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Stochastic Frontier Analysis of Paddy Processing in Adamawa State, Nigeria

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Abstract

The research adopted the stochastic frontier analysis (SFA) to model production function of paddy processing in Adamawa State, Nigeria based on 160 paddy processors stratified according to small, medium and large processors drawn from a multi-stage sampling technique. Output elasticity estimated for production variables conforms with *a priori* expectations in signs and significance as follows: paddy (X_1) = 0.027 ($P<0.05$), labor (X_2) = 0.036 ($P<0.01$), firewood (X_3) = 0.945 ($P<0.05$), water (X_4) = 0.035 ($P<0.01$), transport (X_5) = 0.075 ($P<0.10$) and milling (X_6) = 0.414 ($P<0.10$). Thus, 1% increase in those variables increases the quantity of milled rice by the estimated coefficients in terms of its percentage respectively. The study further ranked the production variables in descending order of magnitude as follows: firewood, milling, transportation, labor, water, and paddy as 1st, 2nd, 3rd, 4th, 5th and 6th most significant inputs in the production function of paddy processing. Result for the inefficiency model revealed that all socioeconomic variables: age, education, experience, credit and family size conforms to *a priori* expectations in sign (-) and statistically significant at varying levels; thus, signifying that higher levels in the socioeconomic variables leads to lower inefficiency in paddy processing. The study advocates for uniformity in paddy varieties, the use of improved varieties, skillful training, provision of credit facilities and subsidy of processing facilities for productive and efficient paddy processing to achieve enhanced efficient productivity in the paddy processing industry.

Keywords: Paddy; Processing; Stochastic; Frontier; Adamawa

Introduction

Rice grain *Oryza sativa* (Asian rice) or *Oryza glaberrima* (African rice) is a staple cereal grain widely consumed in most parts of the world, especially in Asia and the West Indies (Alizadeh and Rahmati, 2011**)**. Globally, rice is approximately grown on 165 million hectares of land. World paddy production estimated at 769.9 million metric tons which gives an approximate output of 519.6 million metric tons of milled rice (FAO, 2018). China is the world's leading paddy producing nation with about 210 million metric tons followed by India with 175 million metric tons of milled rice (FAO, 2018). Nigeria's paddy production reached 15 million metric tons in 2017 and 24 million metric tons are expected to be produced annually (RIFAN, 2018).

Rice production and processing has witnessed some remarkable developments particularly in parboiling and milling aspects. Processed rice serves as both food and cash crop to producers and processors, contributing to smallholders' revenues in the main producing areas (Obisesan *et al.*, 2017). The rate of growth of paddy production and its demand is highly increasing while, processing is inefficient simply because of inadequate modern processing facilities especially in Africa. Nigeria has resorted to the importation of milled rice to bridge the deficit, which resulted in the depletion of the country's foreign reserves. In 2015, the Federal Government of Nigeria (FGN) set up strategic trade policies to arrest this trend by banning the importation of foreign rice. Government reiterated that, Nigeria as a country have all the potential to be self-sufficient in rice production and processing in such a way that the agricultural sector creates more job opportunities to her citizen, efforts were also made to sustain production by developing effective marketing strategies through commercial system (Henry and Erunke, 2015). Despite all the possibilities of self-sufficiency in paddy production and processing, most of the operations in paddy processing is still primitive. Several limitations were identified as restraining factors; among others the following:

manual operation, inadequate skills, poor parboiling skills, inadequate modern processing facilities (FAO, 2016). This study therefore, hinge on the foregoing scenarios to evaluate the production function of the paddy processing industry and identify the constraints militating against its operations in Adamawa State, Nigeria. The study will unravel productivity indicators that will aid reposition the nation's paddy processing sector to a desired level in tandem with the current national derive on paddy revolution in Nigeria.

Hypothesis

Null hypothesis was tested.

H_0: There is difference between choices of functional forms: Translog and Cobb- Douglas in paddy production function.

Materials and methods

Study Area

The research was conducted in Adamawa State; North-Eastern part of Nigeria. The state is located between Latitudes 8.00^0N and 11.00^0N of the equator and Longitudes 11.50^0E and 13.50^0E of the Greenwich meridian with land mass 39,742.12 square kilometers (Adebayo, 1999) and a total population 3,161,374 (NPC, 2006). Further characteristics includes mean annual rainfall in the range 700mm to 1000mm and mean monthly temperature in the range 26.7^0C to 27.8^0C (Adebayo, 1999). The state is agrarian in nature; diverse crops are cultivated and diverse livestock are also reared. Paddy is cultivated in all the Local Government Areas; thus widely cultivated in the state

Sampling Procedure and Data Collection

Multi-stage (4 stage) random sampling technique was employed for the selection of one hundred and sixty (160) respondents. Stratified sampling was used in the first stage to categorize the study area into four strata based on ADP zones (zone 1 to 4). A purposive sampling was then used in the second stage to select two local government areas each in zone 1, 2, and 4 and 3 Local Government Areas in zone 3, based on availability of rice processing activities. Again a purposive sampling technique was used in the in the third stage to select wards within the selected local government areas. Finally, as the fourth stage of the sampling process, a non-proportionate simple random sampling was used to select 18 processing units in each of the nine (9) local governments selected. Thus, a total 162 respondents constituting processing firms were served with questionnaire for the study out of which only 160 was retrieved and analyzed. Data collection was conducted in 2018.

Analytical Techniques

Stochastic Frontier Analysis

The study adopted the stochastic production frontier analysis; where the output of a firm is a function of a set of inputs. According to Coelli and Battese (1996) stochastic frontier production function approach is widely applied in agricultural economics literature. Moreover, tests of hypotheses regarding the existence of inefficiency and the structure of the production (processing in this case) technology can be performed in SFA (Coelli *et al.*, 1998). There are number of functional forms used in the frontier analysis, the likelihood ratio test is used in order to select the best specification for the production function (Cobb-Douglas or Translog) for the given data set, after Cobb-Douglas and Translog estimations. The stochastic frontier has been widely adopted in frontier studies, because this model is flexible and computationally straight forward (Kwon and Lee, 2004; Hye-Jung and Yuyu, 2015).
The generalized form of the frontier production function can be written as:

$Y_i = f\,(;\, \beta)\, exp\, (\varepsilon_i)$………(1)

where

Y_i is the quantity or output of milled rice,

X_i is the vector of input quantities and

β is a vector of parameters to be estimated

ε_i is error term

The general structure of the Translog form with time-invariant model of stochastic frontier used in this study is described as follows:

$\ln y_{it} = \beta_0 + \sum^6_{j=1} \beta j \ln Xjit + 0.5 \sum^6_{j=1} \sum^6_{k=1} \beta jk \ln Xjit \ln Xjit + V_i - U_i$,,……(2)

Where,

$\sum$=Summation

i= indicates an observation for the i^{th} sample in the survey, i = 1, 2, 3,…, n,

y_i= represents the total rice processed of the i^{th} plant expressed ,

x_j and x_k = are the quantity of inputs used in rice processing;

j and k = paddy processed on the i^{th} plant;

β j k = β k j are parameters to be estimated.

v_{is} = are assumed to be independent and identically distributed as normal random variables following an *iid* normal distribution of zero mean and variance of

σv^2, independent of the u_{is}; σu^2, u_{is} represents non-negative technical inefficiency of i^{th} processors which are also assumed to be non-negative, independently distributed as truncations at zero

The empirical model of the stochastic production function frontier applied in the analysis of efficiency of paddy Processing based production is specified as:

$\ln Y_{ij} = \ln\beta_0 + \beta_1 \ln X_{ij} + \beta_2 \ln X_{2ij} + \beta_3 \ln X_{3ij} + \beta_4 \ln X_{4ij} + \beta_5 \ln X_{5ij} + \beta_6 \ln X_{6ij} + V_i - U_i$……(3)

Where:

Y = Total output (kg- of milled rice)

X_1 = Quantity of paddy (Kg)

X_2 = Labor (man hour)

X_3 = Firewood (kg)

X_4 = Water (liter)

X_5 = transportation (₦)

X_6 = Milling (₦)

$\beta_{1\text{-}6}$ = are the unknown parameters to be estimated.

The error term is separated into two components, these are

v_i = is the stochastic error term and

u_i= is an estimate of technical inefficiency.

In SFA studies, an assumption regarding specific functional forms of stochastic frontier is required *a priori*. The wrong choice of production function may influence the results. Absolute level of the technical efficiency is quite sensitive to distributional assumptions; rankings are less sensitive. The determinants of technical inefficiencies can be obtained by regressing the estimated inefficiency effects resulting from an estimated stochastic frontier, upon a vector of plant-specific or firm specific factors in a simultaneous fashion. This is a two-stage approach; first, the inefficiency effects are assumed to be independently and identically distributed and second, the predicted inefficiency effects are assumed to be a function of a number of firm-specific factors, which implies that they are not identically distributed, unless all the coefficients of the factors are simultaneously equal to zero. The inefficiency effects model proposed by Battese and Coelli (1995) are assumed to be independently (but not identically) distributed non-negative random variables. This model assumes the normal distributions, which are truncated at zero to obtain the distributions of the technical inefficiency effects.

It is assumed that the technical inefficiency effects are independently distributed and u_i arises by truncation (at zero) of the normal distribution with mean, u_{ij} and variance δ_2. The technical inefficiency effect model is described by:

$u_{it} = \delta_0 + \delta_i z_{it}$……….(4)

Where: U_{it} technical inefficiency effects are assumed to be a function of explanatory variables, z_{it} vector observed explanatory variables related to the technical inefficiency effects in the t period and δ is a vector of unknown parameters to be estimated.

Here, the determinants of the explanatory variables are described as follows. They are the same variables as in non-parametric approach:

$u_{ij} = \delta_0 + \delta_1 Z_{1ij} + \delta_2 Z_{2ij} + \delta_3 Z_{3ij} + \delta_4 Z_{4ij} + \delta_5 Z_{5ij}$…(5)

Where:

u_i = Technical inefficiency of the i^{th} Processing Unit

Z_1 = Age of the processors (yrs)

Z_2 = level of education

Z_3 = Family size (Number)

Z_4 = Years of Processing experience

Z_5= Access to credit (Access to credit =1, 0 = otherwise)

Results and Discussion

Generalized Likelihood Ratio Test for Choice of Functional Form

Table 1 presents generalized likelihood ratio test used in the selection of functional form between Cobb-Douglas and Translog. In accordance with Kodde and Palm (1986), the null hypothesis that the Cobb-Douglas function better fits the phenomena of paddy processing than the Translog function was rejected on the basis of LR statistics = 26.73, which is higher than a critical value of 14.92. Thus, the Translog function result was used to derive the conclusions of this study.

Table 1: Likelihood Ratio Test for Choice of Functional Form

Null hypothesis	Test statistics	Critical value	Decision
H_O: $\beta_{ii} = 0$ Second order coefficients are zero or the Cobb- Douglass better fits the data	26.73	14.92	Rejected H_o

Source: Computed from Field Survey Data (2018)

Maximum Likelihood Estimate (MLE) of the Stochastic Frontier Model

The Maximum Likelihood Estimates (MLE) of the stochastic frontier production parameters for paddy processing are presented in the Table 2. All the coefficients of the explanatory variables have the expected positive signs and significant, indicating that more output would be obtained from the use of additional quantities of these inputs. Water (X_4) and Labor (X_2) have the expected positive signs and statistically significant at 1%. Paddy (X_1) and Firewood (X_3) have the expected positive signs, but statistically significant at 5%. Milling (X_6) and Transport (X_5) have the expected positive signs, but statistically significant at 10%. In the research, the first order parameters were interpreted as output elasticity of paddy processing. Coelli *et al.* (1998) stated that the first order parameter is interpreted as output elasticity upon subjecting the data to mean correction. Accordingly, mean correction was conducted on data for this study. Thus, output elasticity with respect to quantity of paddy (0.027); means an increase in quantity of paddy by 1%, increases quantity of milled rice 0.027%. In the same vein, output elasticity of labor, firewood, water, transportation and milling are 0.0362, 0.9451, 0.0349, 0.0747 and 0.4143 respectively. These elasticity implies that increase in labor, firewood, water, transportation and milling by 1%, increases quantity of milled rice by 0.0362%, 0.9451%, 0.0349%, 0.0747% and 0.4143% respectively. Summing up output elasticity of all parameters results to scale elasticity 1.532, which is greater than 1.000. Thus, on average, the paddy processing firms process at increasing returns to scale (IRS) or at stage I of the production function, which further imply that the firms are on average not scale efficient. If all firms jointly increase all factor inputs by 1%, milled rice will increase by 1.5322%, *ceteris paribus*. In terms of importance in processing function, the result show that cost of firewood, milling cost, transportation cost, labor cost, cost of water, and paddy cost are ranked the 1st, 2nd, 3rd, 4th, 5th and 6th most important inputs in the paddy processing function.

On the other hand, the inefficiency model showed all socioeconomic variables (age, education, family size, experience and credit) with the *a priori* expected negative signs and all except experience were statistically significant at different levels. The negative signs of the variables included in the inefficiency model showed how increase in these socioeconomic variables reduces inefficiency in the paddy processing. Age (-) means that there is an inverse relationship between age and inefficiency; as age of processor increases, the processor becomes less inefficient. Education (-) also inversely related; implies that higher processing levels of education reduces inefficiency in paddy processing. Education is no doubt a pivot for any progress and development; thus, key in the paddy processing sector of the economy as well. The inverse relationship of experience and inefficiency means that more experienced processors are less inefficient and conversely.

In terms of credit, the study inferred that processors with higher credit facility are less inefficient. This is premise on the fact that availability of credit enables processors to acquire modern equipment required to ensure productive and efficient paddy processing, which hitherto inaccessible by processors with no or limited credit facilities. Family size is a proxy of family labor and its negative sign signifies that processors with large family size are less inefficient in paddy processing than those with small family size. This is more pronounced in small scale paddy processing where the use of local processing facilities, techniques and manual labor is highly demanded.

Table 2: Maximum Likelihood Estimates (MLE) of the Stochastic Frontier Model

Variables	Parameters	Coefficient	Standard error	t-ratio
Constant	β_0	0.0558***	0.0904	6.1679
Paddy (X_1)	β_1	0.0270**	0.0826	3.2664
Labor (X_2)	β_2	0.0362***	0.0707	5.1238
Firewood (X_3)	β_3	0.9451**	0.3430	2.7551
Water (X_4)	β_4	0.0349***	0.0697	5.0134
Transport (X_5)	β_5	0.0747*	0.0314	2.3826
Milling (X_6)	β_6	0.4143*	0.1792	2.3123
$(\text{Paddy})^2$	β_7	-0.768***	0.1326	-5.7959
$(\text{Labor })^2$	β_8	-0.146	0.1050	-1.3873
$(\text{Firewood})^2$	β_9	0.0403	0.1021	0.3943
$(\text{water})^2$	β_{10}	0.2226*	0.1164	1.9133
$(\text{Transport})^2$	β_{11}	0.0065	0.1017	0.0644
$(\text{milling})^2$	β_{12}	0.1280	0.0775	1.6503
Paddy x Labor	β_{13}	0.3186	0.2428	1.3122
Paddy x Firewood	β_{14}	0.9951**	0.3202	3.108
Paddy x water	β_{15}	0.2846	0.1950	1.4597
Paddy x Transport	β_{16}	-0.6529	0.7506	-0.8699
Paddy x milling	β_{17}	0.6248**	0.2091	2.9886
Labor x Firewood	β_{18}	0.0091	0.0092	0.9908
Labor x Water	β_{19}	-0.2841*	0.1670	-1.7018
Labor x Transport	β_{20}	-0.4039*	0.1550	-2.6056
Labor x Milling	β_{21}	-0.0263	0.1954	-0.1344
Firewood x Water	β_{22}	0.0058	0.0203	0.2838
Firewood x Transport	β_{23}	0.2759	0.2612	1.0562
Firewood x Milling	β_{24}	-0.3488	0.2850	-1.2242
water x Transport	β_{25}	0.0372***	0.0094	3.958
water x Milling	β_{26}	0.0537	0.7908	0.0679
Transport x Milling	β_{27}	-0.0005	0.1453	-0.0036
Inefficiency model				
Constant	δ_0	-0.7757***	0.146	-5.3114
Age (Z_1)	δ_1	-0.5354*	0.2426	-2.2069
Level of Education (Z_2)	δ_2	-0.3541*	0.1576	-2.2463
Family size (Z_3)	δ_3	-0.4055*	0.2101	-1.9306
Years of experience (Z_4)	δ_4	-0.006	0.0192	-0.3425
Access to credit (Z_5)	δ_5	-0.7028**	0.2209	-3.1814
Sigma	(δ^2)	0.0141***	0.0012	11.3987
Gamma	(γ)	0.4523***	0.0566	7.9865
	Log likelihood	160.49		
	LR	63.84		

Source: Computed from Field Survey Data (2018)

Table 3 revealed the constraints associated with paddy processing in the study area. It shows inadequate modern milling machines, low skills in paddy drying, poor post-harvest of paddy, inadequate improved variety, low parboiling skills and use of non-uniform paddy variety are ranked the 1st, 2nd, 3rd, 4th, 5th and 6th most worrisome constraints in paddy processing. The inadequate modern machines as one of the major constraints refer to inability to acquire milling machines with latest technology such as polisher, de-stoner and others, hinders the desired quantity and quality of milled rice that can compete with foreign rice. The study unraveled the use of poor or substandard parboiling and drying skills needed to enhance quality and quantity of the milled rice. The research further identified inadequate improved varieties by the processor; this is worrisome since the quantity of milled rice depends on the quality of paddy that is used in the processing and since most processors process the local variety of paddy rather than the improved variety; quantity is thus, compromised. The issue of non-uniformity of paddy also compromises the quality of milled rice since processors mix all sorts of paddy variety in their processing activities. Furthermore, poor paddy post-harvest coupled with lack of latest milling equipment was found to compromise both quality and quantity of the milled rice.

Table 3: Constraints Confronting Paddy Processing in Adamawa State, Nigeria

Constraints	Frequency	Percentage (%)
Inadequate improved variety	21	13.125
Non-uniform paddy variety	13	8.125
Low level of Skills in Parboiling	18	11.25
Low level of Skills in Drying Techniques	38	23.75
Inadequate Modern milling machines	45	28.125
Poor Post harvest	25	15.625
Total	**160**	**100**

Source: Field Survey (2018)

Conclusion

The functional relationship in paddy processing indicates positive and significant relationships of the inputs as *a priori* expected. Similarly, socioeconomic variables in the inefficiency model of the paddy processing shows negative and significant relationships as *a priori* anticipated. However, the following recommendations are imperative in bringing about more efficient productivity in the paddy processing industry of the study area. The study advocates for use of improved paddy varieties, uniformity in paddy varieties during processing such that the milled rice and even its price are graded according to the peculiar variety used. Skillful training on specialized drying and parboiling techniques. Lending organizations should intervene by providing the necessary credit facilities and modern paddy processing facilities at subsidized rate to boost the industry.

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