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Economic Efficiency and Subsidized Farm Inputs: Evidence from Malawi Maize Farmers

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Abstract

Although agriculture is widely regarded as a major channel through which poverty and food insecurity in Africa can be curtailed, the continent's agricultural productivity has been abysmal. Farm input subsidy is becoming a popular policy tool that African governments are using to improve agricultural productivity. Because agricultural productivity is closely linked with efficiency in the use of existing farm inputs, this study uses stochastic frontier analysis to investigate efficiency among farmers and how it is affected by farm input subsidy programs using Malawi maize farmers as a case study. The study finds that farm input subsidy improves efficiency among farmers but even with subsidy, farmers are only 47% efficient in production. Input subsidy alone is therefore not enough to promote agricultural productivity via improvements in farmers' efficiency. Other programs such as irrigation should be promoted along with subsidies.

Introduction

Improvement in agricultural productivity is widely regarded as a major channel through which the widespread food insecurity and poverty in Africa can be curtailed and even eradicated (Future Agricultures, 2010). This notion is based on the well-known fact that majority of the poor and food insecure in Africa derive their livelihood from agriculture. Unfortunately, agricultural productivity has been abysmal since the 1960s - average annual growth in agricultural productivity is less than 1% for the continent as a whole, and negative for some sub-regions. A key step towards improvements in agricultural productivity is the determination of the level of farmers' efficiency in production. This will provide a more informed direction for policy interventions. If farmers are reasonably efficient new inputs and technologies will be the requirement for increased productivity, otherwise improvements in input delivery, extension systems, farm management services, farmers' skills etc. will be the way forward (Ali and Byerlee, 1991).

The “poor-but-efficient” hypothesis of Schutlz (1964) - an enduring thought in the development literature - postulates that smallholder farmers in traditional settings are reasonably efficient in the allocation of scarce resources by positively responding to price incentives. Shultz argue that because traditional farmers mainly use their own resources and are experienced in doing so, they are able to make the most efficient use of resources in their environment. Although the hypothesis has received both anecdotal and empirical backing from development economists and policy makers, it can be criticized on the grounds that contemporary agriculture in the developing world is hardly traditional (Ali and Byerlee, 1991). Agriculture in Africa for instance is currently characterized by a continually changing technical and economic environment making it more difficult for farmers to adjust allocative decisions to keep pace with changes in their environment, and at the same time, maintain an efficient allocation of resources. Moreover, when farmers face different prices and have different factor endowments, efficiency goes beyond the confines of mere input allocation to encompass the production of a given level of output with minimum inputs, and the allocation of outputs in a revenue-maximizing manner (Kumbhakar and Lovell, 2003; Ali and Flinn, 1989). Accordingly, the first objective of this study is to determine the level of efficiency of farmers in the use of existing farm inputs.

Attempting to increase agricultural productivity, African governments are re-embracing farm input subsidy programs that phased out in the 1990s in response to the structural adjustments programs imposed by the World Bank and the International Monetary Funds (IMF). Because these subsidy programs account for substantial share of national agricultural budgets, their impacts have been widely investigated. Ricker-Gilbert, Jayne and Black (2009) and Chibwana et al. (2012) studied the effects of input subsidy programs on farm yield. Other studies investigated the impacts of input subsidy programs on household income and other measures of wellbeing (Ricker-Gilbert and Jayne, 2010; Chibwana, 2010); fertilizer use and demand for commercial and organic fertilizers (Ricker-Gilbert and Jayne, 2009; Ricker-Gilbert, Jayne and Chirwa 2011; Chibwana, 2011); and cropland allocation (Chibwana et al. 2011).

The impact of farm subsidy programs on farmers' efficiency level is however yet to be investigated. The study believes that there is the tendency of subsidized inputs affecting the efficiency of farmers since subsidies increases farmer's access to farm inputs. Thus, the second objective of the study is to investigate the effect of subsidized inputs on farmers' efficiency in production (i.e. do subsidized inputs crowd-out or crowd-in efficiency in production?)

The study concentrates on maize farmers in Malawi because the current farm subsidy program in Malawi has a relatively wider coverage (in term of beneficiaries) than any other farm subsidy program in Africa. The wider coverage of the program allows for the categorization of farmers into three fairly balanced groups: users of only subsidized inputs, users of only commercial inputs, and users of both subsidized and commercial inputs. Such a categorization is necessary if the impact of a subsidy program on farmers' efficiency is to be well investigated. The focus is on maize farmers because maize production is one of the primary focuses of the Malawi farm subsidy program

The study contributes to literature by being the first to analyze the impact of farm input subsidy programs on the efficiency of farmers.

Conceptual Framework

Efficiency is usually analyzed by its two components - technical and allocative efficiency – through the use of frontier production functions (Wadud and White, 2000). It has however been argued that the production function approach to measuring efficiency may not be appropriate when farmers face different prices and have different factor endowments (Ali and Flinn, 1989). This led to the application of stochastic profit function models to estimate farm specific efficiency directly (Ali and Flinn, 1989; Wang et al., 1996). The profit function approach combines the concepts of technical and allocative efficiency in the profit relationship and any errors in the production decision are assumed to be translated into lower profits or revenue for the producer (Ali et al., 1984). Profit efficiency is therefore defined as the ability of a farm to achieve highest possible profit given farm-specific prices and levels of fixed factors. Profit inefficiency in this context is defined as the loss of profit for not operating on the frontier (Ali and Flin, 1989). This study adopts the profit function approach primarily because food crop farmers in Malawi face different prices.

Battese and Coelli (1995) extended the stochastic production frontier model by suggesting that the inefficiency effects can be expressed as a linear function of explanatory variables, reflecting farm-specific characteristics. The advantage of this model is that it allows the estimation of farm specific efficiency scores and the factors explaining the efficiency differentials among farmers in a single stage estimation procedure. Following Rahman (2002), this study utilizes the Battese and Coelli (1995) model by postulating a profit function, which is assumed to behave in a manner consistent with the stochastic frontier concept. The stochastic profit function is defined as:

$$\pi_i = \mathrm{f}\left(P_{ik},\ Z_{im}\right).\exp e_i \tag{1}$$

Where π_i is normalized profit of the i[th] farm and computed as gross revenue less variable cost divided by the farm specific output price. P_{ik} is the price of the k[th] variable input faced by the i[th] farm divided by output price; Z_{im} is the level of the m[th] fixed factor on the i[th] farm; ande_i is an error term.The error term is assumed to behave in a manner consistent with the frontier concept (Aliand Flinn, 1989), i.e.

$$e_i = \mu_i + L_i \qquad (2)$$

where μ_i is assumed to be independently and identically distributed $N(0, \sigma_L^2)$, two sided random errors, independent of the L_i; and the L_i is a non-negative random variable, associated with inefficiency in production. L_i is assumed to be independently half-normally with mean $L_i = -\delta_o - \sum_i \delta_d X d_i$ and variance $\sigma_L^2(|N(L, \sigma_L^2|)$ where X_{di} is the d[th] explanatory variable associated with inefficiencies on farm *i* and δ_o and δ_d are unknown parameters. To investigate the impact of subsidy programs on farmer's level of efficiency,X_{di} include subsidy variables among other covariates.

The profit efficiency of farm *i* in the context of the stochastic frontier profit function is defined as:

$$EFF_i = E[\exp(-L_i)|\mu_i] = E[\exp(-\delta_o - \sum_i \delta_i X_i)|e_i] \qquad (3)$$

Where E is the expectation operator. This is achieved by obtaining the expressions for the conditional expectation of L_i, the observed value of e_i. The method of maximum likelihood is used to estimate the unknown parameters, with the stochastic frontier and the inefficiency effects functions estimated simultaneously.

Empirical Model

Stochastic profit frontiers are usually estimated with either Cobb-Douglas or translog functional forms. The former functional form is a restrictive version of the later. Normalized profit is expressed as a function of normalized price of variable inputs (seed, fertilizer, and hired labor wages) and quantities of fixed inputs (family labor and plot area) in both functional forms. The translog model is expressed as.

$$ln\pi_i = \beta_o + \sum_{j=1}^{3}\beta_j \, lnP_j + \sum_{l=1}^{2}\alpha_l lnZ_l + 0.5\sum_{j=1}^{3}\sum_{k=1}^{3}\tau_{jk} lnP_j \; lnP_k + \sum_{j=1}^{3}\sum_{l=1}^{2}\theta_{jl} lnP_j lnZ_l + 0.5\sum_{l=1}^{2}\sum_{t=1}^{2}\delta_{lt} lnZ_l lnZ_t + \mu_i + L_i \qquad (4a)$$

and $L_i = \sigma_0 + \sum_{m=1}^{9}\varphi_m C_m + \vartheta S_i + \varepsilon$ (4b)

Where

π_i = plot level profit normalized by output price

P_j = price of the variable input j normalized by output price

Z_l = quantity of fixed input l

C_m = Household socio-demographic characteristicand plot-specific condition

S_i = quantity of subsidized fertilizer acquired by household i.

The error term of equation (4a) has two components -μ_i, the statistical disturbance term; and L_i, profit inefficiency measure. Equation (4b) expresses profit inefficiency as a function of covariates including the socio-demographic features of farmers, plot-specific conditions and subsidy variables.

When $\tau_{jk}, \theta_{jl}\ and\ \delta_{lt}$ are jointly equal to zero, equation 4(a), the translog functional form, reduces to the Cobb-Douglas functional form.

Following Rahman (2003) the elasticity of profit with respect to variable input prices and fixed factors are calculated from the parameter estimates of the joint estimation of the deterministic profit function (equation 4a), the input shares equations of the three variable inputs, and the output share equation. The input and out share equations are given by equations (5a) and (5b) respectively.

$$S_j = -\frac{P_j X_j}{\pi} = \frac{dln\pi}{dlnP_j} = \beta_j + \sum_{k=1}^{3} \tau_{jk} lnP_k + \sum_{l=1}^{2} \theta_{jl} lnZ_l \quad (5a)$$

$$S_y = \frac{P_y X_y}{\pi} = 1 + \sum_{j=1}^{3} \beta_j + \sum_{j=1}^{3} \sum_{k=1}^{3} \tau_{jk} lnP_j + \sum_{j=1}^{3} \sum_{l=1}^{2} \theta_{jl} lnZ_l \quad (5b)$$

Where S_j is the share of the jth variable input, S_y is the share of output, X_j is quantity of input j, and X_y is quantity of maize produced. Since the input and output share together form a singular system of equations, the output share equation is dropped and the remaining share equations and the profit function are estimated jointly using the seemingly unrelated regression function in stata.

The profit elasticity with respect to the prices of the variables inputs, the quantities of the fixed inputs and the prices of the maize output are given by $\frac{dln\pi}{dlnP_j}$, $\frac{dln\pi}{dlnZ_l}$ and $\frac{dln\pi}{dlnP_y}$ respectively.

Dealing with possible endogeneity of the quantity of subsidized fertilizer

The quantity of subsidized fertilizer acquired by a household is likely to be endogenous because subsidized fertilizer coupons are not distributed randomly – coupon are distributed to households according to specific household characteristics which may be not be observable (Ricker-Gilbert et al., 2011). In view of this, endogeneity of “quantity of subsidized fertilizer” is tested using the Durbin-Wu-Hausman (Davidson and Mackinnon, 1993; Salidas and Cramon-Taubadel, 2012). Following Salidas and Cramon-Taubadel (2012), an auxiliary tobit regression of quantity of subsidized fertilizer on an instrumental variable and the other independent variables in the original inefficiency model is estimated. The instrumental variable used is the number of years the household head has lived in the community. The number of years that the household head has lived in the community is a sociopolitical capital that can influence the quantity of fertilizer that a household receives (Ricker-Gilbert, 2011). Following the estimation of the tobit auxiliary regression, the frontier model is estimated including the residuals of the auxiliary regression as an additional regressor in the inefficiency model. Under the null hypothesis of no endogeneity, the coefficient on the additional residual term equals zero. If the null hypothesis is rejected, the frontier model will be re-estimated, replacing the endogenous variable with the fitted values from the auxiliary tobit regression.

Data

The study uses the Malawi Third Integrated Household Survey (IHS3) dataset. The sampling design of the survey was based on the cartography of the country's 2008 Population and Housing Census (PHC). Apart from the island district of Likoma, the survey covered the three major regions of the country: North, Center and South. The three regions were segregated into urban and rural strata, with the urban strata consisting of Lilongwe City, Blantyre City, Mzuzu city and the Zomba municipality. The other (27) areas are rural. For easy of data handling, the analysis is conducted at the plot (farm) level rather than the household level. In all, 2891 maize plots were included in the analysis. As mentioned earlier, the study concentrates on maize farmers, mainly because maize production is one of the focal points of the farm input subsidy program in Malawi. The data on tobacco, the other important crop in the subsidy program, is quite scanty.

Results and Discussion

Descriptive Statistics

The summary statistics of the variables in the model are presented in table 1. On average, 11.618 Kg of maize seed and 61.422 Kg of inorganic fertilizer are applied on 1.546 acres of farm land. The average family and hired labor per plot were 336 hours and 1.664 days respectively. The small average plot size and the high family to hired labor ratio are consistent with the nature of farming in most developing countries where farmers produce primarily for subsistence reasons with little or no capital investment. The high inorganic fertilizer application (61.422 kg per 1.546 acres of land) – which is uncommon in developing countries - can be attributed to the large scale fertilizer subsidy program that the Malawi government is currently implementing. About 48.273% of the households used only subsidized inorganic fertilizer; another 27.520% used both subsidized and commercial inorganic fertilizers; and the rest used only commercial inorganic fertilizer.[2] The hired labor wage and the prices of maize seed and inorganic fertilizer faced by the average household are 58.29 KW per day, KW 162.65 per Kg and KW 37.096 per Kg respectively. The prices of maize seed and inorganic fertilizer that the average household faced are lower than their respective market prices because majority (about 76%) of the households

[2]The fertilizer subsidy program notwithstanding, a large number of farmers do not use fertilizer for affordability reasons. Per the specific objectives of the study, only plots where inorganic fertilizer was applied are considered.

were beneficiaries of subsidized maize seed and inorganic fertilizers. The average profit per plot is KW 26834.

Only less than 1% of the plots were irrigated. This is representative of farming in Malawi, and other developing countries, where agricultural production is mostly rain fed. The relatively high concentration (about 51%) of plots in the Central Region is consistent with the income profile of Malawi where the residents of Central Region are relatively richer, and thus more likely to purchase and use inorganic fertilizers, than residents of other regions[3].

Profit and Inefficiency Functions

The maximum-likelihood estimates (MLE) of the parameters in the translog stochastic frontier profit function and the inefficiency function were obtained with STATA 12.0. The results are presented in table 3. A description of the variables in the functions is provided in table 2. Prior to the estimation of the profit and inefficiency functions, a likelihood ratio test for the presence or absence of inefficiency was performed. The null and alternative hypotheses of the test are $\sigma_L^2 = 0$ and $\sigma_L^2 \neq 0$ respectively; i.e. whether or not the standard deviation of L_i, the profit inefficiency measure, equal zero. The test statistic is 160, and is significant at the 1% level. Thus the null hypothesis is rejected, implying that a significant part of the variability in profits among plots is explained by existing differences in the level of technical and allocative. The joint estimation of the profit and inefficiency functions is therefore warranted.

[3] The study considers only plots where inorganic fertilizers were applied.

Profit Function

The Durbin-Wu-Hausman test for endogeneity revealed that "quantity of subsidized fertilizer" is endogenous[4]. The test statistic is significant at the 1% level; hence the null hypothesis of no endogeneity is rejected. Accordingly, "quantity of subsidized fertilizer" was in the inefficiency model was replaced with the fitted values from the tobit auxiliary regression.

Table 4 presents the profit elasticity estimates that were computed from the parameter estimates of the joint estimation of the deterministic profit function, and the input and output share equation. The parameter estimates of the joint estimation are presented in table 5. The profit elasticity with respect to the output price of maize is 2.845, meaning, all things being equal, a percentage increase in the output price of maize will increase profits by 2.845%. As expected, profit relates negatively to the prices of the variable inputs and positively to the quantity of the fixed inputs. A percentage increase in the price of fertilizer results in a 1.201% decrease in the profits; a percentage increase in seed price reduces profits by 0.461%; and a percentage increase in hire labor wage will, all things being equal, cause profits to fall by 0.83%. Thus, in terms of profits, among the variable inputs, inorganic fertilizer is the most important input, followed by seed and wage in that order. A percentage increase in hours of family labor on a plot increases profits by 0.435%. The profit elasticity 0.081 with respect to land shows that plot area has a minimal effect on profit.

[4] In order to reduce the number of tables in the paper, the detailed results of the test for endogeneity are not provided. The results can be made available by the authors upon request.

Profit inefficiency

Figure 1 presents the distribution of the profit efficiency of maize farmers. The average profit efficiency score is 46.33% which implies that improvements in technical and allocative efficiencies could increase the average profit per plot by 53.67%. Profit efficiency varies widely from 0.13% to 87.78%, with a standard deviation of 0.184. Only about 18% of the plots have efficiency scores of 70% and above. The average efficiency score is not only low among farmers in general; it is also low even among users of subsidized fertilizer. The average user of only subsidized fertilizers is only 47% while the average user of both subsidized and commercial fertilizer is only about 45% efficient. Thus there is over 50% room for improvement in efficiency even among users of subsidized inputs.

Factors affecting inefficiency

The effects of socio-demographic factors, plot-specific factors and subsidy on inefficiency are reported in the lower section of table 3. Post-secondary education increases efficiency. By virtue of higher level of education, household heads with post-secondary education are probably able to adopt agronomic practices better than their counterparts without post-secondary education. For instance, household heads with post-secondary education are more likely to follow recommendation for inorganic fertilizer application better than those without post-secondary education. Farmers in the Southern region of the country generally operate at a relatively lower level of efficiency compared to those in the Northern part of the country, but there is no significant difference in efficiency between Central and Northern farmers. The off-farm income and access to useful extension service have no significant impact on efficiency.

A simple t-test of mean difference in efficiency (table 6) shows that efficiency varies significantly across different plot-specific conditions (soil quality and use of irrigation), but these effects are not captured in the inefficiency component of the frontier model. The t-test results show that plots of good quality soil have relatively higher levels of efficiency compared to plots of fairly good and poor quality soil (table 6). Plots of fairly good quality soil also have relatively higher level of efficiency compared to those of poor soil quality. These results are expected since good quality soils contain more nutrients, and thus all things equal result in relatively higher yields, compare to poor quality soils. Like quality soil, irrigation appears to improve efficiency of plots (table 6). Plots with some form of irrigation have relatively higher level of efficiency compared to those that are entirely rain fed. Irrigation improves maize yield, particularly when rainfall is erratic, so the positive effect of irrigation on efficiency is expected.

Quantity of subsidized fertilizer, the subsidy variable – the variable of interest – has a positive and significant effect on efficiency (table 3). This implies that efficiency increases with the quantity of subsidized fertilizer that a household receives. This result is reinforced by the t-test results of some subsidy variables (tables 6). According to the t-test results, users of only subsidized inorganic fertilizer are relatively more efficient compared to users of only commercial fertilizer; and the users of both subsidized and commercial fertilizer results in relatively higher levels of efficiency than the use of only commercial fertilizer. Furthermore, beneficiaries of subsidy programs (measured by “coupon”) appear to be are relatively more efficient. Thus the results of both the frontier model and the simple t-test show that farm input subsidy improves efficiency of farmers. That notwithstanding, as mentioned earlier, the level of efficiency among beneficiaries and users of subsidized inputs is still very low. Users of only subsidized inorganic fertilizer for instance are only 47% efficient.

Conclusions and Recommendations

The study used stochastic frontier analysis to investigate production efficiency and how it is affected by farm input subsidy programs using Malawi maize producers as a case study. The study finds that maize farmers in Malawi are, on average, only 46.33% efficient in production, and that efficiency is positively affected by farm input subsidy, education and irrigation. Although the subsidy improves efficiency, efficiency among beneficiaries of the subsidy program is very low (about 47%). This reveals that although the subsidy program improves productivity, there is over 50% room for improvement in efficiency even among beneficiaries of the subsidy program. Hence pursuing subsidy program alone will be not very effective in improving agricultural productivity via improvements in farmer's efficiency. The subsidy program should be implemented along with other programs like irrigation.

References

Ali, M. and Flinn, J.C. (1989). "Profit Efficiency Among Bastimi Rice Producers in Pakistan Punjab." American Journal of Agricultural Economics, 71:2, 303-10

Ali, M. and Byerlee, D. (1991). "Economic Efficiency of Small Farmers in a Changing World: A Survey of Recent Evidence." Journal of International Development, Vol. 3 No. 1, 1-27

Battese, G. and Coelli, T. (1995). A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data, *Empirical Economics*, **20**, 325-332

Chibwana, C., Fisher, M., Shively, G. 2010."Land Allocation Effects of Agricultural Input Subsidies in Malawi."World Development Vol. 40, No. 1, pp. 124–133, 2012.

Chibwana, C., Fisher, M. Shively, G. 2011. "Cropland Allocation Effects of Agricultural Input Subsidies in Malawi." World Development 40(1): 124-133.

Chibwana, C., Jumbe, C., and Shively, G., 2010. "Measuring the Forest Impacts of Maize and Tobacco Subsidies in Malawi".Working paper, Purdue University, West Lafayette, IN.

Chibwana, C., Jumbe, C and Shively, G. 2013. "Agricultural Subsidies and Forest Clearing in Malawi."Forthcoming in Environmental Conservation 40.

Chirwa, E. W., Dorward A. and Matiat M. 2011."Conceptualizing Graduation from Agricultural Input Subsidies in Malawi". FAC SP Working Paper, Institute of Development Studies: Brighton, UK

Farrell, M. J. "The Measurement of Productive Efficiency." J. Royal Statist. Soc. Series A (general) 21(1957):253-81.

Future Agricultures.(2010). "Rising Agricultural Productivity in Africa, Options for Action and the Role of Subsidies". African Progress panel Policy Brief.

Gurara, D. Z. and Salami, A.O. (2012). Towards Sustaining Malawi's Farm Input Subsidy Program". Africa Economic Brief. Volume 3, Issue 4.

Holden S., and R. Lunduka. 2010. "Too Poor to be Efficient? Impacts of the targeted fertilizer subsidy program in Malawi on farm plot level input use, crop choice and land productivity." Unpublished Manuscript, Depart. of Econ. and Resource Management. Norwegian University of Life Sciences.

Kumbhakar S. C., Lovell, C.A.K. (2003). Stochastic Frontier Analysis.Cambridge University Press.

Mangisoni J.H. 2007. “Input voucher study in Malawi, Mozambique, and Zambia. Synthesis Report”. Food, Agriculture and Natural Resources Policy Analysis Network., September 2007.

Nganga, S.K., Kungu, J., Ridder de, M., Herrero, M. (2010). “Profit Efficiency among Kenyan Smallholders Milk Producers: A Case Study of Meru-South District, Kenya. African Journal of Agricultural Research Vol. 5(4), pp. 332-337.

Rahman S (2002). “Profit Efficiency among Bangladeshi Rice Farmers.School of Economic Studies”.The University of Manchester OxfordRoad Manchester, M13 9PL England, UK.

Ricker-Gilbert, J., Jayne, S.T. and Chirwa E. (2011). “Subsidies and Crowding Out: A Double-Hurdle Model of Fertilizer Demand in Malawi” American Journal of Agricultural Economics,93(1): 26-42.

Ricker-Gilbert, J., Jayne, S.T and Black, J.R. “Does Subsidizing Fertilizer Increase Yields? Evidence from Malawi”. Selected Paper for presentation at the Agricultural & Applied Economics Association 2009 AAEA & ACCI Joint Annual Meeting, Milwaukee, Wisconsin, July 26-29, 2009

Ricker-Gilbert, J., Jayne, S.T .” The Impact of Fertilizer Subsidies on National Fertilizer Use: An Example from Malawi”. Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Orlando, FL, July 27-29, 2008.

Schulz, T. W. (1964). *Transforming Traditional Agricultural.*Chicago: University of Chicago Press.

Wadud A, White B (2000). Farm Household Efficiency in Bangladesh: A Comparison of Stochastic Frontier and DEA Methods. Appl. Econ. 32: 1665-1673.

Wang, J., Cramer, G.L., and Wailes, E.J. (1996). Production Efficiency of Chinese Agriculture:Evidence From Rural Household Survey Data. *Agricultural Economics*, **15**, 17 – 28.

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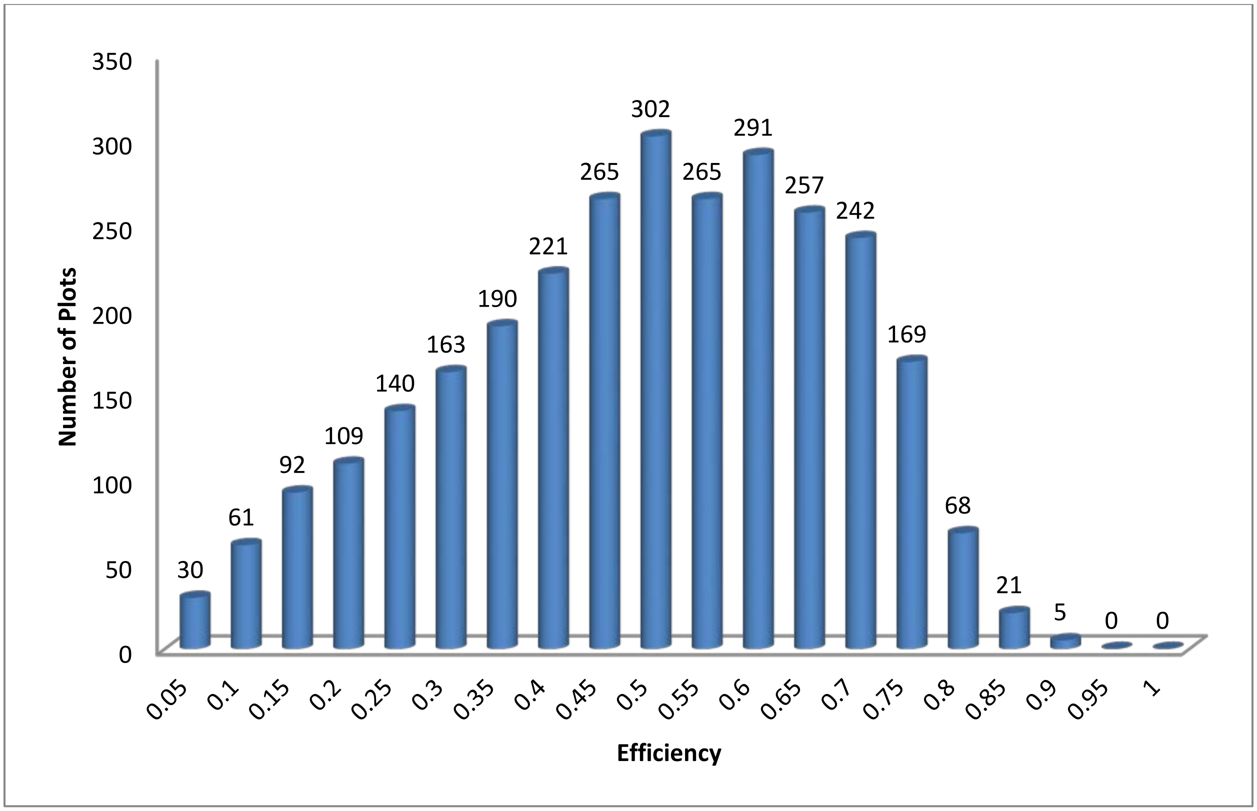
Figure 1: Distribution of Profit Efficiency of Across Plots



Mean Efficiency =0 .4633422

Standard deviation = 0.1838274

Minimum Efficiency =0 .0013143

Maximum Efficiency =0 .8778083

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Table 1: Summary Statistics

Continuous Variable	Mean
Age of household head (years)	41.986
Off-farm income (KW)	37402.670
Price of inorganic fertilizer faced by household (KW/Kg)	37.096
Price of maize seed faced by household (KW/Kg)	162.650
Hired-labor wage faced by household(KW/day)	58.290
Hours of family labor	335.999
Days of hired labor	1.664
Area of plot (acres)	1.546
Price of maize faced by household (KW/Kg)	54.827
Plot level profit (KW)	26833.740
Categorical variables	**Proportion (%)**
Gender of household head	
Male	85.176
Soil quality of plot	
Good	47.192
Fair	43.251
Poor	9.557
Education	
Post-secondary education	8.091
No post-secondary education	91.908
Fertilizer use	
Users of only subsidized fertilizer	48.273
Users of only commercial fertilizer	24.206
Users of both subsidized and commercial fertilizer	27.520
Sample Size (Total number of plots)	2867

Table 2: Definition of Variables in the Frontier Model

Variable	Description
P_fert	Price per kg of inorganic fertilizer
P_seed	Price per kg of maize seed
Wage	Wage per day of hired labor
Fam_labor	Hours of family labor used on farm from planting to harvesting
Land	Area of plot (acres)
Soil_good[a]	A dummy variable for plot soil quality (=1 for good soil quality)
Soil_fair	A dummy variable for plot soil quality (=1 for fairly good soil quality)
Rainfall	A dummy variable for source of water (=1 entirely for rainfed)
Male	A dummy variable for gender of household head (=1 for male)
Education	A dummy variable for education (=1 for post-secondary education)
Central	A dummy variable for region of Malawi (=1 for Central region)
South	A dummy variable for region of Malawi (=1 for Southern region)
Income	Household non-agricultural income (in Malawian Kwachas)
Extension	Whether or not the household head received useful extension service (=1 useful extension information received)
Rainfall	Whether or not rainfall is the only source of water for the plot (=1 for only rainfall i.e. no irrigation)
Only_sub_fertlizer	A dummy variable for fertilizer use (=1 if only subsidized fertilizer is used)
Only_comm_fertilizer	A dummy variable for fertilizer use (=1 if only commercial fertilizer is used)
Coupon	A dummy variable for coupon usage (=1 when a household purchased some quantity of inorganic or maize seed with a subsidized farm input coupon)
Sub_fertilizer	Kg of subsidized inorganic fertilizer that a household received

[a]*Refer to table 1 (under categorical variables) for the omitted group of the dummy variables*

Table 3: Maximum Likelihood Estimates of Profit Frontier Function

Variables	Coefficients
Profit Function	
Intercept	6.919 (0.419)***
lnP_fert[b]	-0.043 (0.050)
lnP_seed	0.411 (0.142)***
ln Wage	-0.1943 (0.156)
lnFam_labor	-0.328 (0.139)**
ln Area	0.508 (0.148)***
½ lnP_fert x lnP_fert	-0.016 (0.009)*
½ lnP_seed x lnP_seed	0.008 (0.033)
½ ln Wage x ln Wage	0.053 (0.046)
lnP_fert x lnP_seed	-0.011 (0.007)
lnP_fert x ln Wage	0.008 (0.009)
lnP_seed x ln Wage	0.005 (0.033)
lnP_fert x lnFam_labor	-0.001 (0 .006)
lnP_fert x ln Area	0.030 (0.008)***
lnP_seed x lnFam_labor	-0.078 (0.024)***
lnP_seed x ln Area	0.025 (0.033)
lnP_Wage x lnFam_labor	0.037 (0.026)
lnP_Wage x ln Area	0.027 (0.037)
½ lnFam_labor x lnFam_labor	0.085 (0.026)***
½ ln Area x ln Area	0.058 (0.034)*
lnFam_labor x ln Area	-0.009 (0.025)
Variance Parameters	
σ_μ^2	0.642 (0.023)
σ_L^2	1.287 (0.042)
$\sigma^2 = \sigma_\mu^2 + \sigma_L^2$	2.069 (0.089)
$\gamma = \sigma_L^2 / (\sigma_\mu^2 + \sigma_L^2)$	0.622
Lamda	2.005 (0.060)
Log Likelihood	-4049.9822
Inefficiency Effects	
Intercept	-1.97 (2.360)
Male	-0.138 (0.093)
Education	-0.319 (0.187)*
Central	0.004 (0.141)
South	0.227 (0.119)*
Income	-0.000 (0.000)
Extension	0.789 (0.897)
Soil_good	-0.170 (0.116)
Soil_fair	-0.100 (0.117)
Rainfed	2.542 (2.107)
Quantity of subsidized fertilizer	-0.0109 (0.005)**

****, **, and * imply significance at the 1%, 5% and 10% levels respectively.*
[a]*Values in parenthesis are standard errors.*
[b]*ln represents natural logarithm.*

Table 4: Estimated Profit Elasticities

Prices and fixed inputs	**Elasticity**
With respect to	
Maize price	2.845
Fertilizer price	-1.201
Seed price	-0.461
Wage	-0.183
Land	0.081
Family labor	0.435

Table 5: Joint Estimation of Translog Profit Function with Variable Input Shares

Variables	**Coefficients**
Intercept	5.685 (0.415)[a]***
lnP_fert[b]	-0.073 (0.049)
lnP_seed	0.346 (0.138)**
ln Wage	-0.156 (0.156)
lnFam_labor	-0.247 (0.138)*
ln Area	0.485 (0.142)***
½ lnP_fert x lnP_fert	-0.020 (0.009)**
½ lnP_seed x lnP_seed	0.063 (0.031)**
½ ln Wage x ln Wage	0.027 (0.043)
lnP_fert x lnP_seed	-0.007 (0.007)
lnP_fert x ln Wage	0.007 (0.009
lnP_seed x ln Wage	0.016 (0.031)
lnP_fert x lnFam_labor	-0.001 (0.006)
lnP_fert x ln Area	0.026 (0.008)***
lnP_seed x lnFam_labor	-0.076 (0.023)***
lnP_seed x ln Area	0.021 (0.032)
lnP_Wage x lnFam_labor	0.032 (0.026)
lnP_Wage x ln Area	0.036 (0.038)
½ lnFam_labor x lnFam_labor	0.070 (0.025)***
½ ln Area x ln Area	-0.017 (0.027)
lnFam_labor x ln Area	-0.010 (0.025)
Fertilizer Share	
Intercept	0.387 (0.090)
lnP_fert[b]	0.387 (0.090)***
lnP_seed	-0.178 (0.353)
ln Wage	0.000 (0.445)
lnFam_labor	0.075 (0.329)
ln Area	0.075 (0.436)
Seed Share	
Intercept	-0.017 (0.270)
lnP_fert[b]	0.043 (0.012)***
lnP_seed	0.360 (0.049)***
ln Wage	0.045 (0.062)
lnFam_labor	0.014 (0.046)
ln Area	-0.083 (0.061)
Hired Labor Share	
Intercept	0.975 (0.609)
lnP_fert[b]	-0.019 (0.028)
lnP_seed	-0.107 (0.110)
ln Wage	0.386 (0.139)***
lnFam_labor	-0.224 (0.103)**
ln Area	-0.150 (0.136)

***, ** and * imply 1%, 5% and 10% levels of significance respectively.

[a]*Values in parenthesis are standard error*

Table 6: Profit Efficiency by Key Categorical Variables

Category	**Efficiency**
Profit loss by level of education	
Post-secondary education	0.490
No post-secondary education	0.461
t-ratio (Post-sec vs No post-sec)	-2.305**
Profit loss by access to useful extension service	
Access	0.463
No access	0.576
t-ratio (Access vs No acess)	1.4970
Profit loss by region	
Northern	0.511
Central	0.452
Southern	0.434
t-ratio (Northern vs Central)	7.344***
t-ratio (Northern vs Southern)	7.893***
t-ratio (Central vs Southern)	2.017**
Profit loss by soil quality	
Good	0.478
Fair	0.457
Poor	0.419
t-ratio (Good vs Poor)	4.843***
t-ratio (Good vs Fair)	2.866***
t-ratio (Fair vs Poor)	3.146**
Profit loss by use of irrigation	
Entirely rain fed	0.462
Irrigation	0.772
t-ratio (rain fed vs irrigation)	4.7793***
Profit loss by coupon	
Users	0.468
Non users	0.448
t-ratio (Users vs Non-users)	-2.581***
Profit loss by fertilizer use	
Users of only subsidized fertilizers (Users_S)	0.470
Users of only commercial fertilizers(Users_C)	0.448
Users of both subsidized and commercial fertilizers(Users_SC)	0.466
t-ratio (Users_S vs Users_C)	2.582***
t-ratio (Users_S vs Users_SC)	0.430
t-ratio (Users_C vs Users_SC)	-1.741*
All plots	**0.467**

***, ** and * imply 1%, 5% and 10% levels of significance respectively.