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# ECONOMIES OF SCALE AND PRODUCTION EFFICIENCY IN SMALL-SCALE RICE FARMERS IN NIGERIA: EMPIRICAL APPROACH FOR HYBRID AND LOCAL RICE.

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**ABSTRACT**

The study examined the economies of scale and technical efficiency of small-scale farmers in Edo State, Nigeria. The data used in the study were mainly from primary sources. The data were collected from 200 rice farmers selected using multistage sampling technique and analyzed using descriptive statistics, and stochastic frontier model. Production functions among hybrid rice and inbred (local) rice producers were estimated independently using the Battese and Coelli (1995) model to specify a stochastic frontier Cobb-Doglas production function with behaviour inefficiency component to estimate all parameters together and the level of significance in one-step maximum likelihood estimation. The returns-to-scale (RTS) for the production function showed that the farmers operated in the irrational zone (stage I) of the production surface having RTS of 0.676 and 1.299 for inbred and hybrid species respectively. The mean technical efficiency of 0.317 and 0.925 for inbred and hybrid varieties respectively were obtained from the data analysis, indicating that the hybrid sample farmers were relatively more efficient technically than the inbred rice farmers. The mean technical efficiency of the farms was estimated as 1.263. This means that average rice farm in the sample area has production that are about 26% above the minimum defined by the frontier. However, the result of the analysis indicated that presence of technical inefficiency had effects in the food crop production as depicted by the significant estimated gamma coefficient of each model, the generalized likelihood ratio test and the predicted technical efficiencies within the farmers. Improved variety of rice as well as the technology improves the efficiency of the farmers.

**KEYWORDS:** hybrid, inbreed, output, inefficiency and Edo State.

## INTRODUCTION

The rate of growth of Nigeria's food production has been very low; food production grows at the rate of 2.5% per annum in recent years while food demand has been growing at the rate of more than 3.5% per annum due to high rate of population growth of 2.83% (FOS, 1996). The apparent disparity between the rate of food production and demand for food in Nigeria has led to: (i) a food demand-supply gap thus leading to a widening gap between domestic food supply and the total food requirement; (ii) an increased food importation and (iii) high rates of increase in food prices due to a growing food supply deficit despite food importation (FMAWRRD, 1988).

Developments in rice production and international rice markets are critical for the environment and for the rural and urban poor. Rice is the staple food of the 70% of the world's poor living in Asia (Gulati and Narayanan 2002). Developing countries account for 95% of global rice production. Asia alone produces 90% of world rice, with China and India accounting for over half of the world's output. Worldwide, rice production has

The most striking increase is observed in Africa, where rice production increased by 133%, albeit from very low levels, reflecting the growing importance of rice in this region.

Other non-traditional rice-producing areas, including South, North, and Central America, have increased rice production at a higher rate than traditional rice producers (IRRI, 2004).

Substitution of rice for coarse grains and traditional roots and tubers has fuelled growth in the demand at an annual rate of 5.6% between 1961 and 1992 (Osiname, 2002). FAO (2003) projected growth in rice consumption for Nigeria beyond year 2000 remains as high as 4.5% per annum. Rice is one of the widely grown and consumed cereal crops in Nigeria, with per capita consumption of between 3.5kg and more than 14kg per year per household (FAO 2002). *Per capita* consumption during the 1980s averaged 18kg per household while it was estimated to have reached 22kg between 1995 and 1999 (Akpokodje, et al., 2001). Since the mid-1980s, rice consumption has increased at an average annual rate of 11% of which only 3% can be explained by



population growth. This phenomenon was largely the result of increased per caput income, rapid population growth and changes in the tastes and diet of Nigerians. The World Bank cited in FAO (2002) estimated that 2.1 million tones of rice was consumed annually, and

urban households obtaining 33% of their cereal based calories from rice, and rice purchases representing a major component of the cash expenditure of cereals. The average share of total calories originating from rice has remained fairly constant during the last six decades for the world as a whole. In Asia this share has fallen

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from 38% to 31%, primarily due to diversification of diets caused by urbanization and increasing incomes. Within Asia, it is notable that the share of calories from rice has declined in China and Japan but this trend is not observed in other Asian countries; instead, the share of rice has remained fairly stable. In Africa, however, the share of rice in total food consumption is growing (IRRI, 2004).

Given such a predominant weight of rice in the consumption expenditure of both rural and urban populace in Nigeria, the increase in the supply of rice to meet the growing demand from the urban sector is critical for the welfare of urban dwellers. Of course, the rice supply may be augmented by imports from abroad. In fact, the government has been manipulating tariffs and quotas as the major means of achieving the long-term stability of rice prices, but the reliance on rice imports would result in a drain on foreign exchange needed for the importation of capital goods and technical know-how critical for development. Thus an expanding demand for rice would have to be met by raising yield per unit of paddy field area. The basic approach to increasing rice yield will be to develop and diffuse high yielding varieties of rice, responding to heavy application of fertilizer (Hayami and Ruttan, 1971). Improved productivity implies lower production costs for domestic rice. This implies an outward shift of the domestic rice supply curve. This outward shift creates an economic surplus for the economy, typically shared between producers and consumers depending on the slopes of the supply and demand curves. This economic surplus could conceivably amount to some N1, 060 million annually (or the equivalent of US$ 8.1 million) for each Naira unit reduction of domestic rice production cost (Erenstein *et al*, 2004).

The objective of this study is to examine the impact of research in rice on the production efficiency of small-scale rice farmers in Edo State, Nigeria. To achieve this objective, the study examined the technical efficiency, the elasticities and returns to scale of the farmers.

**METHODOLOGY**

The data used in the study were mainly from primary sources. The data were collected from four Local Government Areas which were purposively selected because of prevalence of the crop in the areas using multistage sampling technique .The Local Government Areas include Esan Central, Esan West, Esan North-East and Esan South-West of Edo State. The second stage involved a simple random sampling of 50 farmers from each of the four Local Government Areas, thus making a sample size of 200. Data were collected with use of a structured questionnaire to collect input-output data from the farmers. The output data include yield of rice in kg. The input data included the farm size, hired labour in man-days, fertilizer applied in Kg, quantity of agrochemical used, and farm size in hectares. Data were also collected on the socio-economic variables such as age, household size, and the farming experience of the farmers. Production functions among hybrid rice adopters and inbred (local) rice producers were estimated independently and their level of significance, that is, yield responses to different inputs were statistically tested to determine the explanations on the variations on yields.

Battese and Coelli (1995) model was used to specify a stochastic frontier production function with their inefficiency component to estimate all parameters together in one step maximum likelihood estimation. The production structure of rice farmers in the area was specified using a single-output multi-input Cobb-Douglas production function which specifies the production technology of the farmer is given as:

$$Q_i = f(X_i, \beta)\exp(V_i - U_i)$$

This model is implicitly expressed as:

$$\ln Q = \alpha_0 + \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + \alpha_5 \ln X_5 + (\mu - \varepsilon)$$

This model is implicitly expressed as:

$$\ln Q = \alpha_0 \ln X_0 + \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + \alpha_5 \ln X_5 + (\mu - \varepsilon)$$

, Where Q is Output harvested in Kg, $X_1$ is the total quantity of seed used by the $i^{th}$ farmer (kg/ha), $X_2$ is total amount of fertilizer (kg/ha) used by the $i^{th}$ farmer, $X_3$ is the hired labour (man-day/ha), $X_4$ is quantity of active ingredient (agrochemical) used, $X_5$ is the farm size, *αs* are the unknown parameters for the production function, and $(\mu - \varepsilon)$ is composite error term. Some farmer's socio-economic characteristics were incorporated into the frontier model with the belief that they have a direct influence on efficiency.

The systematic component, $\mu_i$ represents random disturbance error associated with the combined effect of inputs variables not included in the production function. It is assumed to be identically and normally distributed with mean zero and constant variance as N (0, $\sigma^2\mu$) .$\varepsilon_i$ is the one-sided disturbance form used to represent production inefficiency and is independent of $\mu_i$. Thus, $\varepsilon_i$ =0 for a farm whose production lie on the frontier, $\varepsilon_i$ >0 for farms whose production is above the frontier and $\varepsilon_i$ <0 for farm identically and independently distributed as N (0, $\sigma^2_{\varepsilon}$.).The two error terms are preceeded by positive signs because inefficiencies are always assumed to decrease production. Moreover, for the study, the production efficiency of an individual farm is defined in terms of the ratio of observed production ($Q_b$) to the corresponding minimum production ($Q_{min}$) given the available technology. The ***α***s are scalar parameters to be estimated. The variance of the random error, $\sigma^2_v$ and that of the production inefficiency effects $\sigma^2_{\varepsilon}$ and the overall variance of the model $\sigma^2$ are related by $\sigma^2 = \sigma^2_{\mu} + \sigma^2_{\varepsilon}$ and $\gamma = \sigma^2_{\varepsilon} / \sigma^2_{\mu} + \sigma^2_{\varepsilon}$. The gamma (γ) measures the total variation of the total production from the production frontier which can be attributed to production inefficiency (Battese and Corra, 1977). The estimate for all the parameters of the stochastic production frontier function obtained using the program FRONTIER version 4.1 (Coelli, 1996). The test for the presence of production inefficiency using generalized likelihood-ratio statistics λ defined by: λ =-2 In ($H_0/H_a$) Where:$H_0$ is the value of the likelihood function for the frontier model in which parameters restriction specified by the null hypothesis, $H_0$ are imposed; and $H_a$ is the value of the likelihood function for general frontier model. If the null hypothesis is true then λ has approximately a mixed chi-square distribution with degree of freedom equal to the number of parameters excluded in the unrestricted model.

The technical efficiency of individual farmers is defined in terms of the ratio of observed output to the corresponding frontiers output, conditional on the level of input used by the farmers. Hence the technical efficiency of the farmer is expressed as

$$TE_i = \frac{Q_i}{Q_i^*} = \frac{f(X_i, \beta)\exp(V_i - U_i)}{f(X_i, \beta)\exp V_i} = \exp(-U_i).$$

sWhere: $Q_i$ is the observed output and $Q_i^*$ is the frontiers output. The TE ranges between 0 and 1.
The technical inefficiency effect is defined as:

$$\mu_i = \varepsilon_0 + \varepsilon_1 Z_{1i} + \varepsilon_2 Z_{2i} + \varepsilon_3 Z_{3i} + \varepsilon_4 Z_{4i} + \varepsilon_5 Z_{5i} + \varepsilon_6 Z_{6i} + \varepsilon_7 Z_{7i}$$

where $Z_1$, $Z_2$, $Z_3$, $Z_4$, $Z_5$, $Z_6$, $Z_7$and $Z_8$ are respectively primary education, secondary education, higher education, adult education, neighbour education, age of farmer, farming experience, household size, $\mu_i$ is a measure of inefficiency of farmer.

**RESULTS AND DISCUSSION**

The summary statistics of variables for the production and cost frontier estimation is presented in table 1. The table shows that the average total farm value of all rice produced for the farmers using the hybrid rice seed was 25, 341.20 with a standard deviation of 12, 305.12 and 24352.43 with a standard deviation of 1210.13 for farmers using the inbred rice. The large variability by the standard deviation implies that the farmers operated at different levels of farm sizes, in addition to the difference in rice variety, which tends to affect their output levels. There was also a greater variability in hired labour, cost of planting materials, cost of labour, and in the cost of total production for the local-breed rice farmers than the hybrid-rice farmers. This difference in variability, among other reasons, is as a result of the difference in variety. The variability in farm size is due to changes in hectare of cassava under the production season. The mean family and hired labour used was N259.14 with a standard deviation of 149.79. The average quantity of fertilizer used was 57.89kg with a standard deviation of 42.34kg for hybrid-rice farmers. Analysis of cost variables of the farms shows that cost of labour accounts for over 70% of the total cost due to the fact that there is a reduction in the number of the household participation in farm operation since most farmers send their children to the cities for proper education .Hence, farmers depend heavily on hired labour to do most of the farming operations, thus justifing the high cost expended on hired labour. The resulting total cost is higher for the hybrid rice than for the local rice. This is due to the extra management cost to sustain the productive capacity of the improved rice variety.
Variables representing the demographic characteristics of the farmers employed in the analysis of the determinant of technical efficiency include; age of the farmers, educational level, household size and farming experience. The average ages of the farmers were 45.13 and 47.23years respectively which mean that the farmers were relatively young. The years of schooling were 15.37 and 12.23 years meaning that most of the farmers were relatively educated. The average years of farming experience were 11.01 and 8.34 years respectively.

**Table 1:** Summary Statistics of Variables

| **Variation** | **Mean** | | **Std. dev**. | |
|---|---|---|---|---|
| Quantity of rice produced | 25341.20 | 24352.43 | 12305.12 | 1210.13 |
| Farm size | 0.54 | 1.50 | 0.32 | 0.87 |
| Haired Labour | 259.14 | 385.52 | 149.79 | 176.31 |
| Cost of planting materials | 1212.50 | 1005.24 | 627.81 | 765.17 |
| Quantity of fertilizer | 57.89 | 15.12 | 42.34 | 11.17 |
| Cost of fertilizer | 619.59 | 116.20 | 476.94 | 131.03 |
| Cost of labour | 15312.41 | 10000.56 | 859.10 | 901.98 |
| Cost of farm tools | 341.91 | 974.21 | 920.15 | 873.01 |
| Age of the farmers (years) | 45.13 | 47.23 | 19.31 | 18.19 |
| Farming experience (years) | 11.01 | 8.34 | 5.62 | 5.07 |
| Educational level | 15.37 | 12.23 | 14.19 | 10.71 |
| Household size | 5.00 | 8.00 | 2.03 | 3.98 |
| Total cost of production | 20122.31 | 12002.10 | 1100.11 | 1120.17 |

**Source**: Survey Data, 2008.

Table 2 shows the OLS estimates of the general production, and the maximum livelihood estimates of the stochastic frontier production function for rice farmers in the study area. The estimated coefficients of all the parameters of production function are positive for both varieties, meaning that total farm production increases by the value of each coefficient as the quantity of each variable increases by 1%. That is 1% increase in the quantity of fertilizer will increase total production by approximately 0.22%. Again 1% increase in the quantity of seed will increase total production by approximately 0.31%. Also, a 1% increase in the quantity of labour will increase total production by approximately 0.11%; 1% increase in the pesticide used will increase total production by approximately 1.31%, while 1% increase in the farm size will increase total production by approximately 0.13% for the hybrid rice producers. However, all parameters are positive, implying that the production function monotonically increases in input quantities. Also, there was a greater contribution to output by quantity of seed and farm size for the hybrid than inbreed for 1% increase in the variables.

**Table 2:** Maximum Livelihood Estimates of the Stochastic Production Function.

| *Variable* | *Parameter* | *General Model Estimates* | | *Stochastic Model Estimates* | |
|---|---|---|---|---|---|
| | | *Hybrid* | *Inbred* | *Hybrid* | *Inbred* |
| ***Efficient model*** | | | | | |
| Quantity of seed | $A_1$ | 0.297 (3.478) | 0.231(2.154) | 0.312*(4.982) | 0.124(1.56)* |
| Quantity of fertilizer | $A_2$ | 0.374 (3.041) | 0.410(3.217) | 0.224*(1.998) | 0.161(1.97) |
| Hired labour | $A_3$ | 1.845 (1.212) | 0.362(1.231) | 0.321*(1.112) | 0.109 (1.25)* |
| Pesticide | $A_4$ | 0.317(-2.019) | 1.342(-1.897) | 0.311* (5.612) | 0.112(0.11) |
| Farm size | $A_5$ | 7.541 (1.890) | 3.412(1.289) | 0.131* (3.405) | 0.170(0.92)* |
| ***Inefficiency model*** | | | | | |
| Education level | $\Delta_1$ | 0 | 0 | -0.437* (-2.045) | -1.23(-0.98) |
| Age of farmer | $\Delta_3$ | 0 | 0 | 5.012* (3.125) | 7.241(2.59) |
| Household size | $\Delta_4$ | 0 | 0 | 0.149* (1.901) | 0.361(1.11) |
| Sex | $\Delta_5$ | 0 | 0 | -0.376* (-2.968) | -0.97(- |
| *Variance parameter* | | | | | |
| Gamma | Γ | 0 | 0 | 0.471 (60.134) | 0.915 (9.13) |
| Log livelihood function | LLF(λ) | -12.652 | -9.984 | -10.954 | - 8.973 |

* significant at 5% level, t-ratios in bracket

Table 2 also shows that there was presence of technical inefficiency effect in rice production as confirmed by the test of hypothesis for the presence of inefficiency effects using the generalized livelihood ratio test. The chi-square computed for the presence of technical inefficiency effect is 28.82 for hybrid and 21.35 for inbreed while the critical value of the chi-square at 5% level of significance with 6 degrees of freedom $\chi^2(5\%, 6)$ was 12.60. Hence the null hypothesis of no technical inefficiency effect in farmers' production process, $\gamma=0$, was simply rejected. The general model therefore was not an adequate representation of the data; hence the stochastic frontier model was the preferred model for further economic analysis.

The estimated gamma parameter ($\gamma$) of stochastic frontier model for the production function was 0.417 for hybrid rice farmer and 0.915 for inbreed rice farmers. This indicates that about 92% (when compared with 41.7% for hybrid) of the variation in the output of rice among the inbreed rice farmers was due to differences in their technical efficiency, i.e. 92% of the variation in output was due to the presence of technical inefficiency. This shows that better variety of rice can improve the technical efficiency of rice producers.

Maximum-likelihood estimates of the parameters of the stochastic production frontier model are also presented in Table 2. All parameters estimate have the expected sign and are highly significant at 5% meaning that the effects of these factors were significantly different from zero and thus were important in rice production. The production elasticities with respect to all input variables used in the production analysis are positive and imply that an increase in the quantity of labour, fertilizer, seed, pesticide, and farm size increases total production.

The table also shows that the coefficients of age of the farmer and household size were positive, indicating that these factors lead to increase in technical inefficiency of farmers in the area of study. The coefficients of educational level and sex, however, were negative, indicating that these variables decrease technical efficiency of rice farmers in the study area.

The estimated coefficients in the explanatory variables in the model presented in the lower part of Table 2 for the production inefficiency effects are of interest and have important implication. The negative coefficients for age and farming experience imply that the aged farmers and the most experienced farmers in the rice production are more efficient than the younger ones meaning that as the age and farming experience of farmers increase in the study area the inefficiency of the farmers decreases. This is in conformity with the assumption that farmers' age affects the production efficiency since farmers different ages have different levels of experience ability to obtain and process information. The positive coefficient of year of schooling indicates that farmers' level of cost efficiency tends to decline with education. This tends to contradict the assumption that educational levels of the farmers will have positive effects on the level of efficiency as they embody skill that can improve their overall efficiency.

**Table 3:** Efficiencies of the small-scale rice farmers in the area

| *Efficiency level* | *Frequency* | *Relative Efficiency (%)* |
|---|---|---|
| 1.0 – 1.1 | 163 | 81.5 |
| 1.2 – 1.3 | 29 | 14.5 |
| 1.4 – 1.5 | 5 | 2.5 |
| 1.6 – 1.7 | 1 | 0.5 |
| 2.0 – 2.1 | 1 | 0.5 |
| 3.0 – 3.1 | 1 | 0.5 |
| Total | 200 | 100 |
| Minimum | 1.243 | |
| Maximum | 3.176 | |
| Mean | 1.263 | |

Source: Derived from Computer Analysis

Table 3 shows summary of technical efficiency scores for the rice farms in the sampled area. The mean technical efficiency of the farms was estimated as 1.263. This means that an average rice farm in the sample area has a production level that is about 26% above the minimum defined by the frontier. In other words, 26% of their resources are wasted relative to the best practice farms producing the same output (rice) and facing the same technology. The higher the value of technical efficiency, the more inefficient the rice farm is. However, the frequencies of occurrence of the predicted technical efficiency between 1.0 and 1.1 representing about 82% of the sampled farmers, implying that majority of the farmers are fairly efficient in producing at a given level of output using resource maximizing input ratios which reflect the farmers' tendency to minimize resource wastage associated with production process from production perspective.

**POLICY IMPLICATIONS**

The study revealed that rice farmers are yet to achieve their best as shown by the returns to scale. This shows that efforts should be made to expand the present scope of production to actualize the potential in it by employing more of the variable inputs. The result further shows that the farmers were resources poor but were fairly efficient in the use of their resources. The rising age of farmers, which lead to a decline in the technical efficiency, means that policy should be targeted on ways to attract and encourage young people who are agile in farming business in general and rice farming in particular. Improved varieties of rice should impact positively on the efficiency of rice producing farmers. This shows that efforts should be made to improve the varieties of rice for higher productivity.

**CONCLUSION**

The study examined the impact of research in rice on the production efficiency in small-scale rice production in Edo State, Nigeria. About 92% (when compared with 41.7% for hybrid) of the variation in the output of rice among the inbreed rice farmers was due to differences in their technical efficiency. The negative coefficients for age and farming experience imply that the aged farmers and the most experienced farmers in rice production are more efficient than the younger ones. This is an indication that as the age and the farming experience of the farmers increase in the study area, the inefficiency of the farmers decreases. The positive coefficient of year of schooling indicates that farmers' level of production efficiency tends to decline with education. Improved varieties, resulting from research and development (R & D), as well as technology improves efficiency of rice producers in the State. The mean technical efficiency of the farms was estimated as 1.263. This means that average rice farm in the sample area has production that are about 26% above the minimum defined by the frontier. In other words, 26% of their resources are wasted relative to the best practice farms producing the same output (rice) and facing the same technology. Hybrid rice improves the technical efficiency of rice farmers.

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