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FARM HOUSEHOLD EFFICIENCY IN MOZAMBIQUE

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Abstract

This article provides estimates of farm household efficiency and its determinants among smallholder farmers in Mozambique. A translog stochastic frontier production function and a first difference model incorporating a model of farm household inefficiency effects are applied to test the existence of agricultural farm household inefficiencies and their determinants in Mozambique. The null hypothesis of equal farm household efficiency among households was rejected.

Variation in farm household efficiency indicates that access to agricultural technology is a severe constraint for most farm households. Factors such as access to advisory services, access to rural credit, membership to an agricultural association, use of improved agricultural technology (irrigation, improved seeds, animal traction and chemical inputs), were found to reduce significantly the level of household farm household inefficiencies.

The stochastic production frontier shifted outwards but many farmers did not move along with it. Changes in access to extension, access to credit explain changes in the inefficiency change between 2002 and 2005.

Key words: *stochastic frontier analysis, farm production efficiency*

JEL Code: C12, C13

Introduction

Despite the growth of national agricultural output in recent years, there is widespread concern that agricultural output and contribution to gross domestic product are well below those attainable, and that, given future population growth this may constrain achievement of food security and poverty reduction objectives. A wide gap exists between actual farm yields and potential yields identified in field trials, pointing to potential technical inefficiency in their current farming practices.

Heavy reliance on antiquated farming techniques; poor complementary services such as extension, credit, marketing, and infrastructure; and ineffective (Arndt et al., 2002) agricultural policies are among the major factors that have greatly retarded the development of Mozambique's agriculture. Despite its dominant share in the country's total agricultural output,

smallholder agricultural production lacked the necessary attention in the country's agricultural development efforts in the past. One of the major policy shifts since the change of government in 2004 has been the substantial emphasis placed on improving the productivity of smallholder agriculture through increased use of a package of improved agricultural technologies, the so called "Green Revolution".

Without good extension services there are possibilities for farmers to experience greater production inefficiency and hence loss of potentially obtainable output from new technology due to lack of familiarity with the new technology, market information and credit. There is, however, lack of adequate empirical evidence regarding the production efficiency of farmers in Mozambique. The objective of this paper is to investigate the extent and determinants of relative technical efficiency indices of smallholder farmers in Mozambique. The rest of the paper is organized as follows. The next section presents the analytical framework and the data and empirical procedures are presented in the third section. In the fourth section, the results are presented and discussed and the last section draws conclusion and implication for development policy.

Analytical Framework

The analytical approach used is based on a framework where production technology is defined with reference to a stochastic production frontier. The production function expresses output as a function of inputs and farm household inefficiencies which capture the degree to which farm households produce below the frontier level of production (see Kumbhakar and Lowell, (2000)).

Stochastic Frontier Analysis (SFA) originated with two papers independently published by Meeusen and van den Broeck (1977) and Aiger, Lovell, and Schmidt (1977). SFA provides information about maximum output relative to a best practice frontier through the inclusion of an additional error term representing farm household inefficiency. This non-negative random component included in the error term measures the ratio of actual to expected maximum output, given inputs and the existing technology. The parametric specification of this frontier is shown in translog form in equation (1) below.

$$\ln y_i = \beta_o + \sum_i^n \beta_i \ln x_i + \frac{1}{2} \sum_{i=1}^n \sum_{j=1}^n \beta_{ij} \ln x_i \ln x_j + v_i - u_i \quad (1)$$

where $u \geq 0$ and $u = \delta Z$

Several hundred papers, describing either methodological issues or empirical applications of these models, have appeared in the literature. Bauer (1990), Greene (1993), and Kumbhakar and Lovell (2000) provide overviews of developments in this area in varying levels of detail. The stochastic frontier models are typically estimated using the maximum likelihood (ML) method.

The SFA can also be readily applied to panel data (Battese and Coelli, 1995). Indexing production units by $i = 1, 2, \dots, n$, the stochastic output frontier is given by:

$$y_{it} = f(x_{it}, \beta) e^{v_{it} - u_{it}} \quad (2)$$

for time $t = 1, 2, \dots, T$, y_{it} output, x_{it} a $(1 \times k)$ vector of inputs and β a $(k \times 1)$ vector of parameters to be estimated. The error term v_{it} is assumed to be independently and identically distributed as $N(0, \sigma_v^2)$ and captures random variation in output due to factors beyond the control of households. The error term u_{it} captures household -specific farm household inefficiency in production, specified by:

$$u_{it} = z_{it}\delta + w_{it} \quad (3)$$

where z_{it} is a $(1 \times m)$ vector of explanatory variables, δ a $(m \times 1)$ vector of unknown coefficients and w_{it} a random variable such that u_{it} is obtained by a non-negative truncation of the parent distribution $N(z_{it}\delta, \sigma_u^2)$. The farm household efficiency of the i -th household in the t -th period for the basic case can be defined as

$$TE_{it} = \frac{E(y_{it} | u_{it}, x_{it})}{E(y_{it} | u_{it} = 0, x_{it})} = e^{-u_{it}} = \exp(-z_{it}\delta - w_{it}) \quad (4)$$

The efficiency measure must have a value in the interval $(0,1]$.

The empirical stochastic frontier model is usually specified in (natural) logs, so the inefficiency term, u_{it} can be interpreted as the percentage deviation of observed performance, y_{it} from the household's own frontier. The model is estimated using maximum likelihood (MLE).

An ordinary least square (OLS) of the first difference between the periods is estimated as indicated by equation 5

$$\Delta \ln Y_i = \Delta \ln a + \sum_{j=1}^3 \beta_j \Delta \ln X_{ji} + \sum_{j < k=1}^3 \sum_k^3 \beta_{jk} \Delta \ln X_{ji} \Delta \ln X_{ki} + D + e \quad (5)$$

where $\Delta \ln Y_i$ is the first difference in the real output between period 2 and period 1 for each household;

X_i represents the difference in the natural logs of dependent variables between the two cropping seasons; District dummy variables (D) were included in the translog production function.

First differencing allows to effectively control for household fixed effects and to take into account changing technology (Hicks neutral) so that the change in the logarithm of agricultural output is explained by the change in the constant term, the change in the returns to explanatory

variables and the change in the value of the explanatory variables. The changes in the explanatory variables represent changes in household endowments.

The technical coefficient for the OLS estimation of the first difference model were used to re-estimate the farm household efficiency model for both cropping seasons 2001/02 and 2004/05.

Data

The data used in this analysis come from a detailed rural household survey of about 4,908 rural households in 80 districts in 2002, and 6,149 households interviewed in 94 districts in 2005 in Mozambique. A panel data set was built covering 4104 households that were included in both surveys. The rate of attrition (households that moved away or dissolved between TIA02 and TIA05) was 16%. The “Trabalho de Inquérito Agrícola” known as TIA surveys are designed to be representative of rural zones at provincial and national levels. Both TIAs were explicitly designed as rural income surveys.

Figure 1 illustrates de number of days of drought in each province in the two cropping seasons (2001-02 and 2004-05). The cropping season 2004/05 had in virtually all the provinces, a higher number of drought days.

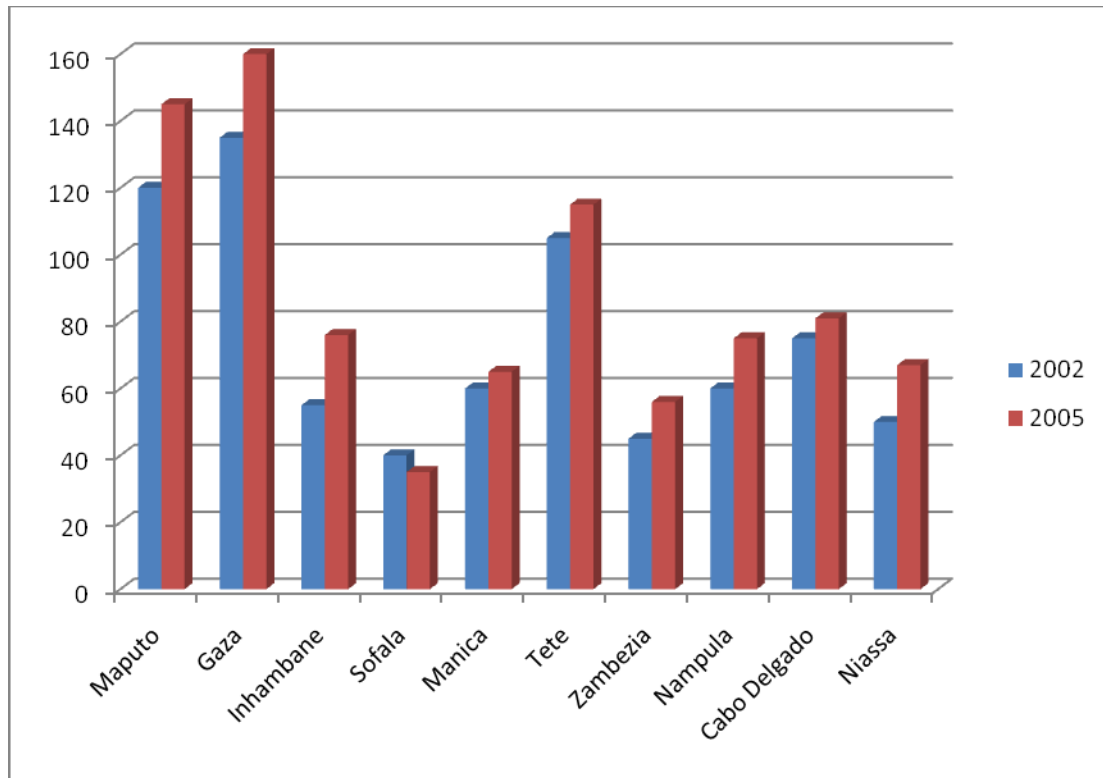


Figure 1 Number of Drought Days per Province per Agricultural Season
Source: Calculated by the author with data from INAM

The cropping season 2004/05 had a higher number of days without rain in almost every province with the exception of Gaza when compared to the cropping season captured by TIA 2001/02.

Table 1 presents the descriptive statistics for 2002 and 2005 for most of the variables used in the stochastic frontier production analysis and on the determinants for the farm household efficiency analysis. The Table shows that the mean real output was higher in 2002 than 2005. The number of people reporting drought occurrence was also higher in 2004/05 (0.91) than in 2001/02 (0.85). In 2004/05 a higher acreage was under cultivation and as a consequence there was a higher use of labor and higher use of intermediate inputs.

Table 1 Descriptive Statistics Dependent and Independent Variables Used

Variable	2001/02				2004/05			
	Mean	StD	Min	Max	Mean	StD	Min	Max
Ln Output (baskets)	6.11	1.10	-0.6	10.7	5.90	1.40	-0.7	10.6
Ln labor (adults)	1.50	1.00	0.0	5.8	1.60	1.00	0.0	3.6
Ln Cultivated area (ha)	0.37	0.90	-4.9	3.7	0.50	0.90	-5.6	4.2
Ln Input cost	1.98	1.30	1.6	10.8	2.10	1.60	1.6	14.9
Head gender (1 if male)	0.77	0.40	0.0	1.0	0.70	0.40	0.0	1.0
Age (years)	44.30	14.90	14.0	99.0	46.60	14.90	15.0	99.0
eduhead1	0.10	0.30	0.0	1.0	0.10	0.30	0.0	1.0
eduhead2	0.05	0.20	0.0	1.0	0.10	0.20	0.0	1.0
eduhead3	0.01	0.10	0.0	1.0	0.00	0.10	0.0	1.0
Grow cotton	0.07	0.20	0.0	1.0	0.10	0.20	0.0	1.0
Grow tobacco	0.04	0.20	0.0	1.0	0.03	0.16	0.0	1.0
Grow horticulture	0.71	0.45	0.0	1.0	0.91	0.28	0.0	1.0
Extension	0.15	0.36	0.0	1.0	0.19	0.39	0.0	1.0
Association	0.05	0.22	0.0	1.0	0.09	0.29	0.0	1.0
Credit	0.035	0.25	0.0	1.0	0.04	0.25	0.0	1.0
Use irrigation	0.16	0.37	0.0	1.0	0.16	0.37	0.0	1.0
Use fertilizer	0.05	0.23	0.0	1.0	0.05	0.22	0.0	1.0
Use pesticide	0.08	0.27	0.0	1.0	0.06	0.24	0.0	1.0
Use animal traction	0.21	0.41	0.0	1.0	0.18	0.38	0.0	1.0
drought	0.85	0.36	0.0	1.0	0.91	0.29	0.0	1.0

Source: TIA 2002, TIA 2005 and author's calculations

Most household heads are male. In 2001/02 crop growing season 77% of the heads were male. Data indicate that the proportion of female headed households is growing. Modern input use is low with fertilizer use at about 5% and pesticide use at about 8% and only 6% in 2005. According to TIA 2002 data, only 5% of households were members of an agricultural association. The number of households reporting being part of an association grew to 9% in 2005. Education of the household head was one of the socio-demographic variables used as a proxy to human capital. Household head education was divided into four categories. For both years around 84% of the household heads were illiterate.

Empirical Models

In this paper, a translog production function as indicated in equation 5 is used. The translog production function nests as special cases the constant elasticity of substitution (CES) and Cobb-Douglas production function.

Variables in the Empirical Model

The dependent variable is the natural logarithm of the total real crop output per household. This single output is an aggregate of multiple crop outputs. The natural log of such an output is represented in Figure 2. The shape of the histogram is close to the normal distribution as shown by the solid line. The analysis is conducted for those household that are part of the panel. There were 4010 households in the panel data.

The regressors used in the model are farm size in hectares, labor (number of adults in farming), input costs, animal traction, fertilizer, pesticides and whether a farm did or did not grow cotton and/or tobacco. Land and labor are transformed using the natural logarithm transformation before they are used in the estimation of farm household coefficients. Both land and labor are the two major inputs in smallholder agriculture in Mozambique.

Capital use in Mozambican agricultural is negligible. Most farmers use hand hoes. Intermediate input use was represented by the cost of inputs used (seeds, fertilizer and pesticides). Dummies indicating the type of farmers (cotton growers or tobacco growers) users or non users of animal traction, agro ecological or administrative regions were incorporated into the production and farm household efficiency function.

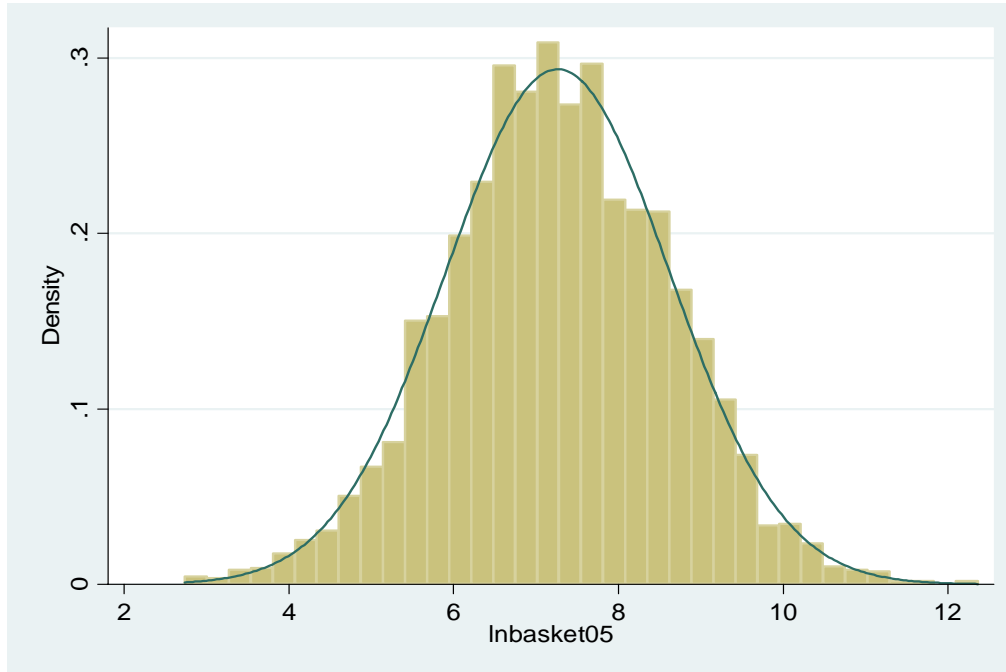


Figure 2 Natural Log Real Output per Rural Household in 2005

The dependent variable in the farm household efficiency model is the stochastic error term (measured in the same units as the dependent variable in the stochastic production model) of each household. The estimated inefficiency index obtained from the model was made an explicit function of available socioeconomic variables.

The determinants of farm household efficiency are estimated using household characteristics such as household head age (years), household head level of education, smallholder membership of an agricultural association (1=yes, 0=no), access to extension services (1=yes, 0=no), and gender of household head (1 =male and 0=female). Access to credit for farming (1=yes, 0=no) and whether the household has any off-farm activity or not, were used as proxies of financial capital. Another set of dummy variables capturing technology use were: use of improved seeds; fertilizer use; pesticide use, access and use of animal traction, use of crop rotation, and hiring of temporary and permanent workers.

Results and Discussion

The maximum-likelihood (ML) estimates of the parameters of the stochastic frontier production function are presented in Table 4. STATA was used to estimate the stochastic frontier model. The results are presented for cross sectional data for cropping season 2001/02, cropping season 2004/05, pooled for the two cross sectional data and an ordinary least square for the first difference model between the two cropping seasons. First, we present the coefficients for the stochastic production function and then present the technical inefficiency coefficients and its determinants.

The Stochastic Frontier Farm Household Model

The ML estimates for the translog farm household model results presented below indicate that area is the key determinant of the composite output value measured in natural logarithms of the number of basket per household. All the coefficients in the farm household model are interpreted as elasticities of real output with respect to inputs (area, labor and input costs). The area cropped has positive elasticity is highly significant for all the cross section data for 2002, 2005, the pooled data and even for the OLS for the first difference as can be seen in Table 2. Labor is only statistically significant for the pooled data. The combined labor and squared labor is significantly different from zero in all specifications.

The results shown in the last column of Table 2 are the robust ordinary least square (OLS) regression on the first difference model. The changes in output between the period 2002 and 2005 are explained by changes in the labor (0.07), area cropped as indicated by the highly significant elasticity coefficient (0.36) and changes in the purchased inputs use (0.07).

Table 2 Stochastic Frontier Translog Production Model

	Frontier 2002	Frontier 2005	Frontier Pooled	Robust OLS First difference
Labor	0.007	0.010	0.289**	0.067*
Area	0.494***	0.614***	0.463***	0.355**
Input use	0.040	-0.040	0.094	0.07*
Labor squared	0.022	0.002*	-0.067	-0.005
Area squared	0.037**	0.078***	0.063***	-0.011
Input cost squared	0.004***	0.0150*	0.004	-0.004
Labor*area	-0.088*	-0.063***	-0.048	-0.007
Area*cost	0.001	0.007	0.013	0.019
Labor*cost	0.035	-0.047	-0.762	0.050
_Iagroecol_3	-0.021	-0.162	-0.762**	
_Iagroecol_4	-0.209*	-0.007	-0.398**	
_Iagroecol_5	-0.201*	0.172	-0.504**	
_Iagroecol_6	-0.007	0.184	-0.529***	
_Iagroecol_7	-0.358***	-0.495***	-0.416**	
_Iagroecol_8	-0.385***	-0.66***	-0.376**	
_cons	6.66***	6.62***	8.45***	-0.466**

Source: Models' results

The coefficients on the intermediate inputs are statistically insignificant in all stochastic frontier models. The constant term in the first difference robust OLS model is negative and highly significant. This reflects a downward shift in the production frontier probably due to a less favorable rainfall year in the cropping season 2004/05 as indicated earlier in the data description.

Farm Household Efficiency Estimates

The efficiency estimates range from as low as 1 per cent to as high as 100 per cent. Table 3 presents the descriptive statistics (mean, standard deviation, minimum and maximum) of the estimated household agricultural farm household efficiency in 2002 and 2005 as well as pooled estimates. The table also presents the estimates of farm efficiency for 2002 and 2005 after the estimation of a difference model using OLS.

All models have shown that agricultural production (income) has come largely from bringing new agricultural land into production. A critical question relates to the scope for meeting future food needs of Mozambique through continuation of land expansion.

Table 3 Farm Efficiency Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
Efficiency 2002	0.60	0.16	0.04	0.95
Efficiency 2005	0.53	0.18	0.01	0.92
Efficiency 2002 after OLS	0.65	0.17	0.04	1.00
Efficiency 2005 after OLS	0.60	0.19	0.01	0.99
Efficiency pooled	0.65	0.15	0.05	0.89

Source: Author's calculations

Figure 3 below shows the cumulative distribution of efficiency for both TIA 2002 and TIA 2005. The cumulative distribution of relative efficiency indices in 2002 shows a first degree stochastic dominance when compared to the relative efficiency distribution in 2005.

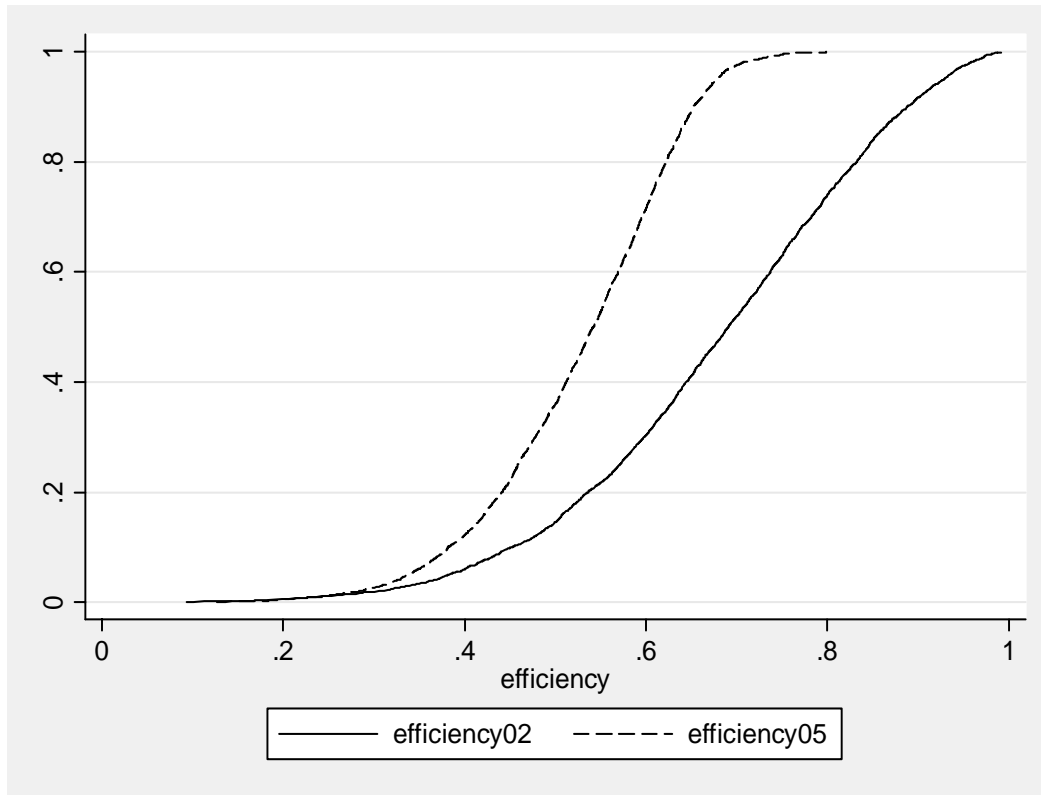


Figure 3 Combined Farm Household Efficiency for TIA 2002 and TIA 2005
Source: Author's calculation

Farm efficiency was statistically and significantly higher in 2002 than in 2005 at a $t=39.03$ and $t=28.48$ respectively for the indices calculated using stochastic frontier and for the indices calculated after applying the OLS on the difference of the two cropping seasons. Climatic factors may have played a role in the difference in the performance as indicated earlier.

Results of the inefficiency model for 2002, 2005, the pooled data and first difference are presented in Table 4. Most the parameters have the expected signs. On average, female headed households are less efficient than male headed household as indicated by the positive and significant coefficient on the inefficiency model. The last two columns of Table 6 provide the determinants of the farm household efficiency for both 2002 and 2005 once noise has been controlled by first differencing between the two years. This was performed using the production

function coefficients from the first difference model shown in Table 3 to each year being analyzed. The production function and the determinants of inefficiency were estimated simultaneously using maximum likelihood estimation.

Results indicate that male headed households are more likely to be efficient than female headed households, in all years using cross sectional data, pooled data or first differencing the panel data. This result is discussed in more detail below.

Age of household head is used as a factor in the inefficiency model to account for such differences in quality and also longer experience in management decisions. The age of the household head was not consistently significant. The older farmers tend to be less efficient according to the cross section models. This is consistent with Okike et al. (2004) finding that age seemed to negatively affect efficiency, as older farmers may be experienced in using traditional technology but may be slow in adopting new technology and learning its management. On the first difference specification, the impact of age is insignificantly different from zero.

Schooling did not significantly affect the farm household efficiency as shown in Table 4. This does not seem surprising since farming in Mozambique is still rudimentary and where more educated households show a higher propensity to engage in more profitable non-farm activities. The low use of improved inputs and tools across the households might explain why there are no discernible differences among households head with different level of schooling. Thus, this result may explain why the expectation of Schultz (1964) that, education increases the ability to perceive, interpret, and respond to new events, enhancing farmers' managerial skills including efficient use of agricultural inputs were not met.

Contrary to what was found in these models, education is arguably an important factor that affects productivity and efficiency. Kumbhakar et al. (1989) suggest that education increases the productivity of labor and land on Utah dairy farms while Kumbhakar et al. (1991) also show that education affects production efficiency. Huang and Kalirajan (1997) find that average household education level is positively correlated with farm household efficiency levels of both maize and rice production in China.

Table 4 Results of the Farm Inefficiency Model

Insig2u	Farm Household Efficiency			Efficiency (First Difference)	
	2002	2005	Pooled	2002	2005
Hh gender (1 if male)	-0.334**	-0.248**	-0.220**	-0.532**	-0.388**
Hh age	0.003	0.005**	0.007**	-0.002	0.004
Schooling (1-3 yrs)	0.103	-0.165	-0.07	0.156	-0.215
Schooling (4-5 yrs)	-0.276	0.060	-0.355	-0.345	-0.025
Schooling (>5 yrs)	0.013	-0.424	-1.335	-0.080	-0.854
Grow cotton	-0.943**	-0.885**	-0.445*	-1.763**	-1.064**
Grow tobacco	-2.69**	-2.38**	-1.63**	-2.735**	-2.136**
Grow horticulture	-0.231**	1.621*	0.018	-0.292**	2.503
Hh extension	-0.306**	0.070	-0.32**	-0.398**	0.048
Hh association	-0.092	-0.267	-0.49**	-0.200	-0.334
Hh Credit	-0.03	-0.04	-0.04	-0.03	-0.04
Use irrigation	-0.090	0.065	-0.141	0.060	0.127
Use fertilizer	0.077	0.324	0.189	-0.950	-1.016
Use pesticide	0.286	-0.60**	0.194	-0.133	-2.185**
Use animal traction	-0.143	0.161	0.157	-0.348	0.025
drought	-0.320	0.202	-0.175	-0.334**	0.217
Crop diversification	-0.24***	-0.033	-0.152**	-0.486**	-0.208**
_cons	0.865***	-1.145**	0.060	1.671	-1.365

Source: Model results

Cotton and or tobacco growers were associated with higher farm household efficiency as indicated by the negative and significant coefficients shown in the Table 7. Cash crop growers receive technical assistance from buyers, as well as inputs such as fertilizers (mostly the tobacco growers) and pesticides (particularly the cotton growers). The use of fertilizer and pesticide did

not significantly impact the farm household efficiency with exception of pesticide use in 2005. The effects of fertilizers and pesticides may have been confounded with the variable indicating the growing of cotton and tobacco.

In this study the higher the crop diversification, as measured by the number of plots grown by each household, the higher the farm efficiency. The results indicated in Table 4 show a significant decrease in farm household inefficiency with the number of plots.

All other variables in the model were not statistically significant. Similar models were run for different provinces and results did not significantly differ from those presented here.

Female headed households were less efficient than male headed households in all cases. This result could arise because a larger fraction of women spend time doing other non-farming household activities whose output is not measured here. It is also possible, however, that the low efficiency scores of female headed households are the result of poor access to new technologies, poor access to capital needed to invest in these technologies as well as poor access to agricultural extension services.

Conclusion and Policy Implications

This paper has presented an economic analysis of farm household efficiency among rural households in Mozambique, where crop activities generate a large part of household income. Using stochastic frontier analysis, the results show evidence of the role of bringing new agricultural land into production as the driving force toward output growth. Econometric analysis of two income rural surveys (TIA 2002 and TIA 2005) shows that cropped area and labor are important inputs and are strongly associated with the total output.

The analysis reports evidence of farm household inefficiency (where farmers do not make use of the best available technology). Large gains in real output can be achieved if technical efficiency can be increased. The results depict a wide gap between the farmers who are quite poor in their efficiency performance (10%) and the highly efficient ones (99%). There is room for farmers to learn from their peers who are more efficient. If any extension work is to be extended to these farmers, it is important to include the other farmers who are more technically efficient.

Raising farmer efficiency represents one great opportunity for enhancing food production through identification and widespread promotion of innovative crop and resource management practices. The existence of substantial performance variation among farmers indicates that knowledge of producing crops and livestock is not uniformly distributed among farmers. Identifying and promoting innovative practices thus offers an opportunity to help farmers raise production through adoption of these practices. However, this requires reorientation of extension services towards promoting not only new technology but also innovative management practices.

The traditional new seed-based extension needs to be renewed to cater for the needs of farmers who cultivate local varieties but who could benefit greatly from innovative crop management options.

Analyses of determinants of inefficiency indicate that households led by males, who have access to extension services, those who grow cash crops such as cotton or tobacco and those households with higher crop diversification, are more likely to be more efficient than the other households.

What policy interventions would be appropriate to increase efficiency at rural household level? The results suggests that policy makers might fruitfully place more emphasis on rural

extension to increase the probability that farmers in such areas will adopt new agricultural technologies, particularly improved seeds, chemical inputs such as fertilizer and pesticides as well as irrigation all important for a green revolution. The lack of government capacity to deliver an efficient agricultural extension service, make it worthwhile to consider the use of 'outgrower schemes'. The term 'outgrower scheme' refers to schemes where agri-business has considerable control over the smallholder production process, providing a large number of services, such as input credits, technical advisory services and guarantee output purchase.

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