasith, Yabo,

and Sato 2012); average age is 54 years old. Farmers in the sample are well educated compared with farmers from other developing countries, in average they have completed 9 years of formal education. 76% are property owners and 64% completed the planting cycle without conducting any soil analysis.

Table 1. Variables description and summary statistics

Variable	Description	Mean	Stnd Dev	Min	Max
Output	Total yield per hectare	11.50	1.97	3.5	16.50
Labor	Total of man-hours per day.	21.67	2.60	1.0	255
Water	Money spent in water applied by hectare by month (MX$).	3039.60	934.11	100	6000
Fertilizer	Quantity of fertilizer applied by hectare in kilograms.	535.78	113.67	250	900
Capital	Value of capital equipment in million (MX$).	12.37	24.82	0.07	230
Spent	Total amount of money spent during the planting cycle per hectare (MX$).	28226.86	4319.99	10000	39000
CAADES	Dummy variable =1 if farmer is a CAADES member, 0 otherwise.	.48	.50	0	1
Education	Level of education of farmer (years).	9.31	4.03	1	17
Age	Age of farmer.	54.66	12.37	24	86
Owner	Dummy variable=1if farmer owns the planting area, 0 otherwise.	0.76	0.42	0	1
Soil	Dummy variable = 1if soil analysis was conducted, 0 otherwise.	0.36	0.48	0	1

Source: Author's computation (2012)

Results

Estimation was conducted using the econometric software LIMDEP 10, sigma-squared coefficient (.2283) is significant at the 1% level, indicating a good fit of the model and that the assumption of the compound error term is correct. The gamma (γ), parameter is close to one, suggesting that differences in corn production in the Sinaloa valley are due to technical inefficiency; as Batesse and Coelli (1996) noted, it indicates that the random component of the inefficiency effects does make a significant contribution in the analysis of agricultural production. This result confirms the presence of the one-sided error component in the specified model and thus, the traditional OLS model is an inadequate representation of the data.

The mean technical efficiency level prevailing in the region is 84% indicating that there is room for farmers to increase their efficiency by 16% with the available inputs and current technology. The minimum level of TE = 0.67 and the maximum TE = 0.98

Before analyzing the results of the inefficiency parameters, it is interesting to notice that a negative sign on an inefficiency parameter implies that the associated variable has a positive impact on technical efficiency or a decrease in inefficiency; whereas a positive sign on the inefficiency parameters means the associated variable negatively impacts technical efficiency.

In support of our prediction, the results suggest that CAADES has negative value of -.0437 and it is significant at the 1% level, indicating that farmers that are CAADES members tend to be slightly more productive that their counterpart non-CADES members. Thus, we failed to reject the null hypothesis. The reason underlying this interpretation is that CAADES helps its members to access new markets, increasing the chance to get better sale prices. CAADES members also have more access to information about technology and how apply it to farm

practices. CAADES also provide some technical assistance, moreover, it also give associates better opportunities to access financial loans. Hence membership to CAADES is a crucial factor for farmers accessing agricultural information and enhancing their ability to apply agricultural technology.

The coefficient of education has a negative sign and is statistically significant at the 5% level, indicating that farmers with higher level of education tend to have higher level of efficiency. Education is very important in agriculture, educated farmers have the opportunity of make better decisions through more access to information on production systems, technology, input prices, and are more able to interpret market needs. In addition, educated farmers tend to be more innovative and are more willing to use hybrid seeds, machinery, and pesticides.

Results show that capital is also a variable that reduces technical inefficiency of farmers, although it is not significant it has the expected sign. It should be noticed that capital variable embraces different issues, as tractors, trucks, warehouses, etc. Thus, farmers with higher levels of capital are assumed to implement better agricultural practices.

Age coefficient is negative, suggesting that older farmers tend to be more efficient than younger farmers. We attribute this relationship to experience that farmers acquire as time passes by. Table 2 presents the set of results.

Table 2. Stochastic frontier model and efficiency estimates.

Variable	Coefficient	Standard Error	Prob Z
SFM			
Constant	-.6670	.7466	.3716
Ln(labor)	-.0630**	.0257	.0144
Ln(water)	.1738***	.0136	.0000
Ln(fertilizer)	.0256***	.0079	.0012
Ln(capital)	.0134*	.0070	.0567
Ln(spent)	.1390**	.0702	.0477
EFFICIENCY			
CAADES	-.0437***	.0131	.0010
Education	-.0075**	.0131	.0000
Age	-.0012**	.0005	.0145
Owner	-.0565***	.0132	.0000
Soil	-.0217*	.0115	.0618
Σ squared(v)	.0052		
Σ squared(u)	.0441		
Sigma(v)	.0724		
Sigma(u)	.2107		
Sigma	.2283***	.0007	.0000
Gamma	.8944		
Lambda	2.9103***	.4314	.0000
Mean efficiency	.84		

*, **, and *** significant at the 10, 5% and 1% levels, respectively.

Source: Author computation.

Conclusion

The present study has estimated the level of technical efficiency of corn producers in Sinaloa, Mexico, and identifies farm-specific characteristics influencing efficiency. The data were obtained directly from farmers located in the interest region of Sinaloa via a survey. A Stochastic Frontier Model was used to examine technical efficiency using the computer software LIMDEP 10.

The key findings were that the estimated coefficients for labor, water, fertilizer, level of capital and total amount of money spent per hectare were positive to corn production. Indicating that if any of these inputs were optimistically improved there could be an increase in crop yields.

The technical efficiency of farmers in the region of interest was 84%. The implication is that technical efficiency in corn production in Sinaloa could be improved by 16% through a better use of available resources and current technology.

Also significantly related to technical efficiency were farmer's level of education, farmer's age, property of planting land, soil analysis and CAADES membership. Higher level of education and experience gained through time imply that farmers are more likely to obtain higher technical efficiency. Thus, age and level of education enhance agricultural product development as well as decisions to improve productivity. Farmers that own the planting area tend to be more efficient than their counterpart, farmers that rent the land. In addition, producers that conduct soil analysis as a cultural practice are also more efficient. Finally, farmers that are CAADES members are more likely to be technically efficient than those who do not. It could be said that CAADES membership played a critical role in farming productivity. This is important in terms of policy development. Policy makers should foster farmers to become CAADES members. In

addition, government could decide to foster CAADES participation in the agriculture industry through subsidies aimed to potentiate the benefits of being a CAADES member.

This study could be replicated in other productive areas of the country, like Jalisco and Michoacan, altogether conform the top three producers nationwide. It might be the case that the main producer (Sinaloa) is not the more efficient. Furthermore, the methodology could be useful to address the relative importance of farmers' associations around the world, which are called to improve farmers' performance.

To the best of our knowledge, this is the first study that addresses the level of technical efficiency in the region, and the first one in determining if membership to an agricultural association or group impacts farmers' productivity in the state of Sinaloa, Mexico. However, this study is not exempt of limitations; first, the study might be improved with a larger sample size. A larger sample size would probably show more variation in output and thus the level of technical efficiency could vary. In addition, the study could be conducted using different specifications of Stochastic Frontier Model like the truncated-normal truncated, exponential, and/or normal-gamma specifications, with the objective of comparing the results and determine whether or not a different specification would be preferable.

Further research should be conducted in order to completely determine if CAADES membership is really making a significant difference in the agricultural field in Sinaloa. Efforts should be made in testing if CAADES also makes a significant contribution for other farmers' type, like tomato growers. Because one of the main benefits of CAADES membership is the opportunity to access international markets, produce from Sinaloa oriented to exportation should be considered as the predicted variable.

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