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Modeling Production Risk In Efficiency Analysis: Evidence From Rice Production In Yobe State, Nigeria

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ABSTRACT
This study was designed to analyse production risk of rice production in three selected local government areas of Yobe state, Nigeria. A multi stage sampling technique was used to collect primary data from 300. The data for the study was sourced from the survey conducted for the period of 2020 farming season. The study employed a translog stochastic frontier production function model with flexible risk specification. The empirical estimate revealed that farm size, fertilizer, labour, insecticide, herbicide and irrigation service were found to be risk- reducing inputs while seed, machine and green manure were risk increasing inputs. This by implication means that an average risk-averse farmer in the study area who is in pursuit of reducing their risk are expected to use more of the risk decreasing inputs and more of risk increasing inputs to better their situation which can alter their technical efficiency score.
Keywords: Production risk, Technical efficiency, Output variability, Stochastic frontier model

1.0 INTRODUCTION

The limited capacity of the Nigerian rice economy to match the domestic demand raises a number of pertinent questions both in the policy circle and amongst researchers. For instance, what factors explain why domestic rice production lags behind the demand for the commodity in Nigeria? To bridge the demand-supply gap, effort has to be channeled towards increasing its productivity. Theoretically, increasing the productivity of rice production would require either increased input use especially acreage expansion, improvement in resource use efficiency and or technological change derived from use of new technologies. Given the constant population pressure and other social and economic constraints in Nigeria, acreage expansion as a source of increased productivity has little application. Hence, the country is left with the option of improving efficiency of farmers by improving on their condition or removing existing institutional, market and socio-economic constraints and introduction of improved technologies.

For more than a decade, it was thought that adopting food import as a policy would address the nation's food shortage problem. However it has become obvious that such policy rather than bring solutions, has fuelled inflation, discouraged local production and created poverty among many rice farmers and tends to cause food insecurity. This therefore necessitated alternative policy actions. Consequently, speedy and extensive introduction of technological change has become one of the crucial concerns in the development of Nigeria's agriculture (International Development Research Centre (IDRC), 2015).

Much effort has been geared towards increasing the availability and adoption of improved technologies in rice production in Nigeria both at the national and state levels. Specifically, the federal government of Nigeria initiated a programme of doubling rice production in Nigeria through promotion of improved production technologies such as fertilizer, hybrid seeds, pesticides, herbicides and better management practices. Several improved rice varieties that are drought-tolerant, low nitrogen-tolerant, Striga-tolerant;

stem borer-resistant and early maturing has been deployed to address the challenge faced by resource-poor farmers in rice production.

Over the years, many Nigerian governments have also introduced policies with technologies to boost domestic rice production. Notable among these policies and programmes are the national fertilizer policy, national seed policy, land use policy, national extension service policy, agricultural credit guarantee scheme fund (ACGSF), commercial agriculture credit scheme, national irrigation policy, government guaranteed minimum producer's price, rice trade policies and rural development programs. The government also simultaneously created several agricultural institutions, agencies, research institutes and universities to implement these policies and programs. The institutions include: Agricultural Development Projects (ADPs), River Basin Development Authorities (RBDA), Bank for Agriculture and Rural Development (BOI) and National Cereal Research Institute (NCRI) and other research institutes. The federal, state and local governments have also encouraged rice farmers to form cooperative societies so as to enhance their credit worthiness and to enable them benefit from the these policies, programs and projects. Despite the investments made in the rice industry to boost productivity, production levels are still low. For instance, the average yield of rice per hectare in Nigeria (about 2 tonnes/ha) is less than half of that of the world (4.3tonnes/ha). Given the importance of the rice subsector in the country's food security agenda, there are suggestions for improvements in productivity.

In Yobe state, the federal and the state government put up measures to boost rice production in the state. These measures includes the provision of irrigation facilities and other farm inputs by the state government for massive production of rice, wheat and maize to complement the national food security and socioeconomic growth; the distribution of farm inputs to 13,922 farmers in the state by the federal government under ANCHOR borrower scheme to boost rice production and to bridge the gap created by the banned of rice importation by the federal government in 2019. Despite these efforts, rice productivity remained low in Yobe state.

Many scholars have worked on technical efficiency in rice production in their studies such as Akerele, Onasanya, Dada, and Odio (2018), Mundia (2018), Linh, Lee, Peng and Chung (2017), Sania, Hina, Muhammad and Khan (2017), Baten and Hossain (2014) Ogundele and Okoruwa (2014) among others without a due consideration to production risk. The previous researchers fail to adequately address an important aspect of production which is production risk. Ignoring the existence of the risk farming will lead to biases some estimates of parameters and level of technical efficiency which will cause problems when the interpretation of productivity phenomenon. The biased estimate may be misleading to policy makers. The aim of this study is to investigate the risk characteristics of inputs of rice farmers in Yobe state.

2.0 Concept of Production Risk

Output risk is an inherent part of the production process of most primary industries e.g. Agriculture, mining and oil extraction (Asche and Tveteras, 1999). Even more so in developing countries 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.

The conventional stochastic frontier model in the equation 2.3 above proposes the same effect of an input on mean output and variance output. Implying that if an input influences output positively, that input is expected to influence output variance positively and vice versa (Coelli, Rao, Donnell & Battese, 2005). However the Just and pope (1978) production function proposes a separate effect of the inputs on the mean output and the variance of output or output risk. The factors of production can positively contribute to output but relate negatively to output variance. For example, pesticides, irrigation and disease-resistant seed varieties can reduce output variance and simultaneously, contribute positively to output in a given production process. These inputs are categorized as risk reducing inputs. On the other hand, inputs that influence output variance positively are termed as risk increasing inputs. Just and Pope concluded that the effect of an input on output variance should not be tied prior to output variance but the risk effect of an input depend on empirical studies (Just and Pope, 1978).

The production environment is uncertain and producers input use decisions, as well as environmental factors ultimately affects output. The variability in output as a result of certain input decisions is the risk associated with input use. In countries where subsistence agriculture predominates, production risk is an issue of great concern. One very important characteristic of a risky production process is the observance of random production shocks after certain inputs decisions have been made. With respect to relative input uses, a source of deviation from competitive levels is the inputs marginal contribution to the level of output risk (Asche and Tveteras, 1999). Some inputs may reduce the level of output risk, while others may increase risk (Asche and Tveteras, 1999). Production uncertainty is therefore one of the most important ingredients in the formulation of government policy in the inputs decision making of producers (Just and Pope 1978).

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 due to market imperfections, asymmetric information and poor communication networks (Fufa and 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). A risk averse farmer thus uses more of a risk reducing factor than a risk neutral farmer (Pope and Kramer, 1979). Some inputs may reduce the level of output risk (e.g. pesticides) while others may increase risk (Asche and Tveteras, 1999). The first attempt to separate the effect of the inputs on the mean output and the variance of output or output risk was by Just and pope (1978).

2.1 Theoretical framework

Most studies dealing with production risk employ the Just and Pope (1978) framework. They proposed a heteroskedastic production function featuring flexible risk effects which allows input usage to affect the variance of production and its mean. They are the situation where the mean variance model may be inappropriate such as when modeling down side risk and rare event and in such cases the flexible moment bases method would be more desirable (Antle, 1987)

The proposed stochastic specification includes the general functions, specifying the effects of inputs on main output variance Just and Pope (1978) as:

$$yi = f(xi; \alpha) + g(xi; ß).\epsilon$$

Where yi denotes the output for i-th farm. (i = 1,2,3---N) x_i represents a (1xK) vector of input used by the ith farm and α and ß are parameter vectors of the mean of production function and variance production function. Here f(xi; α) is the mean production function while g(x:ß) is the variance function. ϵ is the error term with a standard normal distribution of (1,0). This specification allow input vector x to influence both the mean output and the variance output. The expected output is given by E(y) = f(x; α) and the variance by var(y) $=g(x; ß)^2$

Input are classified as risk increasing, risk reducing or risk neutral based on whether they increase, reduce or have no effect on the output variance that is determined by the sign of the partial derivative of the variance with respect to an input. $\partial g(x; ß/\partial x_k$. This is the marginal effect of an input x_k and can be positive (negative) if the input is increasing (reducing) while input would have zero partial derivative.

The marginal production risk therefore is defined as: $\frac{\partial var(y)}{\partial xk} = 2g(x; ß).\frac{\partial gx;ß}{\partial xk}$

3.0 METHODOLOGY

3.1 Study area

The study was conducted in three selected local government areas of Yobe state which are Geidam, Jakusko and Bade local Government Area. Yobe is located in North East Nigeria. It was created on August 27, 1991. Yobe was carved out of Borno State. The capital of the state is Damaturu. The State lies within latitudes 11^0N and longitude 13.5^0E. It shares borders with Jigawa and Bauchi State to the West, Borno State to the East, and Gombe state to the South. It also has an international boundary with the Republic of Niger in the North. The state covered a land area of 45,502 Square Kilometers of which about 85% is arable. It has an estimated population of 2,532,395 people (Nigerian Population Commission NPC, 2006). The climate of the area is hot and dry for greater part of the year and the hottest months is March to May with temperature ranging from 39^0c to 40^0c. The rainy season lasts for about four months between June and September.

The major ethnic group living Yobe state are Kanuri, while other ethnic communities include Ngizim, karai, Bolewa, bade, Hausa, Ngamo, Shuwa, Fulani Bura, Margi and Maga.

Majority of the populace in the State (85%) are farmers engaged in production of rice, groundnut, beans, cotton and gum arabic. The state is also said to have one of the largest cattle market in West Africa located in Potiskum.

3.2 Data and sampling technique

This study will employ a quantitative approach using a cross-section survey to collect primary data from selected units of analysis. A quantitative study was most appropriate for the research study because it allows for the measurement of relationships between two variables (Chipuunza and Berry, 2010). Six villages (Balle, Shuwari, Kurkushe, Zabudum, Gashua and Azbak) were selected from three local government areas (Geidam, Jakusko and Bade local Government Area) of Yobe state. Cross sectional data for the study was collected during the cropping year 2020. Using Yamane's formula for sample selection, 60, 50, 40, 41, 59, 60 for Balle, Shuwari, Kurkushe, Zabudum, Gashhua, and Azbak respectively which occur in semi-deciduous zones where soil and weather characteristics are favourable for optimum rice production. Three hundred (300) respondents were finalized from the selected villages. The simple random sampling was utilized to pick respondents from each of the selected villages. The production process is characterized by one output, rice and nine inputs: farm size, seed, fertilizer, labour, machine, insecticide, herbicide, green manure and irrigation service.

3.3 Statement of Hypothesis

The following hypotheses were formulated to ascertain the appropriateness of the function form of data and to determine whether production risk in inputs significantly explain output variability.

1. H_O: $\beta_{jk}=0$, the coefficient of the second order variables in translog model are zero to become the Cobb-Douglas model;

2. H_O: $\psi_1=\psi_2=\ldots\psi_9=0$, the null hypothesis that output variability is not explained by production risk in input factor.

3.4 Empirical model specification

The production risk model is specified as:

$$g(X_i;\psi)Vi=\psi i\sum_{Mi}^{9}\psi_m X_{mi}$$

Following Kumbhakar (2002), the production process is represented as below:

$$Y_i=F(x_i;\alpha)+g(x_i;\psi)vi-q(x_i;Z)u_i$$

Y_i refers to the observed output produced by i-th farm, f(x; α) is the mean output function, x_i;s are the input variables, α is the estimated coefficients of production function, ψ is the estimated coefficients of the production risk.

$$\ln Y_i = \psi o + \psi_1 \ln X_1 + \psi_2 \ln X_2 + \psi_3 \ln X_3 + \psi_4 \ln X_4 + \psi_5 \ln X_5 + \psi_6 \ln X_6 + \psi_7 \ln X_7 + \psi_8 \ln X_8 + \psi_9 \ln X_9$$

Where X_i represents input variables, $\psi_m{}^s$ are the estimated risk model parameters and the V^s are the pure noise effect. Where Ψm becomes negative it means that the respective input reduces output variance.

The technical efficiency of i-th farmers is given as:

$$TE = \frac{E(\frac{Yi}{Xi};Ui)}{E(\frac{Yi}{Xi};Ui=0)} = \frac{F(Xi;\alpha - g(Xi;\psi)Ui}{F(Xi:\alpha)} = 1 - \frac{Ug(Xi;\psi)}{F(Xi;\alpha)}$$

$$TI_i = \frac{Ug(Xi;\psi)}{F(Xi;\alpha)}$$

$$TE_i = 1 - TE_i$$

$$E(Y_i/X_i;U_i) = F(X_i;U\psi) - g(Xi;\psi)\,U_i$$

The variance of output or production risk is given as:

$$Var(Y_i/X_i;Ui)\ g^2(Xi;\psi)$$

The marginal effect of the input variables on production risk is given as:

$$\frac{\partial var(Yi)}{\partial Xi} = \frac{\partial g2(Xi;\psi)}{\partial Xi} = 2g(X_i;\psi)g_i(X_i;\psi)$$

Thus,

$$\frac{\partial g2(Xi;\psi)}{\partial Xi} < 0 \rightarrow \text{risk decreasing of the i-th input}$$

$\frac{\partial g2(Xi;\psi)}{\partial Xi}>0$ → risk increasing of the i-th input

$\frac{\partial g2(Xi;\psi)}{\partial Xi}=0$ →risk neutral of the i-th input

The marginal effect of the i-th input on production risk is positive depending on the signs of g(Xi; ψ) and gi(Xi; ψ) where the later is the partial derivative of the production risk function with respect to the i-th input. If the marginal risk is positive it means that input is a risk increasing and when the marginal risk is negative it means that the input is a risk decreasing.

The factors i.e farm size, seed, fertilizer, labour, machine, insecticides, herbicides, green manure and irrigation service can either increase production risk or decrease it.

RESULTS AND DISCUSSION

Table 1. Variables in the production risk function and their a priori expectations

Variables	Description	a priori expectation
X_1	Farm size	+/-
X_2	Seed	+/-
X_3	Fertilizers	+/-
X_4	Labour	+/-
X_5	Machine	+/-
X_6	Insecticides	+/-
X_7	Herbicides	+/-
X_8	Green manure	+/-
X_9	Irrigation service	+/-

4.0 DATA PRESENTATION AND ANALYSIS

4.1 Test of hypotheses

Testing of hypothesis results of the hypotheses tested are presented in Table **2**. For the first hypothesis, the null hypothesis that the Cobb-Douglas is suitable for the data is rejected at 5% level of significance in favour of the translog model. The translog form of the model is therefore the best fit for the data. The second hypothesis which states that production risk in inputs is absent from the production process is also rejected at 5% level of significance; implying that the conventional inputs are jointly related to production risk. This means that there is the presence of risk in the production process.

Table 2

Log likelihood tests for underlying hypothesis

Null hypotheses	Test statistic ƛ	Critical Values $ƛ^2$	Decision
H_O: $\beta_{ij}=0$	29.8*	24.4	Reject H_O
H_O : $\psi_I=\psi_2=\ldots\psi_9=0$	181 *	15.2	Reject H_O

* Significant at 5% level; Critical value obtained from table 1of Kodde and Palm (1986)

4.2 Production risk function

Results in table 3 reveal that farm size had a negative effect on risk production. This indicates that farm size is a risk-decreasing variable. This result is consistent with the work of Picazo-Tadeo and Wall (2011) who found land to be a risk-reducing input because the rice farmers had parceled their land into plots such that losses from one plot are compensated by gains in another due to differences of weather at the different plots. The result is in contrast with the work of Tiedemann and Latacz- Lohmann (2012) whose study revealed that greater area cultivated led to increased output variability, possibly suggesting that larger farms are less able to react quickly to unfavourable weather conditions at harvest or planting times.

Seed is positively related to production risk. The result of seed as a risk increasing input is consistent with the work done by Picadzo-Tadeores and Wall (2003). The effect of an input however should not be tied prior to output variance but rather it should be an empirical issue (Just and Pope, 1978).

Result reveal that fertilizer use have negative and significant impacts on risk production function for rice farmers in the study. These findings indicate that more use of fertilizer decreases risk in rice production in the study area. This result is in line with a very recent study conducted in Ethiopia by Ahmed and Melesse (2018).

The result for labour being risk decreasing is inconsistent with the work done by Villano and Fleming (2006) on technical inefficiency and production risk in rice farming: Evidence from Central Luzon Philippines. In this work, labour was also classified as a risk increasing input. The findings is also in contrast with the work of Chang and Wen (2011), but consistent with the studies of Kumbhakar (2002) and Dai (2006)] which reported that labour is a risk-decreasing factor among farmers and has a positive impact on production efficiency.

Moreover, the use of machines has a positive and significant impact on risk function, which means that investment in agricultural equipment and machine use, is a risk-increasing function among the selected categories of rice farmers in the study area. The results of earlier studies is contrary to the findings of Just and Pope 1979 and Chang and Wen (2011).

Insecticide- is found to be a risk reducing input and this is in agreement with the work of Villano and Fleming Villano and Fleming (2006) which disclosed that pesticide was found to be a risk-decreasing factor among rice farmers in the Philippines.

Herbicide- The result of herbicide as a risk decreasing input is consistent with the work done by Villano & Fleming (2006) in which herbicide was found to be a risk reducing input but in contrast with the work of Sibiko (2012) who found a case in Uganda where over-application was attributed to limited knowledge among farmers about the right proportions of herbicides.

Green manure is deemed to increase output variability in the study area. Results also illustrate that irrigation service has negative and significant effects on risk function for the rice farmers in the study area. This means that investment in irrigation systems is risk-decreasing and will encourage rice production. The results of Shakoor, Saboor, Baig, Afzal, and Rahman (2015) support the findings that irrigation services reduce output variability.

Table 3

Maximum likelihood Estimates of the Linear Risk Production Function

Variables	**Parameter**	**Estimate**	**Standard error**	**T-ratio**
Constant	ψ	- 5.114	0.5636	-2.2471 *****
Farm size	ψ_1	-0.5648	0.0446	- 0.6808*****
Seed	ψ_2	0.3683	0.0550	6.6929**ns**
Fertilizer	ψ_3	-0.0094	0.0011	- 1.7696*****
Labour	ψ_4	-0.0612	0.0699	-0.8745*****
Machine	ψ_5	0.0461	03648	0.1264*****
Insecticide	ψ_6	- 0.0424	0.0242	-1.4936*****
Herbicide	ψ_7	- 0.1338	0.0147	- 9.5317ns
Green manure	ψ_8	0.07148	0.0046	15.6243ns
Irrigation service	ψ_9	- 0.0725	0.0046	-1.8677*****

* **Estimate is significant at 5%, ns not significant**

Source: STATA Version 14.1 Computer software

5.0 CONCLUSION AND RECOMMENDATIONS

The study has estimated stochastic model with flexible risk properties. It revealed that production risk determine rice output. Technical efficiency estimates may be compromised when production technology is modeled without the flexible risk component. It is appropriate to incorporate production risk in technical efficiency analysis if the inputs have flexible risk properties (i.e inputs are non- neutral in risk).
Production risk is jointly explained by all farm inputs; farm size, seed, fertilizer, labour, machine, insecticide, herbicides, green manure and irrigation services. Farm size, fertilizer, labour, insecticides, herbicide and irrigation services are risk decreasing input while seed, machine and green manure are risk increasing inputs. The study concludes that not accounting for the production risk in efficiency estimation results in biased efficiency estimations. Seed, machine and green manure increase output variability. A risk averse farmer will therefore employ less of seed, machine and green manure due to the ability of these inputs to cause high fluctuation in yield. He may go ahead and use more of seed, machine and green manure and less of farm size, fertilizer, labour, insecticide, herbicide and irrigation service in order to reduce output variability.

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