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Analysis of Risks Associated with Production Inputs and Technical Inefficiency Among Smallholder Rice Farmers in Borno State, Nigeria

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Abstract: *This study analyzed risks associated with production inputs and technical inefficiency among smallholder rice farmers in Borno State, Nigeria. Descriptive statistics and Stochastic Frontier (SFA) Model with Flexible Risk Specification were used as analytical tools. Survey research design was employed to collect primary data from smallholder rice farmers using structured questionnaire. Multi-stage sampling technique was employed to collect data in two senatorial districts – Borno Central and Borno South using purposively technique. A total sample size of 500 smallholder rice farmers were randomly and proportionately selected using simple random sampling technique from the list of smallholder rice farmers obtained from their association in 20 wards of four (4) Local Government Areas in the study area for the analysis. The result of the mean production function indicates that coefficients of cultivated area, rice seed and hired labour were all positive and significant at 1% while coefficients of fertilizer, family labour and chemicals were negative but only fertilizer and family labour were significant at 10% and 1%, respectively. The finding of the variance function shows that rice seed, chemicals, hired labour, family labour and age of rice farmers were found to be risk-increasing inputs and factor respectively while cultivated area, fertilizer and education were risk-decreasing inputs and factor respectively. The finding of the technical inefficiency model shows that household size, rice farming experience, off-farm income and fertilizer were positive and significant at 1%, 5% and 10% respectively while age of farmers, contact with extension workers and membership of rice smallholder farmers' association were negative and significant at 5% and 1% respectively. It was recommended that risk-averse smallholder rice farmers should use less of rice seed, chemicals, hired labour and family labour; and more of cultivated area and fertilizer as compared to a risk-neutral smallholder farmers in the study area.*

Keyword: *Risks, Production Inputs, Technical Inefficiency, Smallholder, Rice Farmers, Borno State, Nigeria*

INTRODUCTION

Agriculture remains a key source of livelihood for most households and the leading engine of economic growth in developing countries and Nigeria inclusive. The development of agricultural sector is therefore a public priority. The Nigeria Gross Domestic Product (GDP) at basic constant price (real GDP) grew by 2.27 per cent year-on-year from ₦69.80 trillion in 2018 to ₦71.39 trillion in 2019 compared to 1.91 per cent in 2018 (Asunloye, 2020). The growth was largely due to the agricultural sector's contributions of ₦10.50 trillion, with 25.2 per cent shares of the total GDP respectively in 2019 (Asunloye, 2020). In Nigeria, agriculture is the largest economic activity in the rural area where almost 50% of the population live (Umeh & Adejo, 2019). The state of agriculture in Nigeria remains poor and largely underdeveloped and the sector continues to rely on underdeveloped techniques to sustain a growing population with little efforts to add value. This has negatively reflected on the productivity of the Nigeria agricultural sector, its contributions to economic growth as well as its ability to perform its traditional role of food production among others. This state of the agricultural sector has been blamed on heavy dependence on oil and its consequences on several occasions (Umeh & Adejo, 2019; Falola & Haton, 2008).

Nigeria is the largest rice producer in Africa and it currently produces about 8 million tonnes of rice out of the Africa's average of 14.6 million tonnes of rice annually (Anonymous, 2020). The Federal Government of Nigeria is aiming at 18 million tonnes of rice production by 2023 (Anonymous, 2020). It is projected that Nigeria's rice consumption will rise to 35million metric tonnes by 2050, increasing at the rate of 7% per annum due to the estimated population growth (Umeh & Adejo, 2019; Central Bank of Nigeria (CBN), 2015). *Rice is among the three leading food crops of the world, with maize (corn) and wheat being the other two. All three food crops directly provide no less than 42% of the world's required caloric intake* (Klynveld Peat Marwick Goerdeler (KPMG), 2019). Globally, rice is a staple food to over 50% of people, providing over 19% of global human per capita energy (KPMG, 2019). Human consumption accounts for about 78% of global production while the balance serves other uses such as feed (KPMG, 2019).

Rice is one of the major staple foods in Nigeria, consumed across all geo-political zones and socioeconomic classes in Nigeria. Only about 57% of the 6.7 million metric tonnes of rice consumed in Nigeria annually is locally produced, leading to a supply deficit of about 3 million metric tonnes (KPMG, 2019). With rapid growth in the country's population which is estimated to exceed 200 million by 2019, it is expected that the demand for rice will be sustained and increased in the foreseeable future.

In Agriculture, risk is an inherent part of the production process (Asche & Tveteras, 1999). Even more so in developing countries such as Nigeria where subsistence agriculture predominates, production risk is an issue of great concern. Any production related activity or event that is uncertain is characterized as production risk. Agricultural production implies an expected outcome or yield. Variability in outcomes from those expected yield creates risks to the producer's ability to achieve financial goals. Reducing variability in expected yields has been a major focus of farm managers. Agricultural risk can be categorized into two main types namely, production risk which is characterized by high variability of production outcomes and price risk resulting from volatility of the prices of agricultural output and inputs. The effect of risk and uncertainty is more significant in developing countries such as Nigeria due to market imperfections, asymmetric information and poor communication networks (Fufa & Hassan, 2003; Wanda, 2009). The stochastic nature of agricultural production is in most cases a major source of risk, because, variability in yield is not only explained by factors outside the control of the farmer such as input and output prices, but also by controllable factors such as varying the levels of inputs. (Antle, 1983).

Encouraging increase in agricultural production particularly in the rice industry is a strategic goal of the Nigerian government. ''The smallholder farmers mostly apply smaller amount of farm inputs than they would if they maximized anticipated profits. These farmers in some cases do not use or only partly use improved innovations, even when these improved innovations would provide more revenues on labour and land than some pre-existing technologies'' (Guttormsen & Roll, 2014). The unique possible justification for this unwillingness amongst smallholders in most developing countries of the world might be the observed risk profile related with these technologies. According to Just & Pope (1979) input such as fertilizer can increase the anticipated yield but in turn increase risk. The use of fertilizer and other farm inputs among smallholders in developing countries is lesser mainly due to high cost and probably the smallholder's inability to acquire credit (Evenson & Gollin, 2003). Therefore, the anticipated increase in fertilizer use could increase farm output. The risk related with increased use of fertilizer and other farm inputs is closely associated to the smallholder's know-how and experience in farming. As a result, farmers with more years of experience in farming may possibly have the ability to reduce risk related with improved technologies.

According to Byerlee *et al.* (1998), a farmer that is educated would, for example, apply fertilizers and other farm inputs properly, thus decreasing the variability of production. These practices would result in improving well-being of the farmers who are risk-averse. In case of the risk-neutral farmers, this is a precise specification. Though, studies by Bromley & Chavas (1989), Ramaswami (1992), Fafchamps & Pender (1997) and Groom *et al.* (2008) showed that smallholder farmers are risk averse. This study thus analyzed production risk and technical inefficiency among smallholder rice farmers in the study area. The analyses in this study shows how rice smallholders used farm inputs to increase yield and decrease the variability in yield. One of the major significant typical of agricultural production procedures is that random production tremors can be observed merely after inputs decision. Therefore, inputs level influence the anticipated output level and level of output risk (Guttormsen & Roll, 2014). Although in the researcher's anticipation all production inputs were expected to increase yield, according to Shankar *et al.* (2008) ''some among the production inputs could decrease the level of output risk, while others may possibly increase it''.

Efficiency measurement was introduced by Farrell (1957), known as technical competence. This efficiency is determined through efficiency score for each firm. Firms could be analyzed and evaluated and then compared with suitable corresponding firm. There is scope for additional increase in smallholder's rice output from existing hectares, if resources are properly harnessed and efficiently allocated. Hence, this study becomes crucial in examining the risks associated with production inputs and technical inefficiency among the smallholder rice farmers in Borno State, Nigeria.

Objectives of the Study

The main objective of this study was to estimate risks associated with production inputs and technical inefficiency among smallholder rice farmers in Borno State, Nigeria. The specific objectives were to: estimate production risk associated with inputs used in the smallholder rice production in the study area; and estimate the determinants of technical inefficiency among the smallholder rice farmers in the study area.

Hypothesis of the Study

The following hypotheses were postulated for testing; i) H0: there is no technical inefficiency effects in the Cobb-Douglas stochastic frontier production function model of the rice smallholder farms without risk specification; ii) H0: there is no technical inefficiency effects in the Cobb-Douglas stochastic frontier production function model of the rice smallholder farms with risk specification; iii) H0: there is no risk associated with the use of production inputs by the rice smallholder farmers; iv) H0: the determinants of technical inefficiency have no influence on rice production among the smallholder farmers.

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

Production Theory

Production can be considered as a procedure where farmers make use of a given amount of inputs (represented by input vector x) to produce an amount of output (represented by y) (Hokkanen, 2014). The farmers transform a given amount of farm inputs into outputs using some technology of production, which could be characterized either by set-theoretic notions or the accustomed production function method. The explanation of production theory can begin by introducing the sets of input and output along with the technology set for a particular production technology. The set of technology Ψ can be well-described as the set of achievable production systems, which could be produced with definite technology of production particular to the unit of production observed (Hokkanen, 2014): This can be expressed as follows:

$$\Psi = \{(y, x) : x \text{ , this can yield } y\}$$

The border of this set is instinctively the production frontier, which re-counts maximum output producible for any given input vector. The sets of input of the same production technology are therefore described as the sets of inputs vector that are achievable for each component of the output vector y .

$$\varphi(y) = \{x : (y, x) \in \Psi\}$$

Also, the border of this set forms isoquants of the input for the technology of production. Lastly, the output set can be described as the set of achievable outputs, for every likely input vector x.

$$\rho(x) = \{y : (y, x) \in \Psi\}$$

Similarly to the sets described above, the border of the output set describes isoquants of the output for a particular output y . According to Coelli *et al.* (2005), the technology and output sets have overall properties that include non-negativity, weak essentiality, non-decreasing in input and also concave in input. In contrast to the set depiction, production can as well be considered by the accustomed production function as a parametric description of the production procedure for a particular farmer. According to Kumbhakar & Lovell (2003), this depiction though necessitates that the process of production is single output or as an alternative the output vector can be sum up to a compound output vector by means of some optimum weights. The production function provides the association between inputs and outputs, with particular properties that depend on the functional form preferred. The production function permits for the consideration of multiple number of inputs and outputs

Theoretical Framework for the Study

For the purpose of this research, the Stochastic Frontier Analysis (SFA) was extended by examining the risk associated with the use of production inputs by the rice smallholder farmers since it is more robust following Bokusheva & Hockmann (2006) as:

$$y_i = f(x_i; \alpha)\, e^{v_i}\, TE_i$$

Where:

y_i = output of the i-th rice smallholder farm;

x_i = vector of rice production inputs used by the i-th smallholder farmer;

α = vector of technology parameters;

i = 1, 2, 3,………., rice smallholder farmers;

$f(x_i; \alpha)$ = production frontier;

TE_i = output-oriented technical efficiency of the i-th rice smallholder farmer; and

v_i = producer-specific random component.

The technical efficiency (TE) is the ratio of observed output to maximum feasible output in a state of nature represented by $\exp(v_i)$:

$$\text{TEi} = \frac{yi}{f(x_i;\alpha)e^{v_i}}$$

Though, the conventional specification of a stochastic production function has a feature that could extremely limit its potential to portray production technology properly (Bokusheva & Hockmann, 2006). One of the major significant drawback of the traditional multiplicative stochastic specification of production technology is the implicit assumption that if an input has a positive effect on output, then a positive effect of this input on output variability is also imposed (Bokusheva & Hockmann, 2006). According to Just & Pope (1978), the effect of an input on output should not be tied *a priori* to the effect of input on output variability. As an alternative, Just & Pope (1978) suggested a more general stochastic production function specification that comprises two general functions: one that specifies the effects of the input on the mean of the output and another that specifies the effect of input on the variance of the output:

$$y_i = f(x_i; \alpha) + g(x_i; \beta)\, v_i$$

Where:

$f(x_i; \alpha)$ = mean production function

$g(x_i; \beta)$ = variance production function.

α = vector of the mean production function parameters

β = vector of the variance production function parameters

v_i = stochastic term assumed to be independently and identically distributed standard normal random variable. N (0, 1), therefore, E(y) = f(x), and V(y) = g^2 (x). Consequently, the effect of inputs has been divided into two effects, that is, the effect on mean production and the effect on variance production. Since the variance of y is specified as a function of the production inputs $g(x_i; \beta)$, the Just & Pope (1978) production function thus, exhibits heteroscedasticity. The marginal production risk is expressed as:

$$\frac{\partial \operatorname{var}(y)}{\partial x_k} = 2g(x; \beta)\, g_k(x; \beta)$$

The marginal production risk could be positive, negative or zero depending on the signs of $g(x_i; \beta)$ and $g_k(x_i; \beta)$, where the latter is the partial derivative of g with respect to production input k. There are usually some chances for incorporating technical inefficiency (u) into the Just & Pope (1978) production function. These are: a) in additive form suggested by Battese *et al.* (1997), ‘’in this situation, the technical inefficiency term is attached to the variance production function, together with the random term representing production uncertainty’’. It is expressed as:

$$y = f(x; \alpha) + g(x; \beta)(v - u)$$

b) In multiplicative form proposed by Kumbhakar (2002), where the technical inefficiency term is attached to the mean production function. It is expressed as:

$$y = f(x; \alpha)(1 - u) + g(x; \beta)\, v$$

At this point an additional assumption expressed as: exp (-u) = 1-u has to be introduced. c) In the more flexible form proposed by Kumbhakar (2002), here an additional function q(x) for explaining technical inefficiency is further introduced: It is stated as:

$$y = f(x; \alpha) + g(x; \beta)\, v - g(x; \gamma)\, u$$

Hence, models under (a) and (b) are exceptional cases of the model under (c). Based on the selections of the q(x) function, the model in (c) can be reduced to model under (a) when q(x) = g(x) or to model under (b) when q(x) = f(x).

Empirical Studies on Production Risks and Technical Inefficiency

Some earlier studies investigated the effect of risk on agricultural production by directly incorporating a measure of risk in the traditional production functions. Just and Pope (1979) study focused on production risk, determining it by variance of output. They also recommended the use of the production function specifications satisfying some desirable properties. The key focus in their specification is to allow inputs to be either risk increasing or risk decreasing. The Just-Pope framework, however, does not take into account producer's attitude towards risk (Kumbhakar, 2002). Love & Buccola (1991) extended the Just-Pope function to consider producer's risk preferences in a joint analysis of input allocation and output supply decisions. Similarly, Wan & Battese (1992) suggested an alternative stochastic frontier production function which permits the estimation of technical efficiency to account for production risk. In their study, the influence of production risk was investigated by directly incorporating a measure of risk in the traditional production function.

Moser & Mußhoff (2017) compared the use of risk-increasing and risk-reducing production inputs with the experimentally measured risk attitudes of farmers. They employed the Just-Pope production function that indicates production inputs' influence on output risk, and a Holt-Laury lottery was used to measure farmers' risk attitudes. They tested whether more risk averse farmers use more risk-reducing and less risk-increasing production inputs. They used a unique data set which includes 185 small-scale rubber farmers on the Island of Sumatra, Indonesia. The result of the Just-Pope production function indicates that higher fertilizer usage had a risk-reducing effect, whereas higher herbicide usage had a risk-increasing effect. Comparing this with their outcome of the Holt-Laury lottery, they found that more risk averse farmers used more fertilizer (risk-reducing) and less herbicides (risk-increasing).

Guttormsen & Roll (2014) examined production risk in a subsistence agriculture in the Kilimanjaro region of Tanzania using Just & Pope (1978) framework for modeling risk. The data for their study was based on a 2002 survey data of subsistence farmers in the Kilimanjaro region of Tanzania. Their result indicated that extension services do not increase the mean production of the farmers, it could reduce production risk. Furthermore, Guttormsen & Roll (2014) asserted that in the past, agricultural extension and subsidized conventional inputs such as high-yielding seed varieties, fertilizer and pesticides, have become essential element of agricultural aid programs in developing countries. Though, results of this form of aid were rather uncertain, and numerous donor nations have decreased their supports in rejoinder. Risk-averse smallholder farmers would tend to consider both the variance in output and the expected mean. They could hence choose inputs levels that differ from the optimal input levels of risk-neutral producers, who consider only the expected mean.

Roll *et al.* (2006) investigated how production risk could influence the way a risk averse producer like a subsistence farmer chooses optimal input levels. The data for their study was based on a dataset obtained from a survey on smallholders in the Kilimanjaro region in Tanzania.

Risk averse producers will take into account both the mean and the variance of output, and thus farmers are expected to choose input levels which differ from the optimal input level of risk neutral producers. Production risk is of paramount importance in developing countries (Roll, Guttormsen & Asche, 2006), since variance in production might have severe consequences for the farmer. To model the production decision problem under such circumstances, they have made use of the reason that production risk can be treated as heteroskedasticity. Their finding revealed that there was presence of output risk in inputs. They re-estimated the mean and variance function using a maximum likelihood estimator, and correct the standard errors to provide valid inference.

Bokusheva & Hockmann (2006) analyzed production risk and technical inefficiency in Russian agriculture. Their study investigated production risk and technical inefficiency as two possible sources of the production variability. A production function specification accounting for the effect of inputs on both risk and technical inefficiency was used to describe the production technologies of the Russian farms. They used panel data from 1996 to 2001 on 443 large agricultural enterprises from three regions in central, southern and Volga Russia. The findings indicate that there were significant differences in production technologies in the three investigated regions.

Ogundari & Akinbogun (2010) modelled technical efficiency with production risk: A study of fish farms in Nigeria. Data from a total of 64 fish farms randomly sampled from Oyo State, Nigeria. Their study used the stochastic frontier model with flexible risk specification. The findings indicates that the mean fish output is significantly influenced by labour, fertilizer, and feed. They further revealed that fertilizer and feed were found to be risk-increasing inputs, whereas labour was a risk-reducing input. The result also revealed that labour, farming experience, education, and access to market significantly decreases technical inefficiency of farmers.

METHODOLOGY

Study Area

Borno State is one of the largest States in Nigeria, covering a total land area of 69,435 square kilometer, about 7.67% of the total land area of the country (Ministry of Land & Survey, 2019). The State lies approximately between latitudes $10^0$02'N and $13^0$04N and between longitudes $11^0 04^0$E and $14^0$04E (Ministry of Land & Survey, 2019). It shares boundaries with Adamawa State to south Gombe State to South east and Yobe State to the east. It also shares International boundaries with the Republic of Chad northwest and Cameroon to the southwest. According to the 2006 census figures, Borno State has a population of 4, 151,193 with a population density of approximately 60 persons per square kilometer (National Population Commission (NPC), 2006). The state is presently structured into 27 Local Government Areas that include: Maiduguri, Jere, Bama, Gowza, Kala Balge, Ngala, Mafa, Marte, Monguno, Guzamala, Bayo, Kuya Kusar, Biu, Shani, Kaga, Askira Uba, Hawul, Gubio, Kukawa, Abadam, Mobbar, Magumeri, Nganzai, Konduga,

The State, which is predominantly agrarian, is characterized by three natural agro-ecological zones which include the Sahel savannah in the extreme north, the Sudan savannah in the central part and the northern Guinea Savannah in the southern part (Folorunsho, 2006). The climate of the area is characterized by dry and wet season. The wet season lasts from March to October, while the dry season is from October to April. The average annual temperature is about 30^0C with a maximum of 45^0C in March and a minimum of 15^0C during the dry harmattan season. The annual rainfall ranges from 400mm to 700mm in the north and 500mm to 900mm in the southern part (Folorunsho, 2006). The soil types are clay, sandy loam, clay loam, sandy etc. With common weeds such as Sudan grass, spear grass *pennisetum spp*, gamba grass *striga spp* etc, with herbs and shrubs. Major crops grown in the area include millet, sorghum, groundnut, rice, wheat, cowpea bambaranut, etc. Vegetables such as tomatoes, okro, onion, pepper, etc. and livestock such as cattle, sheep, goat, pigs, camel, horse and donkey. The major occupations of people in the area are farming, cattle rearing and fishing. The principal ethnic groups are kanuri, Shuwa/Arab, Bura, Marghi, and Gwoza. Others include Fulani, Hausa, etc.

Research Design and Sampling Technique

The research design employed for this study was the survey research design. In which structured questionnaire was used during the survey process. Multi-stage sampling technique was employed for the study. In the first stage, two (2) senatorial districts – Borno Central and Borno South – were purposively selected out of the three (3) senatorial districts in the State. This was because most of the rice producing areas in Borno North were not accessible by farmers due to insecurity. In the second stage, two (2) Local Government Areas (LGA) were purposively selected from each of the (2) senatorial districts. These LGAs include Dikwa, Jere, Askira Uba and Biu LGAs, making a total of four (4) LGAs for the study. These were major rice producing LGAs in the selected senatorial districts of the State. While in the third stage, five wards were randomly selected from each of the four (4) LGAs, making a total of 20 wards for the study. Finally, a total sample size of 500 smallholder rice farmers were randomly and proportionately selected using simple random sampling technique from the list of smallholder rice farmers obtained from their association in the 20 wards for the analysis.

Sample Size for the Study

A sample size of 500 smallholder rice farmers were randomly and proportionately from the 20 wards of Dikwa, Jere, Askira Uba and Biu LGAs across the two (2) senatorial districts using simple random sampling technique. According to Krejcie & Morgan (1970) and Yamane (1967), a sample size of 500 smallholder rice farmers was adequate for a study of this nature. The formula for the determination of the sample size is therefore expressed as:

$$n = \frac{N}{1 + N(e)^2}$$

Where:

n = Sample size

N = Population size (sample frame)

e = Level of significance = 5%

1 = constant

Sources of Data

Data for the study were collected from both primary and secondary sources of information. The primary data were collected using structured questionnaire that was designed and administered to 500 smallholder rice farmers in the study area. The secondary sources of information included journal, bulletins, textbooks, internet, conference papers, past projects, dissertation etc.

Method of Data Collection

Primary data were collected by employing survey instruments via face-to-face interview using structured questionnaire. The questionnaire were administered by the researcher alongside trained enumerators (extension agents) of the Borno State Agricultural Development Programme (ADP). Qualitative information were also recorded from selected smallholder rice farmers with a view to having the right output from the survey work. To ensure validity of the data, information were triangulated through conducting discussions with extension agents and other staff of the zonal agricultural offices in the study area. Data were collected on rice output, production inputs, age of farmers in years, education measured in years spent in school, household size in numbers, rice farming experience in years, off-farm income and rice income both in naira; access to credit, 1 if rice smallholder farmer has access to credit and 0 otherwise; contact with extension workers, 1 if frequent contact with extension agents and 0 otherwise; and membership of rice smallholder farmers' association, 1 member and 0 otherwise.

Analytical Technique

The analytical tools employed for this study includes descriptive statistics and stochastic frontier Analysis (SFA) with flexible risk specification. Descriptive statistics such as frequency, percentage and mean were used to organize and summarize the findings to achieve specific objective (i). The risk associated with the use of production inputs and technical inefficiency of the rice smallholder farmers were estimated using the Cobb-Douglas functional form which gave the best functional form that adequately represented the data. Though, other forms such as translog and quadratic functional forms were also employed to determine the best functional form that adequately represents the data. The Cobb-Douglas functional form was used to achieve specific objective (ii) and (iii). The reduced form of the Cobb-Douglas model is specified as:

$$\ln Y_i = \alpha_0 + \alpha_{1i} \ln X_{1_i} + \alpha_{2i} \ln X_{2i} + \alpha_{3i} \ln X_{3i} + \alpha_{4i} \ln X_{4i} + \alpha_{5i} \ln X_{5i} + \alpha_{6i} \ln X_{6i} + V_i - U_i$$

Where:

lnY= rice output in kg/ha;

$\alpha_0 =$ slope of the intercept;

$\alpha_1 - \alpha_6 =$ parameter estimated;

$\ln X_1$ = cultivated area in ha;

$\ln X_2$ = rice seed in kg/ha;

$\ln X_3$ = fertilizer in kg/ha;

$\ln X_4$ = chemicals in liters/ha;

$\ln X_5$ = hired labour measured in man-days/ha;

$\ln X_6$ = family labour proxy by opportunity cost of labour measured in man-days/ha;

i = number of rice smallholder farms;

The Cobb-Douglas functional form imposes serious restrictions on the technology by restricting the production elasticities to be constant and the elasticities of input substitution to be unity (Villano & Fleming, 2004). The translog functional form model is expressed as:

$$\ln Y_i = \alpha_0 + \sum_{i=1} \alpha_i \ln X_i + \frac{1}{2} \sum_{i\leq} \sum_{k} \alpha_{ik} \ln X_i \ln X_{ki} + \alpha_6 X_{6i} + \frac{1}{2} \sum_{i\leq} \sum_{k} \alpha_{ik} \ln X_i X_{6i} + V_i - U_i$$

Where: k = number of variable inputs and other variables as previously defined. The quadratic functional form is specified as follows:

$$Y_i = \alpha_0 + \sum_{i=1} \alpha_i X_i + \frac{1}{2}\sum_{i\leq}^{6} \sum_{k}^{6} \alpha_{ik} X_i X_{ki} + V_i - U_i$$

Having specified the functional forms above, the model for technical inefficiency following Battese & Coelli (1995) is expressed as:

$$\mu_i = \delta_0 + \sum_{i=1} \delta_i Z_i$$

Where:

Z_1 = age of farmers in years**;**

Z_2 = education measured in years spent in school**;**

Z_3 = household size in numbers**;**

Z_4 = rice farming experience in years**;**

Z_5 **=** off-farm income in naira**;**

Z_6 = rice income in naira;

Z_7 = access to credit, 1 if rice smallholder farmer has access to credit and 0 otherwise**;**

Z_8 = contact with extension workers, 1 if frequent contact with extension agents and 0 otherwise; Z_9 = membership of rice smallholder farmers' association, 1 member and 0 otherwise;

Z_{10} = fertilizer in kilogram.

RESULTS AND DISCUSSION

Production Risk Associated with Inputs Use in the Smallholder Rice Production

The findings of mean production, variance and technical inefficiency functions in table 2 were estimated based on Cobb-Douglas production function. The Cobb-Douglas functional form is highly restrictive according to Bokusheva & Hockmann (2006), though the study tried other functional forms such as translog and linear-quadratic for robustness check which provided poor estimates. Most of the estimated coefficients of the translog and linear-quadratic functional forms were negative and insignificant, monotonicity and quasi-concavity were generally not achieved. That is, the first-order coefficients estimates of all inputs in the quadratic functional form which is interpreted as marginal products of the inputs calculated (Ogundari & Akinbogun, 2010; Bokusheva & Hockmann, 2006), were not positive, meaning absence of non-negative production elasticities.

The likelihood ratio (LR) test statistics in table 2 reveals that the coefficients of the production variance function were different from zero, meaning that the Cobb-Douglas stochastic frontier production model with risk specification was the best representation of the data. The null (H0) is thus rejected. The value of lambda (λ) 232876.600, implies that the variation in sigma (u) was more pronounced than the variation in the random component sigma (v). The null (H0) is thus rejected. The lambda (λ) represents Cobb-Douglas production model with a risk specification, implying technical efficiency difference among smallholders rice farms were the main causes for variation of rice yield.

The null (H0) is thus rejected. This still emphasizes on the variance associated with the technical efficiency estimates when the production risk constituent is left out in stochastic frontier production model specification. The coefficients of cultivated area, rice seed and hired labour were all positive and significant at 1%. This is consistent with the production theory (Tijani, 2017). While coefficients of fertilizer, family labour and chemicals were negative but only fertilizer and family labour were significant at 10% and 1%, respectively in the mean production function. The result further indicates that cultivated area and hired labour had the highest elasticity of 0.3592 (35.92%) and 0.1418 (14.18%) followed by 0.1227 (12.27%) for rice seed.

Analysis of the coefficients of the production variance function in table 2 indicates that rice seed, chemicals, hired labour, family labour and age of rice farmers were positive while cultivated area, fertilizer and education were negative. This implies that rice seed, chemicals, hired labour, family labour and age of rice farmers were found to be risk-increasing inputs and factor respectively while cultivated area, fertilizer and education were risk-decreasing inputs and factor respectively. A risk-increasing inputs increases production variability while risk-decreasing input decreases production variability among smallholder rice farmers (Tijani, 2017). This suggests that a risk-averse smallholder rice farmer uses less rice seed, chemicals, hired labour and family labour; and more of cultivated area and fertilizer as compared to a risk-neutral rice smallholder, which could have effect on rice production. Generally, since rice smallholders receive some assistance from government in form of anchor borrowers loan, subsidies, improved seeds, training workshops etc, it is likely that these might influence their behaviour/propensity towards more risk-taking activities, such as the use of more production inputs which are risk-increasing.

Table 2: Production Risk Associated with Inputs Use in the Smallholder Rice Production

Items	Estimated Parameters	Coefficients	Standard Error	Z- Statistics
Mean Production Function:				
Constant	$\ln X_0$	7.891578	0.7099317	11.12***
Cultivated area (ha)	$\ln X_1$	0.3592006	0.096316	3.73***
Rice seed (kg/ha)	$\ln X_2$	0.1226834	0.0318754	3.85***
Fertilizer (kg/ha)	$\ln X_3$	-0.260335	0.2059459	-1.26**
Chemicals (liters/ha)	$\ln X_4$	-0.0287505	0.0431459	-0.67
Hired labour (man-days/ha)	$\ln X_5$	0.1417381	0.030901	4.59***
Family labour (opportunity cost of labour) (man-days/ha)	$\ln X_6$	-0.1134322	0.0305235	-3.72***
Production Variance Function:				
Cultivated area	β_1	-4.027221	2.70786	-1.49**
Seed	β_2	0.3729317	0.2832945	1.32**
Fertilizer used	β_3	-1.06072	0.2127306	-4.99***
Chemicals	β_4	0.0954834	0.2185442	0.44

Hired labour	β_5	0.1882831	0.3650607	0.52
Family labour	β_6	0.453763	0.1545788	2.94***
Age of Rice farmers	β_7	0.1034902	0.0296536	3.49***
Education	β_8	-8.513203	5.015558	-1.70**
Variance Parameters:				
Lambda	λ	232876.600		
		(23792537.65***)		
Sigma Squared	σ^2	0.0287		
		(8.660***)		
Sigma u	σ_u	0.1695		
Sigma v	σ_v	7.28		
Log likelihood		-311.72265		
Wald chi-square (6)		77.74		
		(0.0000***)		

Source: Computed using field survey data, 2021, Figures in parentheses represents z-value,

*** = Significant at 1%, **= Significant at 10%

Determinants of Technical Inefficiency among the Smallholder Rice Farmers

The finding of determinants of technical inefficiency estimation based on Cobb-Douglas production frontier function with risks specification in table 3 shows that household size, rice farming experience, off-farm income and fertilizer were positive and significant at 1%, 5% and 10% respectively while age of farmers, contact with extension workers and membership of rice smallholder farmers' association were negative and significant at 5% and 1% respectively. The positive coefficient of household size implies that oil palm smallholders with large number of persons in their households tend to be technically inefficient. The reason could be due to the fact that an increase in number of persons in the household leads to an increase in household consumption expenditure, which would carry away some proportion of the household income meant for the procurement of modern farm inputs and other farm operations that can lead to technical inefficiency (Daniel *et al.,* 2015).

The positive coefficient of rice farming experience also suggests that as the smallholder rice farmer's experience increases technical inefficiency would likely increase, which sounds illogical. This might be due to the effect of age of the farmer (Reddy & Sen, 2004). The reason could probably be due to the fact that farmers with more years of farming experience are older (Tijani, 2017). The positive coefficient of off-farm income suggests that rice smallholders who earn higher income from off-farm activities were likely to be technically inefficient than low income earners. The reason could be due to the fact that smallholder farmers with greater responsibilities tend to exert more pressure on their meager incomes obtained from off-farm activities than those with less responsibilities.

Table 3: Determinants of Technical Inefficiency among the Smallholder Rice Farmers

Determinants	Estimated parameters	Coefficients	Standard error	Z-value
Constant	Z_0	1.351859	0.5916679	2.28**
Age of farmers (years)	Z_1	-0.014087	0.0062797	-2.24**
Education (years spent in school)	Z_2	-0.0423105	0.0401049	-1.05
Household size (numbers)	Z_3	0.1213203	0.0388325	3.12***
Rice farming experience (years)	Z_4	0.0119757	0.0086924	1.38*
Off-farm income (naira)	Z_5	0.0000304	0.0000129	2.36**
Rice income (naira)	Z_6	-5.16e-07	8.40e-07	-0.61
Access to credit (dummy)	Z_7	0.1813548	0.2506858	0.72
Contact with extension workers (dummy)	Z_8	-2.125821	0.2708532	-7.85***
Membership of rice smallholder farmers' association (dummy)	Z_9	-1.587515	0.2291034	-6.93***
Fertilizer (kilogram)	Z_{10}	0.0003755	0.0002165	1.73*

Source: Computed using field survey data, 2021, Figures in parentheses represents z-value,

*** = Significant at 1%, **= Significant at 15%, *= Significant at 10%

The positive coefficient of fertilizer in table 3 implies that technical inefficiency likely increases with increase in the amount of fertilizer used by the rice smallholder farmers. The reason for the inefficiency might be due to over utilization of fertilizer in rice production. Hence, the more the amount of fertilizer used the higher the level of technical inefficiency among the rice smallholders. The negative coefficient of age of farmers implies that older rice smallholders are likely to be technically efficient than their younger ones. The reason for decreased in technical inefficiency among older rice farmers than their younger counterpart could be due to the experience they have acquired over the years.

The negative coefficient of contact with extension workers implies that smallholders who associates with extension agents were likely to be more efficient than those who do not have contacts. This is plausible because smallholders who had contacts with extension agents obtain information on recommended farming technologies and useful information that could improve their production efficiency and make them more efficient (Reddy & Sen, 2004). The negative coefficient of membership of rice smallholder farmers' association, implies that technical inefficiency likely reduces with rice smallholder being a member of farmers' association. The significance of membership of rice smallholder association cannot be overemphasized (Tchale, 2009), because farmers who are members of an rice farmers' association would get advantage from the mutual knowledge among themselves in the areas of new farming techniques, have more access to agricultural information, credit and economies of scale in accessing production inputs, as well as more improved ability to adopt innovations (Bhatt & Bhat, 2014). Thus member smallholders tend to be likely technically efficient than non-members.

Conclusion

In agriculture, risk is an inherent part of the production process. Even more so in developing countries such as Nigeria where subsistence agriculture predominates, production risk is an issue of great concern. Any production related activity or event that is uncertain is characterized as production risk. The study concluded that rice seed, chemicals, hired labour, family labour and age of rice farmers were found to be risk-increasing inputs and factor respectively whereas cultivated area, fertilizer and educational level were risk-decreasing inputs and factor respectively. The finding of the study further concludes that household size, rice farming experience, off-farm income and fertilizer were positive and significant at 1%, 5% and 10% respectively while age of farmers, contact with extension workers and membership of rice smallholder farmers' association were negative and significant at 5% and 1% respectively.

Recommendations

The following recommendations were made based on findings of the study:

i. The government should re-strategies the extension service program for effective monitoring and supervision of the rice smallholder farmers for proper use of farm inputs that would enhance their efficiency levels.
ii. There need to improve the quality of adult education extension program to educate the rice smallholder farmers
iii. The risk-averse rice smallholder farmers should use less of rice seed, chemicals, hired labour and family labour; and more of cultivated area and fertilizer as compared to a risk-neutral smallholder. These would have effect on rice production in the study area.
iv. There is need for the theoretical framework for examining technical efficiency among rice smallholder farmers in the study area to be extended to take account of production risk.

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