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Small is Beautiful: Empirical Evidence of an Inverse Relationship between Farm Size and Productive Efficiency in Small-Holder Cassava Production in Ideato North LGA of Imo State.

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Abstract
This study examined the relationship between farm size and technical efficiency in small holder cassava production in Ideato LGA of Imo state using data from a 2008 farm-level survey of 90 rural households. The study showed a strong inverse relationship between farm size and technical efficiency. Smaller farms are found to be more technically efficient, than larger farms. These results favour land redistribution policies targeted towards giving lands to the small-holder farmers. Policies of de-emphasizing cassava production in the estate sector while encouraging it in smallholdings will foster equity and efficiency.

Keywords: Farm Size, Productivity and Technical Efficiency
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Introduction
Cassava is a staple food crop in South-Eastern Nigeria. It contributes about 15% of the daily dietary energy intake of most Nigerians and supplies about 70% of the total calories intake of about 60 million people in Nigeria (Ezulike *et al*., 2006). Nigeria is the world's largest producer of cassava, with about 45.75 million metric tones and ranks 2nd after yam in extent of production among the root and tuber crops of economic value in Nigeria (FAO, 2007). Planting of high yielding and improved varieties has resulted in higher cash income, especially in areas with access to improved processing technology and market (RMRDC, 2004)

One of the important economic arguments in favor of the equitable distribution of farmland is that smaller farms are more productive (Masterson, 2007). The majority of studies of agricultural productivity in developing countries support the view that there is an inverse relationship between productivity and farm size (Berry and Cline, 1979; Barrett, 1996; Heltberg, 1998; Hazarika and Alwang, 2003; Masterson, 2007; Gul Unal, 2008; Okoye *et al*., 2007, 2008a and 2008b). Land reform could contribute to improving both equity and efficiency in agriculture. One of the most common characteristics of developing countries is the large share of agriculture in their economies. This feature produces the widely observed inverse size-yield relationship (IR) (Gul Unal, 2008).

Due to its policy implications for employment, efficiency, equity, and sustainability, IR has been one of the most important and hotly debated topics in agricultural economics for more than 40 years. (Heltberg, 1998 and Gul Unal, 2008). One critique leveled at the literature on the productivity-farm size relationship is that the measure used, land productivity, is inappropriate. Because it only compares total output to the size of the farm, ignoring other factors of production and inputs, land productivity is said to be, at best, an incomplete measure of efficiency (Masterson, 2007). This study will address this issue. Small farms have both higher land productivity and equal or better technical efficiency. This is true even when controlling for many of the factors literature suggests as possible explanations for the inverse relationship (ibid, 2007).

Following the classical definition of Farrell (1957), a firm is considered to be technically efficient if it obtains the maximum attainable output given the amount of inputs and the technology used. Since technical efficiency is unobservable, it has to be estimated somehow. In the parametric approach the typical way to do this is to model inefficiency as part of the random term (Aigner *et al*., 1977). By examining the relationship between farm size and technical efficiency in cassava production, this paper aims to discover whether smallholder cultivation has increased efficiency. This paper explores the relationship between farm size and technical efficiency in small-holder cassava production in Ideato LGA of Imo State.

Methodology

Analytical Procedures

a. Stochastic Frontier Model

In our analysis of the data we use the Cobb-Douglas stochastic frontier production function. Since the basic stochastic frontier model was first proposed by Aigner *et al*. (1977) and Meeusen and van den Broeck (1977), various other models have been suggested and applied in the analysis of cross-sectional and panel data on producers. Some models have been proposed in which the technical inefficiency effects in the stochastic frontier models are also modeled in terms of other observable explanatory variables (Seyoum *et al*., 1996). The stochastic frontier model is defined thus;

$$\ln Yi = f(\ln Xi;\beta)\exp(Vi-Ui), \quad i = 1,2\ldots n \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where the subscript, i, indicates the ith farmer in the sample (I =1, 2, …., 90); ln represents the natural logarithm (i.e., logarithm to base e); Y represents the productivity of cassava (kg/ha); Xi is the vector of input quantities used by the i-th farm, β is a vector of unknown parameters to be estimated, f( ) represents an appropriate function (e.g Cobb-Douglas, translog etc). The Vi's are assumed to be independent and identically distributed random errors having $N(o, \sigma_v^2)$ distribution; and the Ui's are non-negative random variables, called technical inefficiency effects, which are assumed to be independently distributed such that Ui is defined by the truncation (at zero) of the $N(o,\sigma_u^2)$ distribution (i.e. half-normal distribution) or have exponential distribution. The maximum-likelihood estimates for all the parameters of the stochastic frontier and inefficiency model, defined by Eq. (1), are simultaneously obtained by using the program, FRONTIER Version 4.1 (Coelli, 1996). The technical efficiency of production of the ith farmer in the appropriate data set, given the levels of his inputs, is defined by

Technical efficiency (TE) = Yi/Yi*

$$= f(Xi;\beta)\exp(Vi-Ui) / f(Xi,\beta)\exp(Vi) = \exp(-Ui) \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where Yi is the observed productivity and Yi* is the frontier productivity. The technical efficiency of a farmer is between 0 and 1 and is inversely related to the level of the technical inefficiency effect. The technical efficiencies can be predicted using the

FRONTIER program which calculates the maximum-likelihood estimator of the predictor for Eq. (2) that is based on its conditional expectation (Battese and Coelli, 1988).

b. Empirical Model

The stochastic frontier model for farmers is defined by the the Cobb-Douglas type defined as follows:

$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + Vi\text{-}Ui$ …........……..(3)

Where Y is productivity of cassava in kg/ha., X_1 is farm size in hectares, X_2 is labour input in mandays, X_3 is fertilizer input in kg, X_4 is planting material in bundles and X_5 is capital input in naira made up of depreciation charges on farm tools and equipment, interest on borrowed capital and rent on land. β_0-β_5 are regression parameters to be estimated while Vi and Ui are as defined earlier.

Determinants of Technical Efficiency

In order to determine factors contributing to the observed technical efficiency in cocoyam production, the following model was formulated and estimated jointly with the stochastic frontier model in a single stage maximum likelihood estimation procedure using the computer software Frontier Version 4.1 (Coelli, 1996).

$TEi := ao+a_1Z_1+a_2Z_2+a_3Z_3+a_4Z_4+a_5Z_5+a_6Z_6$ …… ……………………………...…...(4)

Where TEi, is the technical efficiency of the i-th farmer; Z_1 is farmers age in years; Z_2 is farmers level of education in years; Z_3 is no of extension contacts; Z_4 is household size; Z_5 is farm size in hectares and Z_6 is square of farm size in hectares while a_1-a_6 are parameter estimates.

Data

The study was carried out in Ideato North L.G.A. of Imo State using a two-stage randomized sampling technique. At the first stage, three circles were randomly selected from the LGA. At the second stage, 30 farmers were randomly selected form each circle using the community list of farmers from the ADP for detailed study. This gave a total of 90 farming households. Data were collected by means of well structured questionnaires on their production activities in terms of inputs, output, and socio-economic characteristics for the year 2008.

Results and Discussion

Average Statistics of Cocoyam Farmers: The average statistics of the sampled cassava farmers are presented in Table 1. On the average, a typical cassava farmer in the LGA is 48 years old, with 10 years of education. The average cassava farmer cultivated 1.47 ha, made an average of 1 extension contact in the year, used about 257.08kg of fertilizer and 68 bundles of cassava stems, spent about ₦1542.12 on capital inputs, employed 145 mandays of labour and produced an output of 4635kg of cassava. The results of the analysis show that individual farm level technical efficiency was 75%.

Table 1: Average Statistics of Cassava Farmers in Ideato LGA of Imo State, Nigeria.

S/N	Variables	Mean	Maximum	Minimum Value

o		Value	Value	
1	Farm size (ha)	1.4695	2.60	0.25
2	Labour (mandays)	144.8167	251.00	39.00
3	Fertilizer input (kg)	257.0833	96.40	0.00
4	Cocoyam setts (kg)	250.25	500.00	50.00
5	Capital input (₦)	1542.119	11200.00	355.00
6	Age (yrs)	48.40	65.00	32.00
7	Education (yrs)	10.2667	18.00	4.00
8	Extension contact	1.43	4.00	0.00
9	Planting materials (bundles)	68.00	20.00	135.00
10	Output (kg)	4635.92	9200.00	1195.00
11	Technical Efficiency(%)	75.00	91.00	35.00

Source: Survey data, 2008

Table 2 presents weighted maximum-likelihood estimates of the stochastic production frontier. The productivity of cassava significantly increases at 1% level in the value of output per hectare, with increase in labour and fertilizer. Productivity, however, appears to decrease with farm size and was significant at 1%. The coefficients for depreciation in capital inputs and planting materials had a negative and positive relationship with productivity but were not significant. The elasticity of production of farmers was estimated to be less than one (0.53). Decreasing returns to scale would explain the inverse relationship (Masterson, 2007). This is perhaps not surprising, given that the mean farm size for cassava in the area is 1.4ha.

The estimated variance (σ^2) is statistically significant at 1% indicating goodness of fit and the correctness of the specified distribution assumptions of the composite error term. Gamma (γ) is estimated at 0.962 and is statistically significant at 1% indicating that 96.2% of the total variation in cassava output is due to technical inefficiency.

Table 1: Estimated Cobb-Douglas Stochastic Frontier Production Function for Cassava Farmers in Ideato LGA of Imo State

Variables	Parameters	Coefficients	Standard Error	t-value
Production factors				
Constant term	β_o	5.1554	0.8496	6.0674***
Farm size	β_1	-0.2016	-0.0322	-6.2433***
Labour	β_2	0.5811	0.1642	3.5382***
Fertilizer	β_3	0.1875	0.0341	5.4670***
Planting Materials	β_4	0.2694	0.2412	1.1169
Depreciation	β_5	-0.3050	0.5620	-0.5437
Elasticity		0.5314		

Efficiency factors				
Constant term	a_0	3.8444	1.6839	2.2830**
Age	a_1	-0.2827	0.0451	-6.2673***
Levels of Education	a_2	-0.1214	0.1472	0.8248
Extension Contact	a_3	0.9775	1.5198	0.6431
Experience	a_4	0.1774	0.3359	0.5281
Farm size	a_5	-6.1462	1.4591	-4.2122***
Farm size^2	a_6	-2.6657	0.0548	-4.8672***
Diagnostic statistics				
Total Variance (Sigma squared)	σ^2	0.1973	0.0259	7.589***
VarianceRatio (Gamma))	γ	0.9620	0.0463	20.7807***
LR Test		22.9902		
Log Likelihood Function		-45.3918		

Source: Computed from frontier 4.1 MLE results/Surveys data, 2008, * and ** are significant levels at 1.0% and 5.0%.**

Sources of Technical Efficiency

The estimated determinants of technical efficiency in cassava production as presented in Table 2 shows that age, farm size and farm size interaction had a negative and significant effect on efficiency at 1% level of probability. We expect age to have a positive relationship since age is used as a proxy for experience. However, old age might pose disadvantages in agriculture because most of the work is physically demanding and also because older household heads might be too conservative to try new, more efficient techniques. This is in line with the findings of Ajibefun and Daramola (2003); Ajibefun and Aderionla (2004); Okoye, 2007; 2008a and 2008b).

One reason why small farms produce more value per hectare is because land utilization is much higher on smaller farms since large farms cultivate less land in proportion to their size, i.e., larger farms have more idle land. Thus, even if small and large farms produce equal value of output per hectare cultivated, this does not disprove the “IR puzzle.” (Gul Unal, 2008). Doubling the farm size also results in decreased technical efficiency. Research in developing countries has centered round the ‘inverse hypothesis’ that smaller farms are more productive because land is used more intensively (Bharadwaj, 1974 and Cornia, 1985).

Conclusion

Given the inverse productivity/efficiency-size relationship in agriculture, what is needed for increased productivity and efficiency in agriculture and overall growth is land redistribution supported by technical and financial assistance for farmers. Policy conclusion to be drawn from these results is that policies favorable to large-scale farms may foment overall growth in the agricultural sector, but they will do less than nothing to combat the problem of rural poverty. They will contribute neither to the well being of small farmers nor to employment opportunities for landless peasants, since the larger farms are so capital intensive. It is no stretch to say that the argument for redistribution of land is bolstered by this study. Giving land to smaller farms will increase overall productivity and efficiency, as well as improve the welfare of the small and landless peasantry. The questions of how to achieve this goal is outside the scope of this study. The results also call for policies aimed at encouraging new entrants especially the youths to cultivate cassava.

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