Parametric Estimation of Allocative Efficiency among Cotton Farmers in Zamfara State, Nigeria: Application of Stochastic Frontier Models

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Abstract
The central focus of this study was on estimating allocative efficiency among cotton farmers in Zamfara State Nigeria. The specific aims of the study were based on describing the levels of cost incurred in cotton production, estimate the levels of allocative efficiency among cotton farmers and examine the factors affecting allocative inefficiency in cotton production. Zamfara state
was used for this study. A multistage sampling technique was used in selecting 220 farmers who produce cotton. The analytical tools used to achieve the stated objectives were descriptive statistics and stochastic frontier models. Estimation of cost incurred in cotton production showed that seed was positively related and significant at 10% level of probability while cost of agro-chemicals, family labour and hired labour were positively related and significant at 1% level of probability. The variance parameter, sigma squared ($\sigma^2$) was (13.92). The generalised likelihood ratio (LR) test was (264.69). The model expressed a goodness of fit of the data used in the estimation. The log likelihood function of (-170.19) expressed the goodness of fit of the model. The gamma ($\gamma$) statistics of (0.998) showed that inefficiency factors were present in cotton production in Zamfara State, Nigeria. The average allocative efficiency score was 0.64 implying that farmers can still maximise the utilisation of inputs and increase their production frontier by 36%. Age, major occupation, access to credit and extension contact were the random variables increasing allocative efficiency of cotton farmers. It was recommended that government should support farmers through timely provision of inputs required in cotton production at affordable prices, provide adequate credit facilities that will grant farmers ability in adopting improved technologies and carry out adequate and intensive research, and extension service delivery programme should pursue a consistent and systematic campaign for cotton production.

**Key words:** Parametric estimation, allocative efficiency, allocative inefficiency, cotton farmers, Nigeria.

At independence, the contribution of agriculture to the GDP was about 25% between 1975 and 1977. This was partly due to the phenomenal growth of the mining and partly as a result of the disincentives created by macroeconomic environment. Similarly, the growth rate of agricultural productivity exhibited a downward trend during the period. Thus, between 1970 and 1982 agricultural productivity stagnated at less than one percent annual growth rate at a time when the population growth rate was 2.5 to 3.0% per annum (Adubi, 2001). According to the National Bureau of Statistics (NBS) (2011), the percent share in the GDP of the crop sub-sector between 1981 to 1990 had been fluctuating between 28.37% and 22.99% and did not register any significant increase. This trend continued as the contribution of the crop sub-sector was almost stagnant at about 36% from 1994 to 1997 and from 2003 to 2006. With respect to cotton, production trend had not witnessed remarkable improvement between 2007/2008 cropping years while the 2010 – 2012 cropping seasons experienced a decline (USDA, 2011). Batterham (2000) asserted that supply is yet to satisfy the level of demand for cotton. This is as result of low productivity and low efficiency of resource utilisation among cotton farmers.
There are a number of factors affecting the productivity of farmers such as age, cropping patterns, years of farming experience, and lack of access to credit which tend to impact negatively on productivity and efficiency. Despite all human and material resources devoted to Nigerian agriculture, the productive efficiency of farmers for most crops still fall below 60%. The inefficiency problem is attributed to factors such as use of low input technologies, lack of knowledge of high input technologies and poor farm management skills, poor extension services, unavailability and high cost of inputs (Obasi, 2005; Anyanwu and Obasi, 2010a; Anyanwu and Obasi, 2010b). This has caused great concern in the textile cotton fibre supply situation in the local market and export profile in the country thereby having a declining effect in its contribution to the agricultural economy of the country. It is with respect to this that cotton was chosen to form the basis of this study culminating in the following research questions and subsequently some objectives of the study.

Research Questions
i. What are the levels of cost incurred in cotton production?
ii. What are the levels of allocative efficiency among cotton farmers?
iii. What are the factors affecting allocative inefficiency in cotton production?

Research Objectives
The broad objective of the study is estimation of allocative efficiency among cotton farmers in Zamfara state, Nigeria. The specific objectives of the study were to:

i. estimate the levels of cost incurred in cotton production;
ii. estimate the levels of allocative efficiency among cotton farmers;
iii. examine the factors affecting allocative inefficiency in cotton production.

Materials and Methods
Study Area
Zamfara State was used for this study. The state lies between latitude 10° 50’N and 13° 38’N and longitudes 4°16’E and 7°18’E. The state is located in the Sudan Savanna ecological zone of Nigeria. It has a land area of 39,762 km². Zamfara State shares common borders with Sokoto and the Republic of Niger to the north, Katsina and Kaduna States to the east, Niger and Kebbi States in the south (Yakubu, 2005; www.zamfarastate.net, 2010). The State has a population of about 3,259,846 people in 2006 according to the National Population Commission (NPC) (2006). This is projected in 2011 to be 3,667,326 people representing 3.2% annual growth rate in population. The climate is essentially that of tropical climate. The climate is generally characterised by alternating dry and wet seasons. The rains usually commence in...
May/June and end in September/October. The effective rainy season in the study area is restricted to July to mid-September (Yakubu, 2005).

Specifically, four local government areas namely Kaura, Gusau, Tsafe and Bungudu were chosen as the study area. They are in the northwestern part of the state. These areas were chosen because they are well known for cotton production. A significant proportion of cotton produced in Zamfara State comes from these areas (www.zamfarastate.net. 2010). The main ethnic groups in these areas are Hausas, Beriberis, Buzzaye and Fulanis. Indeed, agriculture forms the main occupation of the entire population. This constitutes the bulk of those involved in traditional farming, fishing, hunting and nomadic pastoralism.

Sampling Procedures and Sample Size

The field survey employed the list from reconnaissance survey of farmers conducted by Zamfara State Agricultural Development Project (ZADP, 2010). A multistage sampling technique was employed in selecting the study farmers. The first stage was purposive sampling of four local government areas as earlier indicated. These are Kaura, Gusau, Tsafe and Bungudu. The second stage involved a selection of two villages known to be cotton growers from each of the local government areas based on the prevalence of cotton farmers and their involvement in cotton production and accessibility. Hence, a total of eight villages were selected for the study.

The third stage involved using the list of cotton growers obtained from the reconnaissance survey to randomly select 15% of farmers from each of the eight villages in the ratio of 26, 33, 23, 26, 33, 22, 31 and 26 from Kasuwa-Daji, Kabarawa, Danba, Magami, Tsafe, Kucheri, Kwatarkwashi and Tashar-rawaya respectively constituting 220 out of a total of 1471 farmers.

Primary data was used for this study. The primary data was collected for the study based on 2012/2013 cropping year known as cross-sectional data. The analytical tools that were used to achieve the stated objectives in this study were descriptive statistics and stochastic frontier cost analysis, allocative efficiency and allocative inefficiency models.

Stochastic Frontier Cost Function

The Stochastic cost frontier function is of Cobb-Douglas functional form. The allocative efficiency was estimated through the stochastic frontier cost function. In other words, the stochastic frontier cost function was estimated in order to arrive at allocative efficiency. The allocative efficiency of cotton farmers is defined in terms of the ratio of the predicted minimum cost ($C_{i}^{*}$) to the observed or actual cost ($C_i$). It is expressed as the process involved in minimising cost without reducing the level of output realised in the production frontier. Hence, EE is the inverse of the cost frontier function. The allocative efficiency is part of objective (ii) of the study.
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The model is specified as follows;

\[ C_i = f(Px_i, \lambda) \exp. (v_i + u_i), \quad i = 1, 2, \ldots n \]  

Where,

\( C_i \) = total input cost (₦) of the \( i \)th farmer  
\( f = \) functional form represented by Cobb-Douglas production function.  
\( Px_1 = \) Cost of land (₦),  
\( Px_2 = \) Cost of seed (₦)  
\( Px_3 = \) Cost of fertilizers (₦),  
\( Px_4 = \) Cost of family labour (₦)  
\( Px_5 = \) Cost of hired labour (₦),  
\( Px_6 = \) Cost of agro-chemicals (₦)  
\( \lambda_1 - \lambda_6 = \) Unknown parameter to be estimated  
\( \lambda_o = \) Intercept term,  
\( e_i = V_i - V_i = \) random errors (composite error term).  

The allocative efficiency of the individual farmers is defined in terms of the ratio of the predicted minimum cost \( (C_i^*) \) to the observed cost \( (C_i) \) that is,

\[ AE_i = C_i^*/C_i \]

\[ AE_i = f(Px_i, \lambda) e^{v_i + u_i}/f(Px_i, \lambda) \exp. v_i + \exp. u_i. \]  

The allocative efficiency scores index for each farmer also ranges between 0 and 1. Hence, the specification of the cost frontier function is in accordance with the Cobb-Douglas function illustrated in the allocative efficiency expressed below;

\[ \log C_i = \lambda_0 + \lambda_1 \log Px_1 + \lambda_2 \log Px_2 + \lambda_3 \log Px_3 + \lambda_4 \log Px_4 + \lambda_5 \log Px_5 + \lambda_6 \log Px_6 + v_i + u_i \]  

**Allocative Inefficiency Model**

The assumption in the allocative inefficiency model is that inefficiency effects are independently distributed and \( U_{ij} \) arises by truncation (at zero) of the normal distribution with mean \( U_{ij} \) and the variance \( \sigma^2 \). The specific variables involved are closely associated with socio-economic factors of the farmers and other factors within farmers’ control. The determinants of allocative inefficiency effects \( (U_{ij}) \) are specified as:

\[ U_{ij} = \gamma_0 + \sum \gamma_i Z_{ij} \]

\[ U_{ij} = \gamma_0 + \gamma_1 Z_1 + \gamma_2 Z_2 + \gamma_3 Z_3 + \gamma_4 Z_4 + \gamma_5 Z_5 + \gamma_6 Z_6 + \gamma_7 Z_7 + \gamma_8 Z_8 + \gamma_9 Z_9 \]  

Where;

\( U_{ij} = \) Farmers’ allocative inefficiency, \( \gamma_0 = \) Intercept term  
\( \gamma_1 - \gamma_9 = \) Parameters (vectors) to be estimated,  
\( Z_1 - Z_9 = \) Socio-economic variables  
\( Z_1 = \) Major occupation,  
\( Z_2 = \) Age of farmers in years  
\( Z_3 = \) Level of education in years,  
\( Z_4 = \) Marital Status  
\( Z_5 = \) Household composition,  
\( Z_6 = \) Experience in years  
\( Z_7 = \) Access to credit facilities,  
\( Z_8 = \) Membership of cooperative  
\( Z_9 = \) Extension contact

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These variables were included in the model to indicate their possible influence on the allocative inefficiencies of cotton farmers. The $\gamma_1 - \gamma_9$ are the scalar parameters to be estimated. The variances of the random errors $\sigma^2V$ and that of allocative inefficiency effects $\sigma^2U$ and the overall variance of the model $\sigma^2$ are related as follows:

$$\sigma^2 = \sigma^2V + \sigma^2U$$

Equation 5 measures the total variance of output which can be attributed to technical inefficiency (Battese and Corra, 1977). Its value is expected to be between 0 and 1. Hence, there is need for estimation.

The values of $\gamma$ indicate the relative magnitude of the variance associated with the distribution of the inefficiency effects which can be captured by the stochastic frontier analysis in the model that is, $\mu_i$’s. If $\mu_i$ in the stochastic frontier are not present or alternatively if the variance parameter $\gamma$ associated with the distribution of $\mu_i$ has zero value, then $\sigma^2U_i$ in equation (4) and (5) is zero. Then, the model reduces to a traditional production function with variable inputs which are included in the production function or variables that are devoid of any stochastic (disturbance or noise) which implies that inefficiency effects are not stochastic.

**Results and Discussion**

**Stochastic Frontier Cost Function**

Stochastic frontier cost function of Cobb-Douglas form was used to estimate the cost of cotton production in order to determine the relationship between cost and level of output produced. Table 1 shows that cost of land was positively related but insignificant in cotton production. This is probably because the cost of acquiring land is proportionally negligible to cost of producing cotton since most of them inherited or got their farmland on lease. Also, cost of agro-chemicals was positively related and significant at 1% level of probability. A unit increase in agro-chemicals resulted in 0.124 increases in output produced. This shows that agro-chemicals had impact on production of cotton since they are important in the cost of production. This input is influencing the level of output in the production process. It is important that attention need to be given to its utilisation since it is contributing to production.
Table 1: Maximum likelihood Estimation Results of Stochastic Frontier Cost Function

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficients</th>
<th>Standard error</th>
<th>T-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant ($\beta_0$)</td>
<td>7.698</td>
<td>0.876</td>
<td>8.781***</td>
</tr>
<tr>
<td>Cost of land ($X_1$)</td>
<td>0.064</td>
<td>0.052</td>
<td>1.236</td>
</tr>
<tr>
<td>Cost of seed ($X_2$)</td>
<td>0.109</td>
<td>0.065</td>
<td>1.676*</td>
</tr>
<tr>
<td>Cost of fertilizer ($X_3$)</td>
<td>0.047</td>
<td>0.031</td>
<td>1.478</td>
</tr>
<tr>
<td>Cost of family labour ($X_4$)</td>
<td>0.138</td>
<td>0.053</td>
<td>2.611***</td>
</tr>
<tr>
<td>Cost of hired labour ($X_5$)</td>
<td>0.108</td>
<td>0.046</td>
<td>2.339***</td>
</tr>
<tr>
<td>Cost of agro-chemicals ($X_6$)</td>
<td>0.124</td>
<td>0.032</td>
<td>3.851***</td>
</tr>
</tbody>
</table>

**Variance Parameters**

<p>| | | | |</p>
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Sigma squared ($\sigma^2$)</td>
<td>13.92</td>
<td>2.96</td>
<td>4.689***</td>
</tr>
<tr>
<td>Gamma ($\gamma$)</td>
<td>0.998</td>
<td>0.005</td>
<td>175.7***</td>
</tr>
<tr>
<td>Log likelihood function</td>
<td>-</td>
<td>170.19***</td>
<td></td>
</tr>
</tbody>
</table>

\[
\sigma^2 = \sigma_v^2 + \sigma_u^2, \quad \gamma = \sigma_u^2 / \sigma^2 \quad *** = P < 0.01, \quad ** = P < 0.05, \quad * = P < 0.10
\]

Cost of family labour and hired labour were positively related with respect to their coefficients and they were significant at 1% level of probability. Unit increases in family and hired labour inputs lead to increase in cotton output by 0.138 and 0.108 respectively. Seed was also positively related and significant at 10% level of probability. Therefore, seed, family labour, hired labour and agro-chemicals are inputs that increase cost of production. In this regard, there is need to reduce costs that are incurred on procurement and utilisation of these inputs in order to minimise cost. In other words, all input costs must be positively related since no negative cost is incurred when inputs are employed in production. This is why in stochastic frontier cost function; we calculate economic efficiency as the inverse of frontier cost function.

The maximum likelihood estimates (MLE’s) of the stochastic frontier cost function revealed that the estimated variance parameter, sigma squared ($\sigma^2$) was (13.92). The value was significantly different from zero at 1% level of probability. This indicates a goodness of fit and the correctness of the specified distributional assumption of the composite error term in the model. The gamma ($\gamma$) statistics of (0.998) was due to farmers’ inefficiency factors. The result showed that technical inefficiency factors were present in cotton production in Zamfara state, Nigeria. The generalized likelihood ratio (LR) test was (264.69). This ratio exceeds the critical value at 1% level of significance implying that the model expressed a goodness of fit of the data used in the estimation. The log likelihood function of (-170.19) expressed the
goodness of fit of the model. This vector represents the value that maximises the joint densities in the estimated model.

Also, the inefficiency effects in cost frontier are positively correlated and must be added to the cost of production instead of being subtracted as in the case of the production frontier. Hence, the production function represents maximum output while the cost function represents minimum cost. On the whole, the goal of the farmer is to strive on how to minimise cost without reducing the level of output so as to maximise profit at that minimum cost. This is the essence of allocative efficiency in stochastic frontier analysis. The estimation of the stochastic frontier cost function is needed in order to arrive at the estimation of the allocative efficiency in the production process. This is possible since the inverse of the stochastic frontier cost function is equal to economic efficiency.

Farmers’ Allocative Efficiency Indices

In allocative efficiency in cotton production, the frequency distribution showed that some of the farmers had allocative efficiency range between 0.01 - 0.10 while a small proportion had allocative efficiency range between 0.11 - 0.20. The majority of sampled farmers operated their farms with the allocative efficiency range of 0.71-0.80 while those that operated their farms with efficiency range of 0.91-1.0 were a small proportion of the respondents. The minimum allocative efficiency score index was 0.02 while the maximum allocative efficiency score index was 0.97. The mean allocative efficiency score index was 0.64 in cotton production (Table 2). From this result, there exists ample opportunity for farmers to embark on rational allocation and utilisation of inputs by 0.36 so as to minimise costs and maximise profits in their cotton production enterprises.

Allocative efficiency is a measure of how an enterprise uses production inputs optimally in the right combination to maximise profits (Inoni, 2007). According to Kibirige (2008) for a farm to be allocatively efficient, the following questions need to be answered;

i. What is the optimal combination of inputs so that output is produced at minimal cost?

ii. How much profit could be increased by simply reallocating resources?

Therefore, the firm has to choose a combination of inputs to be used in right proportions and technically efficient at low prices so that output is produced at minimal costs. This results into profit maximisation. Though, there are new methods used to estimate allocative efficiency, traditionally it has been hard to estimate allocative efficiency without input and output prices.
Table 2: Frequency Distribution of Allocative Efficiency Estimates

<table>
<thead>
<tr>
<th>Allocative efficiency range</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01-0.10</td>
<td>26</td>
<td>11.82</td>
</tr>
<tr>
<td>0.11-0.20</td>
<td>6</td>
<td>2.73</td>
</tr>
<tr>
<td>0.21-0.30</td>
<td>9</td>
<td>4.09</td>
</tr>
<tr>
<td>0.31-0.40</td>
<td>1</td>
<td>0.45</td>
</tr>
<tr>
<td>0.41-0.50</td>
<td>3</td>
<td>1.36</td>
</tr>
<tr>
<td>0.51-0.60</td>
<td>4</td>
<td>1.82</td>
</tr>
<tr>
<td>0.61-0.70</td>
<td>19</td>
<td>8.64</td>
</tr>
<tr>
<td>0.71-0.80</td>
<td>85</td>
<td>38.64</td>
</tr>
<tr>
<td>0.81-0.90</td>
<td>63</td>
<td>28.64</td>
</tr>
<tr>
<td>0.91-1.0</td>
<td>4</td>
<td>1.82</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>220</strong></td>
<td><strong>100.00</strong></td>
</tr>
</tbody>
</table>

Average = 0.64
Maximum = 0.97
Minimum = 0.02

Based on this argument, some scholars such as Farrell (1957) called it price efficiency, referring to the ability of a firm to choose the optimal combination of inputs given inputs prices.

3.3 Determinants of Allocative Inefficiency

The result of allocative inefficiency model is in Table 3. The coefficients of age, access to credit, marital status and extension contact were negatively related and they were significant at 1% level of probability. This implies that these socio-economic variables reduce allocative inefficiency among farmers in cotton production. Major occupation was also negatively related while it was significant at 5% level of probability. Hence, farming as a major occupation reduces allocative inefficiency among farmers involved in cotton production in the study area. The coefficient of marital status was negative and significant at 1% level of significance. This shows that allocative inefficiency is decreasing among cotton farmers. By implication, married farmers were allocatively efficient compared to farmers who are otherwise. This could be attributed to their ability to afford and have access to family labour as married farmers tend to have larger household sizes that could provide labour for farm operations. Access to credit was found negative and significant at 1% which showed that this variable reduces allocative inefficiency. Access to credit may reduce liquidity
constraints as noted by Oyewole (2012) and this will enhance farmers’ access to production inputs thereby increasing allocative efficiency.

Table 3: Socio-economic factors influencing allocative inefficiency

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficients</th>
<th>Standard error</th>
<th>T-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant ($Z_0$)</td>
<td>2.566</td>
<td>2.247</td>
<td>1.141</td>
</tr>
<tr>
<td>Age ($Z_1$)</td>
<td>-0.283</td>
<td>0.016</td>
<td>-17.634***</td>
</tr>
<tr>
<td>Major occupation ($Z_2$)</td>
<td>-1.252</td>
<td>1.194</td>
<td>-2.110**</td>
</tr>
<tr>
<td>Education ($Z_3$)</td>
<td>-0.034</td>
<td>0.222</td>
<td>-0.156</td>
</tr>
<tr>
<td>Access to credit ($Z_4$)</td>
<td>-4.258</td>
<td>1.292</td>
<td>-3.295***</td>
</tr>
<tr>
<td>Marital status ($Z_5$)</td>
<td>1.870</td>
<td>0.585</td>
<td>-3.196***</td>
</tr>
<tr>
<td>Gender ($Z_6$)</td>
<td>-123</td>
<td>1.020</td>
<td>-0.120</td>
</tr>
<tr>
<td>Farming experience ($Z_7$)</td>
<td>-0.091</td>
<td>0.738</td>
<td>-0.123</td>
</tr>
<tr>
<td>Membership of cooperative</td>
<td>0.105</td>
<td>0.079</td>
<td>1.334</td>
</tr>
<tr>
<td>-Extension contact ($Z_9$)</td>
<td>-1.422</td>
<td>0.333</td>
<td>-4.263***</td>
</tr>
</tbody>
</table>

*** = $P < 0.01$, ** = $P < 0.05$, 

In the same vein, extension contact and visits by agricultural extension agents was negatively related with allocative inefficiency and significant at 1% level. Hence, extension contact had a resultant increases in allocative efficiency by enhancing farmers’ awareness about the existence of improved cultural practices in their domain. The adoption of improved cultural practices serves as innovation for farmers to improve on productivity and efficiency in cotton production. Indeed, extension programme as an institutionalised socio-economic variable is a vital vehicle that transforms the traditional rural agriculture to a modern, efficient and productive agricultural system.

Conclusion and Recommendations

The results of the stochastic cost frontier analysis revealed that seed, family labour, hired labour and agro-chemicals were inputs that increase cost of production. With respect to allocative efficiency, cotton production was above average while majority of cotton farmers had their efficiency indices between 0.71-0.80 of allocative efficiencies. Estimation of inefficiency effects revealed that most of the coefficients of socio-economic variables were negatively related and significant. This implies that these variables reduce allocative inefficiency among farmers in cotton production thereby enhancing allocative efficiency among cotton farmers. As a result, the following recommendations were made:
Farmers should be supported by government through timely provision of inputs required in cotton production at affordable prices so as to minimise cost and maximize profits in cotton production.

Efficiency and productivity of cotton farmers should be enabled by government in cotton production. This can be achieved through timely provision of adequate credit facilities that will enhance farmers in adopting improved technologies.

Adequate and intensive research and extension service delivery programme should pursue a consistent and systematic campaign for cotton production by government. Increased use of recommended production practices such as improved cotton varieties, timely weeding, spraying and fertilizer application are recommended.

References


