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Analysis of cotton production with flexible risk specification, using trans-log stochastic production function

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Abstract: This paper analysed the production of cotton with flexible risk specification, using a trans-log stochastic production function. Data were obtained from a sample of 360 respondents using a structured questionnaire and analysed, using Trans-log production trans-log stochastic production function. The result reveals that, apart from risk-increasing labour, seed, fertilizer, and agrochemicals are risk-decreasing. Therefore, their effective use and proper management can help reduce output variance. Labour is a risk-increasing variable, meaning that farmers should employ less labour due to its ability to cause high fluctuation in output. The result also shows that six out of eight variables used in the inefficiency effect of the trans-log stochastic production model have a priori expected signs, four of which are significant. The negative coefficient indicates that the variables reduce inefficiency in cotton production. The result shows that technical inefficiency is significantly downsized with education, farming experience, marital status, extension visits, and access to credit. The negative sign of the age variable indicates that an increase in a farmer's age decreases the farmer's inefficiency level, meaning that older farmers are more efficient than younger farmers. Based on the study findings, it is recommended that the government should make adequate and timely provision of variable inputs such as seed, fertilizer, and agrochemicals as they increase mean output positively in the production process and are used in reducing the effect of risk in the production process.
Keywords: Cotton production, Risk specification, Stochastic production function, technical inefficiency.

INTRODUCTION

The cotton and textile sectors are significant because they play a vital role in the economic development of any nation. Cotton contributes to the Gross Domestic Product (GDP) and creates jobs and income for farmers in the country. As a cash crop, it is cultivated in most states of the Federation and helped in turning the country's fortune around before the discovery of oil in Nigeria. Unfortunately, many factors had militated against the survival of the cotton value chain in Nigeria. One of these is the capacity of this sector to contribute less than 15 percent to Nigeria's Gross Domestic Product (GDP). In the 1980s and 1990s, Nigeria was the third largest African textile industry, with over 180 textile mills functioning optimally, employing nearly 450,000 workers and contributing more than 25 percent of the workforce to the manufacturing sector. Recently, Nigeria has been ranked as Africa's 4th largest cotton producer, with an estimated production of around 300,000 metric tons annually. The country has a long history of cotton cultivation, with the northern regions being the main cotton-producing areas. The government has been increasing cotton production through various initiatives and support programs for farmers. However, challenges such as poor infrastructure, lack of modern farming techniques, and pest infestations continue to hinder the growth of the cotton industry in Nigeria (AGOA, 2021).

In addition, there has been a severe decrease in cotton farming, as statistics revealed that the cotton contribution to the country's GDP fell woefully from 25 percent in 1980 to 5 percent as shown by the recent economic indicators. In terms of the nominal non-oil contribution to domestic growth, the agricultural sector contributed 5.06 percent, which was higher than the 4.76 percent recorded in the preceding quarter. On the other hand, if crop production contributed 4.23 percent in the country, then cotton must be given prior attention by the government because of the setback experienced in its production in the country (Kriger, 2005).

As of the latest available data, the contribution of cotton to Nigeria's GDP is relatively small, accounting for less than 1% of the total GDP. The cotton industry in Nigeria faces various challenges such as low productivity, inadequate infrastructure, and competition from imported textiles. Efforts are being made to revitalize the cotton sector through initiatives such as the Cotton, Textile, and Garment (CTG) policy, which aims to increase local cotton production and boost the textile industry's contribution to the economy, (NBS,2020).

Due to a lack of vision on the part of those managing the economy at some point in time, a vibrant textile industry has turned to a shadow of its former self as most of the factories have all shut down, in some cases, taken over by churches and other sundry uneconomic ventures. Presently, the record has shown that less than 25 percent of those industries can be said to be functioning (AGOA, 2021).

Therefore, the study aims to analyze cotton Production with Flexible Risk Specification, Using a Trans-Log Stochastic Production Function. The study becomes incumbent, as it would identify factors that reduce risk in cotton production in the study areas. Identifying those factors would be a valuable exercise because they are significant for policy formulation.

The study employed a parametric model to examine the effect of risk on cotton production in the area. The parametric analysis is the stochastic frontier analysis (SFA) with flexible risk specification and technical inefficiency analysis.

Incorporation of production risk in the stochastic frontier model

The adopted model used in estimating stochastic production technology has accounted for production risk and technical inefficiency. Scholars have employed one of the three outlined variations in this aspect. The various models differed in accordance with how the inefficiency effect has been incorporated into the model. Battase & Broca, (1997) unfold that there is a possibility for the integration of production risk and the technical inefficiency in a model to add the inefficiency effect of the variance function together with the random noise component that represents the effects of uncertainty as shown in the below equation:

$y_i = h(x_i; \alpha) + g_i(x_i; \beta)(v_i - u_i)$……………………………………………(1)

The second possibility for production risk and technical inefficiency to be incorporated in a model is that of the multiplicative form where the inefficiency effect should be added to the mean output function as shown in the below equation:

$y_i = h(x_i; \alpha)(1 - u_i) + g(x_i - \beta)v_i$…………………………………………(2)

Here, the additional assumption; $\exp\{-u_i\} = 1 - u_i$ has been incorporated into the model. The third possibility for the production risk and technical inefficiency to be incorporated into a model is the flexibility form of that model suggested by Kumbhakar (2002). For explaining technical inefficiency, therefore, the additional function q(x) was introduced in the model. This can be shown by the formular below:

$y_i = h(x_i; \alpha)(1 - u_i) + g(x_i - \beta)v_i - q(x_i; z)u_i$…(3)

Where $h(x_i; \alpha)(1 - u_i)$ represent the mean production function, $g(x_i - \beta)v_i$ represent the risk production function, α represent the vector of mean production parameters and β represent the vector of output risk parameters. While v_i represent the stochastic term, u_i represent the non-negative inefficiency variable. $q(x_i; z)u_i$ explains technical inefficiency with xi's as the input variables.

Conceptual Framework

Conceptual framework in figure 1 attempts to show the relationship between the dependent and independent variables of the research. The independent variables were Land Seed Fertilizer Labour and Agrochemical. The dependent variable is the cotton output. The intervening variables are Demographics: they include age, education level, Marital status, household size, and farming experience; the technological include land cultivation, planting, harvesting, and seed variety, and Institutional: workshop/seminar, credit access, and extension contact. Cotton (output) consists of three components: production model (Mean output function), factors affecting technical efficiency (inefficiency component), and production risk (output risk function). Mean production function, production risk, and technical inefficiency will be estimated simultaneously in the stochastic frontier production function. The independent variables that include land, seed, fertilizer, labour, and Agrochemical are considered to influence both the mean output and output risk. Likewise, the factors that influence technical efficiency are categorized into three parts, namely: demographic, technological, and institutional factors, (Figure 1). This is in line with the production function of Kumbhakar (2002). which enables mean production function, production risk, and technical inefficiency to be estimated simultaneously in the stochastic frontier framework.

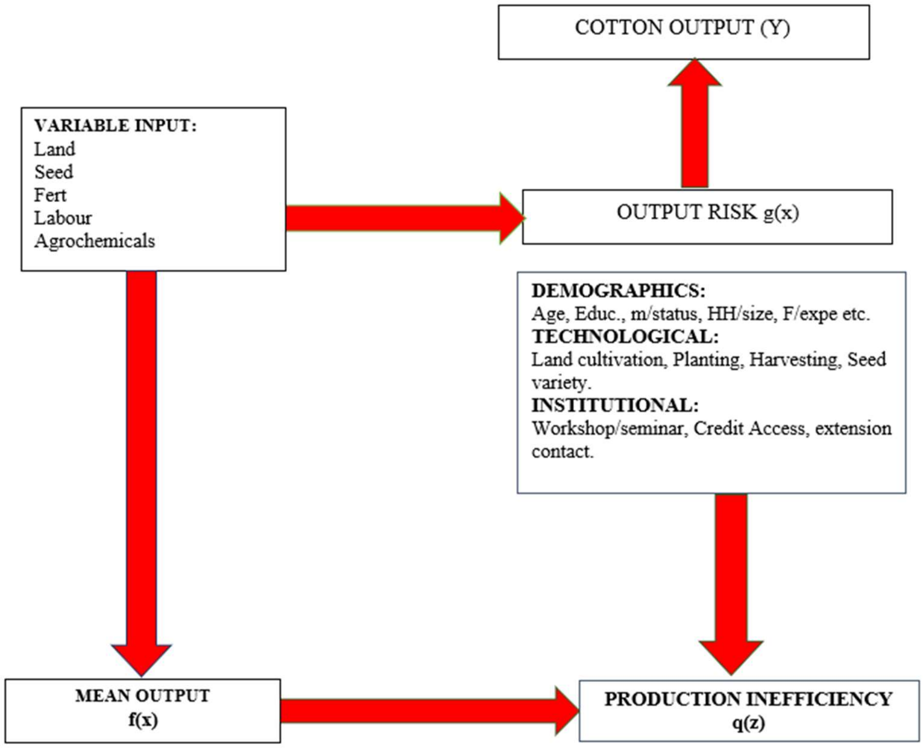

Figure 1: Conceptual Framework.

Source: Muhamma, B. (2018).

METHODOLOGY

The study was conducted in the Northeast zone of Nigeria. The Northeast zone is one of the six geopolitical zones of Nigeria that comprise six States-Adamawa, Bauchi, Borno, Gombe, Taraba, and Yobe. It covers one-third (280,419 km2) of Nigeria's total land area (909,890 km2). The zone has an estimated population of about 26 million people, around 12% of the total population of the country, Muhammad, B. (2018).

The target population for the study are the cotton farmers in the three states of the Northeast zone: Adamawa, Gombe and Taraba State. Adamawa state has twenty-two (22) local governments and five (5) were selected. Gombe State has eleven (11) local governments and three (3) were selected. On the other hand, Taraba State has sixteen (16) local governments and four (4) were selected (Table1).

Table1: Selected Local Government from the study area

State	Local Government	Local Government Selected
Adamawa	22	5
Gombe	11	3
Taraba	16	4
Total	**49**	**12**

Source: Field Survey data, 2016

The list of cotton farmers was obtained from the Afcott out-growers scheme. In arriving at the representative sample for the study from the list, a two-stage and simple random sampling (SRS) procedure for the choice of local government and cotton farmers was employed. A total of twelve (12) local governments were selected as the first stage for the study through a randomized sampling design of forty-nine (49) local governments in the study area. At the final (second) stage a total of 165 cotton farmers were selected out of 501 farmers in Adamawa state. In Gombe State, 102 cotton farmers were selected out of 520, while 93 cotton farmers were selected from Taraba State out of 338 cotton farmers in the area. This gives 360 sampled respondents out of 1359 cotton producers in the study area (Table 2).

Table2: Sample Design Outlay for the Study

State	Selected Local Govt	Cotton Growers	Farmers
Adamawa	5	501	165
Gombe	3	520	102
Taraba	4	338	93
Total	**12**	**1359**	**360**

Source: Field Survey data, 2016

Sampling techniques and sample size

Yamane (1967) provides a simplified formula for computing sample sizes. Following the formula in calculating sample size as proposed by (Yamane, 1967), the study arrived at its sample size based on the population of cotton farmers available in the study area during the period of the study area during the period of the study. Yamane formula is specified as follows:

$n = \frac{N}{1+N(e^2)}$ .... (4)

Where n = sample size, N = population size and e = level of precision.

The total sample size of cotton farmers is determined as:

N = 4000, e = 0.05 (0.95 confidence interval). Therefore:

$n = 4000/1+4000(0.05)^2$

= 360 respondents in all.

The sample size of the respondent in each state in the study area was determined using N= 1359, e = 0.05 (95% confidence interval). Hence, the sample size from each state can be obtained as:

Adamawa sample size

$n = \frac{501}{1359} x\ 360 = 165\ farmers$ .... (5)

Gombe state sample size

$n = \frac{520}{1359} x\ 360 = 102\ farmers$ .... (6)

Taraba state sample size

$n = \frac{338}{1359}\ x\ 360 = 93\ farmers$ .... (7)

Method of data collection

Primary data was used for this study, and the data was gathered from the sampled respondents in the study areas using a structured questionnaire as a research instrument to collect information from 360 randomly selected cotton farmers in the study. Information on socioeconomic variables such as age, education, farming experience, extension contact, credit access, and off-farm activities was included in the questionnaire. The secondary information was gathered from journals, bulletins, and other literature materials from the international network (internet) like Google Scholar to enhance the farmer's response.

Method of data analysis

Two functional forms of the stochastic frontier model, that is, Cobb-Douglas and Trans-log functions are used as various studies have employed them in their analysis. Trans-log stochastic production function model was employed with flexible risk specification because it is known to be less restrictive and permits the combination of squared and cross-product terms of the exogenous variable inputs with the view of having the goodness of fit of the model, using a single-stage maximum likelihood function estimation procedure of Frontier version (4.1).

Trans-Log stochastic production model specification

As stated earlier the two common functional forms of stochastic frontier model that are generally used are Cobb-Douglas and Trans-log functions as various studies have employed them in their analysis. Trans-log stochastic production function model was employed with flexible risk specification for it is known to be less restrictive and permits the combination of squared and cross-product terms of the exogenous variable inputs with the view of having goodness of fit of the model, Donkoh *et al.* (2013). The trans-log stochastic production function model with flexible risk specification can be presented as follows:

$$lnP_j = \alpha_0 + \sum_{i=1}^{4} \alpha_i lnx_i + 0.5 \sum_{j=1}^{4} \alpha_{ii} lnx_i^2 + \sum_{i=1}^{4} \sum_{k=1}^{4} \alpha_{ik} lnx_i lnx_k + \varepsilon_j \quad (8)$$

ε_j is the stochastic disturbance term and is presented as:

$$\varepsilon_j = g(x;\varphi)v_i - h(x;z)u_i \quad (9)$$

In addition, the linear production risk function is specified as:

$$lnv_i^2 = \omega_0 + \sum_{w=1}^{4} \omega_w lnx_{wi} \quad (10)$$

Where:

X_i's represents input variables, v_i^2's is pure noise effects, ω_0's and ω_w's are the estimated risk model parameters, x_1 is the number of seed used measured in kg/ha, x_2 denotes quantity of fertilizer measured in kg/ha, x_3 means Agrochemical used measured in lt/ha and x_4 is labour used measured in man-days/ha. The input variables, seed, fertilizer, agrochemical, and labour, can either decrease or increase input output. Thus, ω_w's are the marginal production risks of individual inputs and when it is positive, it implies that the respective input is a risk increasing input (increasing output variance). However, when ω_w becomes negative, it indicates that the respective input is risk decreasing (reduces output variance).

RESULTS AND DISCUSSIONS

Mean estimates of marginal output risk

Just and Pope (1978) approach separates the difference between the input effect on output and its impact on output variability using mean estimates of Marginal output of risk estimation. Moreover, the output variability in the production process has been determined by the input's factors. Some of these inputs are risk-reducing while others are risk-increasing, meaning that they can be used to sustain cotton production in the study area. The information of Marginal Output Risk estimate of inputs is presented in Table 3.

Table 3: Marginal Production Risk estimates for Variance Function

Variable	Parameter	Coefficient	Std Error	P-Value
Constant	β_0	17.2258**	2.9774	0.000
lnSeed	β_1	-4.2386**	1.2059	0.000
lnFertilizer	β_2	-2.3372*	1.1645	0.045
lnChemicals	β_3	-0.1234	0.4844	0.799
lnLabour	β_4	0.1299	0.6446	0.840

Source: Field Survey data 2016. **Note** * and ** denote significance at 5% and 1% level respectively.

The results in Table 3 reveal that seed and fertilizer risk-decreasing variables are significant at 1% and 5%. These estimated results hint that effective use and proper management of seed and fertilizer can help reduce output variance. The results for agrochemicals and labour are not significant. While the former is negatively related to the dependent variable, the latter is positively related. Being the risk-increasing variable, it is in line with the result obtained by Picazo-Tadeo and Wall (2011), Villano and Fleming (2006) and Kaka (2016), respectively. This, hypothetically, indicated that an average risk-averse farmer in the study area is anticipated to employ less labour due to its ability to cause high fluctuation in output. Instead, Seed, fertilizer and agrochemicals would be used relative to a risk–neutral farmer who is insensitive to risk, regardless of whether it is high or low risk, to reduce output volatility.

Inefficiency effect of trans-log stochastic production model

The inefficiency parameters were itemized by virtue of those revealing farmers' specific socio-economic characteristics, be it institutional or otherwise. Six out of eight variables used in the model have priori expected signs and four of them are significant. A negative coefficient indicates that the variables increase the efficiency (in other words, reduces inefficiency) in cotton production and vice versa. The outcome of technical inefficiency effects, as presented in Table 4 display that technical inefficiency is significantly downsized with age, education, farming experience, and access to credit. The negative sign of age variable indicates that a farmer's age decreases the farmer's inefficiency level, signifying that the older farmers are more efficient than the younger farmers. In other words, older farmers are more familiar with farming techniques in agricultural production than younger ones.

Table 4: Inefficiency Effect of Trans-Log Stochastic Model

Variable	Parameter	Coefficient	Std Error	P-Value
Constant	γ_0	-4.0711**	-4.0711	0.000
Age	γ_1	-0.0011*	-0.0011	0.032
Education	γ_2	-0.0125*	-0.0125	0.057
Marital Status	γ_3	-0.0034	-0.3841	0.193
Household size	γ_4	0.0090	0.0364	0.803
F/Experience	γ_5	-0.0034*	-0.0034	0.049
Extension Visit	γ_6	-0.1528	0.1107	0.167
Credit Access	γ_7	-0.3790*	0.1717	0.027
Off Farm Activities	γ_8	-0.3790	-0.2146	0.614

Source: Field Survey Data 2016. **Note** * and ** denote significance at 5% and 1% level respectively.

The result corroborates with the findings of Udoh and Akpan (2007); Amor and Muller (2010) that says older farmers are technically more efficient than the younger ones. But Villano and Fleming (2006) believe that age's influence on technical efficiency is relative to the empirical data being analysed. To them, age can only negatively influence technical efficiency if the farmers are unwilling to risk adopting the best farm practices. If experience is the best teacher, the longer a person endures in a job, the more likely he becomes skilful.

Due to the risks and uncertainties involved in farming, there is a need to handle all the changes that may happen along the production process so that the farmer can remain in the business or stay on the farm for quite a long time. A distinct farmer who has been prosperous for many years in cotton farming is likely to be more knowledgeable about the pattern of rainfall, pest and disease indices, and the area's natural condition, contrary to a farmer who delves into the business without know-how or education on the business. The result of the study shows that experience has affected technical inefficiency negatively, insinuating that the more experienced the farmer, the less inefficient he will be. This decision is unvarying with the findings of Ogundari & Akinbogun (2010), and Alam *et al.* (2013).

The coefficient of education is negative as expected and statistically significant at a 10-percent significant level. This signifies that a higher level of education increases the chances of the farmer in the study area using improved and citified technology and techniques that require training, reading manuals, and attending conferences to help increase yield and optimum utilization of resources. This is in line with that of Maurice *et al.* (2015), and Oladimeji & Abdul Salam (2013) in their findings that farmers with more years of schooling tend to be more efficient in their production, presumably due to their enhanced ability to acquire technical knowledge, which make them closer to the frontier.

The coefficient of farming experience is estimated to be negative and statistically significant at a 5-percent level. The implication is that farmers with more years of farming experience tend to be more efficient in cotton production. This conforms with the finding of Coelli and Battese (1996) who reported a negative production elasticity concerning farming experience for farmers in India, thus suggesting that the older farmers are relatively more efficient, and vice versa. It is possible that such farmers gained more years of farming experience through ‘’Learning by doing”, And thereby becoming more efficient.

The estimated coefficient of farmers' access to credit was also negative and significant and it indicates that the use of credit could decrease the inefficiency effect of production. On the other hand, farmers with fewer liquidity constraints may restrain the farms using the optimal input through optimal output. The result is therefore acknowledged and conceded with the findings of Bravo-Ureta and Pinheiro (1993) and Mailena *et al.* (2014).

Al-Hassan (2008) concludes that extension visits to farmers enable them to use approved cultural practices in their production process, which will encourage them to increase their efficiency in the long run. Extension agents are supposed to maintain advisory services and train farmers to enhance their efficiency. The coefficient of the Extension agents as shown in Table 4, has negative effects on inefficiency, which by implication, means that the more farmer acquired knowledge from extension services the more he becomes less inefficient, which is in consistent with the findings of Ghee-Thean *et al.* (2012).

CONCLUSION AND RECOMMENDATIONS

The study concluded that production risk contributes considerably to the vitality of cotton in the study areas because output variability is primarily explained by technical inefficiency and production risk. Production risk, as analyzed, is explained by seed and fertilizer as they are the only variable inputs that are significant and risk-reducing variable inputs. These variables can, therefore, be used to alleviate the effect of risk in the production process. Inefficiency factors like age, educational level, farming experience, and extension contact tend to improve farmers' technical efficiency in the study areas as they have negative coefficients and significance.

Based on the findings of this research, variable inputs, such as seed and fertilizer, are essential in boosting cotton production. Therefore, it is recommended that the government make adequate and timely provisions for them as they increase mean output positively in the production process and reduce the effect of risk in the production process. In addition, cotton farmers in the study area should be encouraged to take up off-farm activities as they help boost their income and raise their living standards. It is recommended that the government should ease the accessibility to credit facilities and enlighten the farmers on the advantages of off-farm activities for their livelihood. Regarding technical inefficiency factors, especially education, there is a need for policy to promote formal education to enhance efficiency in production over a long period. This would enable farmers to make better technical decisions and help them allocate their production inputs effectively. In the short run, informal extension education could be effective, especially when targeted at farmers with limited formal educational opportunities.

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