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ESTIMATION OF TECHNICAL INEFFICIENCY AND PRODUCTION RISK AMONG SMALL SCALE MAIZE FARMERS IN THE FEDERAL CAPITAL TERRITORY (FCT) ABUJA, NIGERIA

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ABSTRACT

Background. Estimation of technical inefficiency and Production risk play a key role in farmers' decisions pertaining to input allocation and subsequent output. The study provided empirical evidence on technical inefficiency and associated production risk among small scale maize farmers in the Federal Capital Territory (FCT) Abuja, Nigeria.
Material and methods. A multistage sampling technique was adopted in the selection of 154 respondents. Data were analyzed using descriptive statistics and a stochastic frontier function with a heteroskedastic error structure.
Results. The results show that farm size and agrochemicals significantly influenced maize production at ($P < 0.01$) and ($P < 0.1$), respectively. An increasing return to scale in Maize production was observed in the study area. There was significant evidence of production risk associated with inputs used in maize production. From among the production inputs considered in the study, only seed was found to significantly reduce risk ($P < 0.01$). The technical inefficiency of farmers in the area ranged between 0.06-0.99 with a mean inefficiency of 0.27 (27%).
Conclusion. On average 27% of the output was lost as a result of technical inefficiency in maize production and production risk could be reduced significantly if an additional quantity of maize seed is planted per hectare.

Key words: consumption, income, maize production, output

INTRODUCTION

Maize belongs to the grass family (*Poaceae*) and is the third most widely grown cereal crop in Nigeria, after Sorghum and Millet (Kashim *et al.*, 2014). Maize is widely and popularly consumed by a majority in the world, as well as by livestock. It is an important cereal crop and constitutes a staple food for 1.2 billion people in Africa. Nigeria accounts for about 48% of the total production in western and central sub-Saharan Africa (Kashim *et al.*, 2014). Nigeria, being the largest producer of Maize in Africa, produces about 10 million tonnes per year, however, crop yield is lower than 2.0 tonnes per hectare. The land area for maize planting in West Africa increased from 2.7 million hectares in 1961 to 11.5 million hectares in 2018 causing an increase in production from 2.02 million metric tonnes in 1961 to 11.5 million metric tonnes in 2018 (FAO, 2020). As a staple, maize consumption per capita is between

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52 to 328 g/person/day and constituted about 5–51% of the calorie intake in West Africa in 2017 (IITA Report, 2018).

Maize is among the most important cereal crops and considering its numerous uses and the fact that 90% of its production is in the hands of small scale holders with a traditional and underdeveloped farming system then meeting the demand for the crop may be difficult (Iken and Amusa, 2004). The demand for maize in the agro-based industries for beverage, soap and pharmaceutical purposes has led to a change in cultivation from subsistent to commercial (Aye and Mungatara, 2012). Close to 80% of maize produced is consumed by humans and animals, while the remaining 20% is used by the agro-based industries for production of starch, corn, sweeteners, ethanol, alkaline, etc (Onuk *et al.*, 2010).

The production of maize in any location like FCT Abuja is greatly dependent on farmers' ability to efficiently combine resources and farming techniques, which is also a function of their socio-economic uniqueness and farm characteristics (Shamsudeen *et al.*, 2017). The trend of maize production in Table 1 shows that there was decrease in national yield from 1900 kg·ha^{-1} in 2010 to 1600 kg·ha^{-1} in 2015, along with a corresponding increase in area of land planted. In 2016, yield increased to about 1700 kg·ha^{-1} while the area planted was about 6.5 million hectares. However, yield later decreased to about 1600 kg·ha^{-1} in 2017 while the area planted remained at 6.5 million hectares with an estimated output of about 10.4 million metric tons. The increase in output over this time was attributed mainly to expansion in cultivated land areas rather than technical efficiency in crop production. There was still a drop in output from 10.6 million tonnes in 2015 to about 10.4 million metric tons in 2016. In 2017, the output remained the same as in 2016.

Table 1. Maize production in Nigeria (2010–2017)

Year	Yield in kg·ha^{-1} ('000'kg)	Land Area (ha) ('000000')	Output (tonnes) ('000000')
2010	1.9	4.2	7.7
2011	1.6	5.5	8.9
2012	1.5	5.8	8.7
2013	1.5	5.8	8.4
2014	1.8	5.9	10.8
2015	1.6	6.8	10.6
2016	1.7	6.5	10.4
2017	1.6	6.5	10.4

Source: FAOSTAT, 2018.

By conducting a risk analysis within a stochastic frontier framework one can investigate whether inputs remain risk-increasing (or -decreasing) even after accounting for inefficiency. The low yield, which is characteristic for crop production in Nigeria and particularly so for maize, could be attributed to not only poor resource productivity occasioned by inefficiency in resource utilization in crop production in the country, but also to production risk; particularly input induced risks. Production risk in inputs influences the production structure and subsequently the technical efficiency estimates. Furthermore, an analysis of production risk in inputs and technical inefficiency in maize production has not been properly examined within the study area. It is based on this gap that the present study was designed to estimate the technical inefficiency and production risks in maize farming among maize farmers through the following specific objectives: (i) estimating the functional relationship between inputs and output of maize; (ii) estimating the technical inefficiency and production risks in maize production in the study area.

MATERIAL AND METHODS

Study Area

This study was carried out in the Federal Capital Territory of Nigeria (FCT), Abuja. FCT is located in the heart of the country in the guinea savanna. It is located between longitude 6°20' E and 7°33' E of the Greenwich meridian and latitudes 8°30' N and 9°20' N of the equator. It occupies a land area of about 8,000 square kilometers, (FCDA, 2018). The rainy season, which runs from March to October, has an average day temperature of 28°C (82.4°F) to 30°C (86.0°F) and a night temperature of about 22°C (71.6°F) to 23°C (73.4°F). Though the capital city is largely inhabited by civil servants the majority of the rural population are farmers of different agricultural products, especially crops like maize, rice and sorghum.

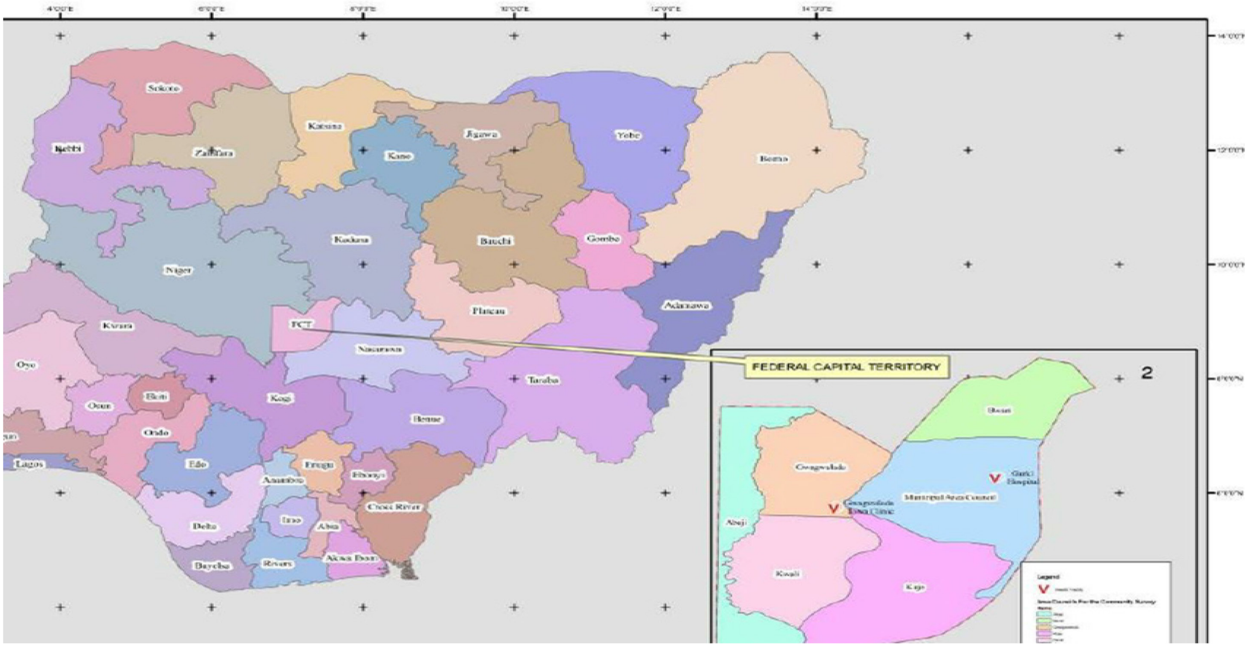

Fig. 1. Map of Nigeria showing the study area

Sampling procedure and sample size

The research targeted maize farming households in FCT Abuja. A multistage sampling technique was employed. Three Area Councils were purposively selected from the 6 area councils in the study area. This was due to the fact that some of these areas fell within the agricultural designated areas of the FCT. The second stage involved the purposive selection of 5 villages from each of the 3 Councils earlier selected. This is also in line with the government designated agricultural areas in the FCT as provided for in the Abuja master plan and also for the fact that the majority of those who practice real farming dwell close to their farms. Then thirdly, a proportionate random selection of 15% of respondents using the balloting method, that is, in each village 15% of the number of maize farmers were selected and this gave a sample size of 154 maize farmers for the study. Data for the study was collected using a structured questionnaire and interviews where necessary. The data collected was for the 2018/2019 cropping season on variables such as: educational level of household head/farmer, types of inputs (seed, fertilizer, and herbicides), output of maize, area planted/harvested, engagement of extension agents and farm location.

Analytical technique

The data collected were analyzed using the descriptive statistics and stochastic production function model. Descriptive statistics, such as the mean, standard deviation and coefficient of variation, were employed to ascertain the extent of deviation of the variables from the mean of the output while the stochastic frontier model was used to determine elasticities of inputs on output and technical inefficiency scores. The model was further extended to capture the heteroskedastic error structure in order to identify the risk content in maize production

Model Specification

Just and Pope (1978) proposed a model that captures production risk in a stochastic production function framework. This model paved the way to understand production risk in inputs through estimating input-dependent heteroskedasticity regression incorporated with additive specification. Based on this, the Just and Pope model is implicitly specified as:

$$y = f(\chi) + g(\chi)\nu \qquad (1)$$

where:

- y = yield,
- χ = input,
- $f(\chi)$ = average output function,
- $g(\chi)$ = production risk function for inputs that enables heteroskedasticity in random error in v as;

$$\sigma^2_v = g(\chi) \qquad (2)$$

where:

- ν = independently and identically distributed random error iid – $N(o, \sigma^2_v)$.

According to Ogundari and Akinbogun (2010), the coefficient of $g(\chi)$ in the model shows marginal production risk with reference to the variable input x, which is either positive or negative. Just and Pope (1978) and Battese *et al.* (1997) additively combined the structure of the conventional stochastic frontier production model postulated by Aigner *et al.* (1977) and Meeunsen and van Den Broeck (1977) to give a Stochastic Frontier Production function with a flexible risk specification as represented below;

$$Y_i = f(\chi_i : \beta) + g(\chi_i : y)\, \nu - u\, (z :: o) \qquad (3)$$

Where $f(\chi_i : \beta)$ is the production function, $g(\chi_i : y)$ is the risk function and v and u denote the random noise and technical inefficiency effects, respectively. y, χ, $f(\chi)$, $g(\chi)$ are as explained in equation 1 while u is the error term for inefficiency. According to Ogundari and Akinbogun (2010), the 'u' added in equation 3 differentiates it from the conventional SFP model of equation 1, thereby imposing the same variable inputs and functional form on the heteroskedasticity in ν and u.

Similarly, Battese *et al.* (1997) model was broadened by Kumbhakar (2002) to allow for a generalized form of the SFP function using a flexible risk specification. This extension enabled the effects of the variable inputs and the functional forms to differ on the heteroskedasticity of u and ν. The generalized form is specified below:

$$Y_i = f(\chi_i : \beta) + g(\chi_i\, \psi)\nu - \rho(z : \delta)u_i \qquad (4)$$

Where $f(\chi_i : \beta)$ is the production function, $g(\chi_i\, \psi)$ is the risk function, ψ is the parameter to be estimated for production risk, $\rho(z : \delta)$ is the Technical Inefficiency model and δ is the parameter for the Technical Inefficiency model. y, χ, $f(\chi)$, $g(\chi)$, u and v are as explained in equations 1 and 3 above.

A flexible Cobb-Douglas functional form was employed to specify $f(\chi)$ to allow for consistency on the parameters of the risk function value based on the Just and Pope framework.

The Cobb Douglas functional form according to Oppong *et al.* (2016) is transformed as below:

$$\mathrm{Ln}y_i = \beta o + \sum_{j=1}^{n} \mathrm{Ln}x_{ji} + \varepsilon_i \qquad (5)$$

where:

- y = output of maize by the ith farmer and ε is the error term expressed thus,
- $\varepsilon = g(x_i : \Psi)v_i - q(z_i : \delta)u_i$,

X = vector of j explanatory variables of inputs of the ith farmer,
Y = Output (kg),
X_1 = Land (ha),
X_2 = Fertilizer (kg),
X_3 = Herbicides/Pesticides (dm^{-3}),
X_4 = Seed (kg),
X_5 = Labor ($man \cdot day^{-1} \cdot ha^{-1}$),
Ln = Natural log.

Following the Cobb-Douglas Production functional form used previously, we followed Kumbhakar (2002); Jaenicke *et al.* (2003); Kumbhakar and Tveterås (2003); Bokusheva and Hockmann, (2006) and modified equation 2 and specify the variance function as:

$$\sigma^2 v = g(\Psi_0 \sum\nolimits^{n}_{j=1} \Psi_j X_j) \quad (6)$$

From the above equation, (χ) is assumed to describe production risk in inputs used. To achieve optimization in both u and v, heterogeneity was allowed in the mean of the inefficiency term, U, (Jaenicke *et al.*, 2003) with a model as specified below:

$$U_j = \rho\ (\xi_0 + \sum\nolimits^{n}_{j=1} \xi_j X_j + \sum\nolimits^{n}_{j=1} \varphi_j Z_j) \quad (7)$$

where:
Z = vector of socioeconomic variables/ characteristics of the household
Z_1 = Level of Education (Number of Years),
Z_2 = Farm Experience (Yrs),
Z_3 = Age of Respondent (Yrs),
Z_4 = house hold size (Number),
Z_5 = Contact with Extension Agent (frequency/ Yr),
Z_6 = membership of cooperative (Yrs),
Ui = mean inefficiency effect,
ρ, ξ and φ = parameters to be estimated in relation to the socioeconomic variables of farmers, elasticity of input, marginal input risk and inefficiency effects of inputs.

Note: Because of the paucity of data concerning socioeconomics characteristics of the farmers the inefficiency effect model was not estimated.

RESULTS AND DISCUSSION

Inputs and output level in Maize production

The results of the descriptive statistics of inputs and output in the production frontier analysis are presented in Table 2. Maize yield obtained ranged from 8.333 $kg \cdot ha^{-1}$ to 10,500 $kg \cdot ha^{-1}$ with a mean of 1514.035 kg per hectare. This is low compared to the expected average output of 4000 kg per hectare in the country (ATA, 2012). The standard deviation of the output was 1155.597 while the coefficient of variation was estimated at 76.338%. This implies that there is wide variation among the individual output of farmers in the area. In terms of labor a minimum of 3 $man \cdot day^{-1} \cdot ha^{-1}$ and a maximum of 29 $man \cdot day^{-1} \cdot ha^{-1}$ were used. The mean amount of labor used was 11.75 $man \cdot day^{-1} \cdot ha^{-1}$. Agrochemical usage was between 0.000 liter and 23.333 liters per hectare, with a mean value of 3.955 liters as compared to the recommended rate of 1 liter per hectare. This is about 3 liters above the recommended quantity. With a mean of 3.955 it shows that farmers in the study area may have over used the chemicals due to a lack of knowledge of the required quantity. This could also be as a result of poor combination of resources, which could lead to resource wastage and low yield of output. The mean values obtained for seed and fertilizer (NPK and Urea) were 16.559 $kg \cdot ha^{-1}$ and 182.550 $kg \cdot ha^{-1}$, respectively, as against a recommended rate of 20 $kg \cdot ha^{-1}$ for seed and 100 kg/hectare and 50 $kg \cdot ha^{-1}$ for NPK and Urea, respectively. The coefficients of variation were 38.673% for seed and 39.524% for fertilizer with standard deviations of 6.404 and 72.152, respectively, for seed and fertilizer. The implications of these results are that the high variations from their means may also affect the overall output of the farmers in the area.

Table 2. Descriptive statistics of the variables used in the analysis

Variables	Min	Max	Mean	Std deviation	Coefficient of variation
Output (kg)	8	10,500	1514.035	1155.796	76.338
Farm size	2	20	4.85	1.830	37.731
Fertilizer (kg)	53.333	600.000	182.550	72.152	39.524
Labor (m/day)	3.000	29.000	11.749	5.239	44.591
Seed (kg)	3.000	49.000	16.559	6.404	38.673
Agrochemical (ltr)	0.000	25.333	3.955	2.518	63.666

Source: Field survey, 2018.

Maximum Likelihood Estimates of the Production Function

The Maximum Likelihood Estimates of the stochastic production function for maize production in the study area is presented in Table 3. The result shows that the coefficient of farm size (0.93) was statistically significant at ($p < 0.01$). This implied that an increase of 1% in the area of farm land would result in 0.93% increase in maize output in the area. This result was in conformity with the findings of Umar *et al*. (2017), who found that farm size significantly influenced maize output in the study area. This result was also consistent with the findings of Oppong *et al.* (2016). The coefficient of labor though positively associated with maize output did not influence the maize output significantly. The coefficient of agrochemicals was also positive and significant at ($p = 0.10$). There was increasing return of scale in Maize production in the FCT. This is indicated by the summation of the coefficients of the variables used in maize production, which was greater than unitary or one. According to Aigner *et al.* (1977) the statistical significance of the variance parameter sigma squared (δ^2) and gamma (γ) were clear indications of a good fit of the model used and a confirmation of the normal distribution of the complex error.

Table 3. Maximum Likelihood Estimates of the stochastic Production Function

Variables	Parameter	Coefficients	Std. error	T-ratio
Farm size (X_1)	Ψ_1	0.930	0.180	5.113***
Seed (X_2)	Ψ_2	-0.130	0.134	-0.940N_S
Labor (X_3)	Ψ_3	0.030	0.102	0.274N_S
Agrochem (X_4)	Ψ_4	0.162	0.094	1.728*
Fertilizers (X_5)	Ψ_5	-0.034	0.172	-0.200N_S
Constant (0)	Ψ_0	7.762	0.967	
Summation of output elasticity		0.960		
Sigma squared	δ^2	1.890	0.304	
Gamma		0.926	0.020	

Source: Field survey, 2018.

The coefficients of variance parameter δ^2 (sigma squared) (6.20) and Gamma (γ) (49.14) were different from zero at 1% levels of significance. The value of gamma was estimated at 0.92, which indicated that about 92% of the variation observed between the potential and observed output could be as a result of inefficiency of the farmers in the area. This is an indication that if all the inputs used for maize production are all increased at the same time, maize output would increase by more than the increase in the quantity of inputs employed if technical inefficiency is reduced.

Maximum Likelihood Estimates of the Production Risk Function

The results of the maximum likelihood estimates of the production risk function are presented in Table 4. The results show that production risk in inputs was significant in the production process in the study area. Farm size (0.93), labor (0.03) and agrochemical inputs (0.16) increased maize production risk significantly at ($p < 0.01$) in the study area. Though fertilizer was positively related to the production risk, it did not significantly increase maize production variability. Only seed was a risk-decreasing input in the study area. This implies that seed input decreased production risk significantly in maize production. This finding conforms to Oppong *et al.* (2016). Theoretically, the result of this study implies that risk- averse farmers would use smaller farm size and less labor and agrochemicals, and use more seed for maize farming in the study area as compared to risk-neutral farmers. This is because the more allocation of risk increasing inputs in maize production the more are the chances of experiencing output variability, which may be unfavorable to farmers' output expectations.

Table 4. Maximum likelihood estimate of production risk

Variable	Parameter	Coefficient	Std. error	T-ratio
Farm size	ξ_1	1.630	0.431	3.78***
Seed	ξ_2	-0.112	0.019	-5.80***
Labor	ξ_3	0.106	0.024	4.36***
Agrochemicals	ξ_4	0.241	0.087	2.75***
Fertilizers	ξ_5	0.005	0.002	1.87 ^{NS}
Constant	ξ_0	9.614	0.493	19.50***

Source: Field survey, 2018.

Technical Inefficiency Estimates of the Stochastic Frontier Model

Technical inefficiency estimates from the stochastic frontier model are presented in Table 5. The technical inefficiency of maize farmers ranged from 6% to 99%. This implies that there was a wide gap in technical efficiency among the farmers. This is also an indication of the wide variability in the combination and efficient utilization of production inputs by the farmers in the area. The results show that the majority (62%) of the respondents had technical inefficiency scores of between 6–25%. while only a few respondents (7%) had inefficiency scores of above 45%. The mean inefficiency of farmers in the area was 27%. Conversely, the results imply that the potential output of the farmers could still be increased by 27% on average if farmers could have training and other related education for the utilization of resources in order to produce at maximum (frontier) capacity.

Table 5. Frequency Distribution of Technical Inefficiency of farmers

Inefficiency range		Frequency	Percentage	Mean
0.06-0.25		95	62	
0.26-0.45		43	28	0.27
0.46-0.65		7	4	
0.66-0.85		4	2	
0.86-1.00		3	1	
Total		152	100	
Minimum technical inefficiency	0.06			
Maximum technical inefficiency	0.99			

Source: Field survey, 2018.

CONCLUSIONS

Technical inefficiency differentials exist among maize farmers in the study area. The wide gap observed in efficiency among farmers could be closed with proper reorientation on the need for adequate knowledge and training to improve their maize production levels. Production risk can be reduced in maize production if additional quantities of maize seeds are planted.

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SZACOWANIE NIEWYDOLNOŚCI TECHNICZNEJ I RYZYKA PRODUKCYJNEGO WŚRÓD HODOWCÓW KUKURYDZY NA MAŁĄ SKALĘ NA FEDERALNYM TERYTORIUM STOŁECZNYM ABUJA, NIGERIA

Streszczenie

Oszacowanie niewydolności technicznej i ryzyka produkcyjnego odgrywa kluczową rolę w decyzjach rolników dotyczących alokacji nakładów i późniejszej wydajności. Badanie dostarczyło empirycznych dowodów na nieefektywność techniczną i związane z nią ryzyko produkcyjne wśród drobnych rolników zajmujących się uprawą kukurydzy na Federalnym Terytorium Stołecznym Abudża w Nigerii. Przy wyborze 154 respondentów przyjęto wielostopniową technikę doboru próby. Dane analizowano za pomocą statystyki opisowej i stochastycznej funkcji granicznej. Wyniki pokazują, że wielkość gospodarstwa i substancje agrochemiczne znacząco wpłynęły na produkcję kukurydzy. Na badanym obszarze zaobserwowano powrót do coraz większej skali w produkcji kukurydzy. Istniały istotne dowody na ryzyko produkcyjne związane z materiałami używanymi do produkcji kukurydzy. Spośród rozważanych w badaniach nakładów produkcyjnych stwierdzono, że tylko nasiona istotnie obniżały ryzyko ($P < 0,01$). Nieefektywność techniczna rolników na tym obszarze wahała się między 0,06 a 0,99; średnia nieefektywność wynosiła 0,27. Średnio 27% produkcji zostało utracone w wyniku technicznej niewydolności w produkcji kukurydzy, a ryzyko produkcyjne mogłoby zostać znacznie zmniejszone, gdyby wysiano dodatkową ilość nasion kukurydzy na hektar.

Słowa kluczowe: dochody, konsumpcja, kukurydza, produkcja