# Analysis of Cost efficiency in Small Scale Irrigated Tomato Production: Empirical Evidence from Niger State, Nigeria.

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*This study investigated analysis of cost efficiency in small scale irrigated tomato production: empirical evidence from Niger State, Nigeria. Data used for the study were obtained using structured questionnaires administered to 100 randomly selected irrigated tomato farmers from Kontagora and Wushishi Local Government Areas of the state. Stochastic frontier cost function was used to represent the cost frontier of the small scale irrigated tomato farms. The result showed that there was relative presence of economies of scale among the farmers meaning that average farm in the study area produced at a minimum cost considering the size of the farm indicating that they operated in stage II of production surface. The mean cost efficiency of 1.09 obtained from the analysis showed that an average farm in the study area was 9% above the cost frontier, indicating that they were relatively efficient in allocating their scarce resources.*
***Keywords: Cost efficiency, economies of scale, irrigated tomato***

## *Introduction*

Tomato (*Lycopersicon esculentum*) is one of most cultivated vegetable in most regions of the world, ranking second in importance to potatoes (*Solanum tuberusum*) in many countries. Although tomato origin and early history of its domestication are obscure, the weight of evidence suggested that tropical America and Mexico were probable centre of origin. African tomato varieties introduced to Africa and Nigeria in particular at the end of the 19th century.

Production of tomatoes is increasing in most regions of the world, brought about by increased hectarage subsequently increased yields. In 2004, tomato assumed the position of one of the most important fruits in terms of worlds' vegetable produced. Furthermore, in Nigeria, about 88900 metric tones were produced in 2004 (FAO, 2005). Tomato (*Lycopersicon lycopersicum*) is perhaps the most important popular vegetable crop grown all over the country. Both the wet and dry season cropping system contributes immensely to the national requirement. But the bulk production is from the dry season cropping system grown yearly under irrigation in southern states (Alabi, 2007).

In Nigerian cities and their suburbs, tomato is used in foods almost every day in fresh, dry or processed form. In industry, tomato is processed into paste, puree, sauce, ketchup of tomato juice. Tomato is an important source of vitamins A and C in human nutrition. Plant carotenoids, which represent the major pigment in tomato fruit are the primary dietary source of vitamin A. A medium sized tomato (5.3 oz) contains 35 calories, is rich in vitamin C, vitamin A, potassium, and fiber (Hector *et al*., 2002). The fruit of tomatoes are eaten raw or cooked. Large quantities of tomatoes are used to produce soup, juice, sauce, ketchup, puree, paste and powder. They are extensively used in the canning industry. Green tomatoes are used for pickes and preserves (Adepoju and Bot, 2007).

However, the unfolding performance of irrigated tomatoes can be attributed to the fact that bulk of the country's farm, over 90% is dependent on subsistence agriculture (small holder farmers) with rudimentary farm system, low capitalization and low yield per hectare (Olayemi, 1994).

However, irrigated tomato farms just like the other crop farms in Nigeria are the small-scale types which are characterized by very low productivity. The crucial issue in agriculture is that of low productivity. The problem of declining crop productivity in Nigeria is important. Despite all human and material resources devoted to agriculture, the productive efficiency for most crops still fall under 60 percent(FACU, 1992, FDA1993 and FDA1995) Farmers output must therefore be expanded with existing levels of conventional inputs and technology. More than ever, farmers will have to produce more efficiently, that is produce maximal output from a given mix of inputs or use the minimum levels of inputs for a given level of output. An improvement in the understanding of the levels of production efficiency and its relationship with a host of farm level factors can greatly aid policy makers in creating efficacy of present and past reforms.

The objective of this paper is to contribute towards better understanding of small scale farmers' production efficiency in Nigeria with a view of predicting allocative efficiencies (a measure of firms' ability to produce at a given level of output using cost minimization input ratio) of irrigated tomato in Niger State, Nigeria using stochastic frontier cost function. This paper will in addition investigate factors that determine the economies of scale of the farmers.

## THEORETICAL AND CONCEPTUAL FRAMEWORK OF STOCHASTIC FRONTIER METHODOLOGY

Efficiency measurement and the procedure of maximum likelihood estimation are the basic theoretical constructs on which this study is conceptualized. In economic analysis, much is concerned with the technical and economic efficiencies or resource transformation and allocation (Coelli, 1994). Production efficiency is concerned with the relative performance of the process used in transforming inputs into output. The concept of efficiency goes back to the pioneering work of Farrel (1957) who distinguishes between three types of efficiencies: technical efficiency (TE), allocative or price efficiency (AE), and economic efficiency (EE). Technical efficiency in production is the physical ratio of product output to the factor input, the greater the ratio, the greater the magnitude of technical efficiency Allocative efficiency is concerned with choosing optimal sets of inputs. A firm is allocatively efficient when production occurs at a point where the marginal value product is equal to the marginal factor cost. Economic efficiency is a situation where there are both technical and allocative efficiencies. The simultaneous achievement of both efficient condition according to Heady (1952) occurs when price relationship are employed to denote maximum profits for the firm or when choice indicators are employed to denote the maximization of other economic objectives. So, economic efficiency refers to the choice of the best combination for a particular level of output which is determined by both input and output prices.

However, over the years, Farrel's methodology had been applied widely, while it undergoes many refinement and improvement. Such improvement is the development of stochastic frontier model that enables one to measure firm level of efficiency using maximum likelihood estimate. The stochastic frontier model incorporates a composed error structure with a two sided symmetry and one sided component. The one sided component reflects inefficiency while two sided component capture random effects outside the control of production unit including measurement errors and other statistical noise typical of empirical relationship.

Economic application of stochastic frontier model for efficiency analysis include Aigner *et al* (1977) in which the model was applied to U.S. agricultural data. Battese and Corra (1977) applied the technique to the pastoral zone of eastern Australia. More recently, Ogundari *et al* (2006), Ogundari and Ojo (2005), Ojo and Mohammed (2008), Ajibefun *et al* (2002) and Fasasi (2007) in which they offer a comprehensive review of the application of the stochastic frontier model in measuring of agricultural producers in developing countries.

The production technology can be represented inform of cost of function. The cost function represents the dual approach in that technology is seen as a constant towards the optimizing behaviour of firms (Chamber, 1983). In the context of cost function any error of optimization is taken to translate into higher cost for the producers. However, the stochastic nature of the production frontier would still imply that the theoretical minimum cost frontier would be stochastic.

The cost function can be used to simultaneously predict both technical and allocative efficiency of a firm (Coelli, 1995). Also, it can be used to resurrect all the economically relevant information about farm level technology as it is generally positive, non-decreasing, concave, continuous and homogenous to degree one to one input prices(Chambers, 1983).

***Model Specification:*** In this study, Battese and Coelli (1995) model was used to specify a stochastic frontier cost function with behaviour inefficiency component and to estimate all parameters together in one step maximum likelihood estimation. This model is implicitly expressed as:

$$\ln C = g(P_i, Y_i; \alpha) + (V_i + U_i)$$

Where C represents the total production cost, g is a suitable functional form such as Cobb-Douglas; P, is a vector variable of input prices (labour, fertilizer, seeds, agrochemical and annual depreciation cost of farm tools). $Y_j$ is the value of irrigated tomato produced in kg, α is the parameters to be estimated. The systematic component, $V_i$ represents random disturbance costs due to factors outside the scope of farmers. It is assumed to be identically and normally distributed mean zero and constant variance as $N(0,\delta^2 v)$. $U_i$ is the one-sided disturbance form used to represent cost inefficiency and is independent of $V_i$. Thus, $U_i = 0$ for a farm whose costs lie on the frontier and $U_i>0$ for a farm whose costs lie above the frontier and $U_i<0$ for a farm whose costs lie below the frontier. The two error terms are preceded by positive signs because inefficiencies are always assumed to increase cost.

Moreover, for the study the cost efficiency of an individual farm is defined in terms of the ratio of observed cost ($C^b$) to the corresponding minimum ($C^{min}$), given the available technology. That is

$$\text{Cost Efficiency } (C_{EE}) = \frac{C^*}{C} = \frac{g(P_i, Y_i, \alpha) + (V_i + U_i)}{g(P_i, Y_i; \alpha) + (V_i)} = \exp(U_i)$$

Where the observed cost ($C^b$) represents the actual total production cost while the minimum cost ($C^{min}$) represents the frontier total production cost or least total production cost level. $C_{EE}$ takes value of 1 or higher with 1 defining cost efficient farm. And, following the adoption of Battese and Coelli (1995) framework for the analysis of the data, the explicit Cobb-Douglas functional for the irrigated tomato farms in the study area is therefore specified as follows:

$$\ln C = \alpha_0 + \alpha_1 \ln P_{1i} + \alpha_2 \ln P_{2i} + \alpha_3 \ln P_{3i} + \alpha_4 \ln P_{4i} + \alpha_5 \ln P_{5i} + \alpha_6 \ln Y_i + (V_i + U_i)$$

Where $C_i$ represents total production cost in naira (₦); $P_1$ represents cost of labour (₦); $P_2$ represents cost of fertilizer (₦); $P_3$ represents cost of seed (₦); $P_4$ represents cost of agrochemical (₦); $P_5$ represents annual depreciation cost of farm tools (₦) and $Y_i$ represents output of irrigated tomato in (kg). The choice of the Cobb Douglas is based on the fact that the methodology requires that the function be self dual as in the case of cost function in which this analysis is based on.

The inefficiency model ($U_i$) is defined by:

$$U_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_5$$

Where Z1, Z2, Z3, Z4, Z5 represent farm size, household size, age, educational level and farming experience. These socio-economic variables are included in the model to indicate their possible influence on the cost efficiency of the farmers.

The gamma ($\gamma$) measures the total variation of total cost of production from the frontier cost which can be attributed to cost inefficiency (Battese and Corra, 1977). The estimate for all the parameters of the stochastic frontier cost function and the inefficiency model are simultaneously obtained using the program FRONTIER version 4.1c (Coelli, 1996). The test for the presence of cost inefficiency using generalized likelihood- ratio statistics $\lambda$ defined by:

$$\lambda = -2\ln\left( {H_0}/{H_a} \right)$$

Where $H_0$ is the value of the likelihood function for general frontier model in which parameters restriction specified by the null hypothesis, $H_0$ are imposed; and $H_a$ is the value of the likelihood function for general frontier model.

***Economies of Scales (Es):*** Economies of scale may be defined in terms of elasticity of cost with respect to output. However, in a multi-product setting, economies of scale (***Es***) is defined as those reduction in average cost when all output are increased proportionally holding all other input prices constant (Ogundari *et al*). ***Es*** mathematically is equivalent to the inverse of the sum of all the elasticities of total production cost with respect to all output. Economies of scale prevail, if ***Es*** is greater than 1 and, accordingly diseconomies of scale exist if ***Es*** is below 1. In the case of ***Es*** = 1 no economies of scale or diseconomies of scale exist. Return to Scale and economies of scale are equivalent measures if and only if the product is homothetic (Chamber, 1983). Here, since Cobb-Douglas function was used, this assumption is imposed.

***Methodology***

***Study Area:*** The study was conducted in Niger State of Nigeria. The state is located within latitudes $8^o$ – $10^o$ north and longitudes $3^o$ – $8^o$ east of the prime meridian with land area of 76,363 square kilometers and a population of 4,082,558 people (Wikipedia, 2008). The state is agrarian and well suited for production of arable crops such as cowpea, yam, cassava and maize because of favourable climatic conditions. The annual rainfall is between 1100mm – 1600mm with average monthly temperature ranges from $23^o$C and $37^o$C (NSADP, 1994). The vegetation consist mainly of short consist mainly of short grasses, shrubs and scattered trees.

***Sampling Techniques:*** The data mainly from primary sources were collected from two Local Government Areas (LGAs) which were purposively selected because of prevalence of the crop in the area using multistage sampling technique. The LGAs include Kontagora and

Wushishi LGAs. The second stage involved a simple random selection of 50 farmers from each of the two LGAs, thus, making 100 respondents. The data were collected with the use of structured questionnaire designed in line with objectives of the study.

**RESULTS AND DISCUSSION**

**Table 1: Summary statistics of the variables in stochastic frontier model**

| **Variables** | **Mean** | **Standard .Deviation.** | **% of TC** |
|---|---|---|---|
| Total production Cost (TC) (₦) | 32914.20 | 11005.38 | |
| Labour Cost (₦) | 13504.40 | 8489.13 | 41.03 |
| Fertilizer Cost (₦) | 7978.50 | 3272.46 | 24.24 |
| Seed Cost (₦) | 992.05 | 1625.29 | 3.01 |
| Agrochemical cost (₦) | 5404.10 | 2874.32 | 16.42 |
| Annual depreciation (₦) | 5035.15 | 2567.74 | 15.30 |
| Irrigated Tomato Output (kg) | 3167.00 | 2333.58 | |
| Farm Size (ha) | 1.04 | 6346 | |
| Family Size | 4.31 | 2.4 | |
| Age (years) | 41.80 | 9.54 | |
| Education level (years) | 5.33 | 4.01 | |
| Farming Experience (years) | 7.34 | 3.74 | |

The summary statistics of the variables for the frontier estimation is presented in Table 1.The mean value of ₦32, 291.20 as total cost of producing 3,167kg of irrigated tomato per annum was obtained from the data analysis with a standard deviation of ₦11, 005.38. The large size of the standard deviation conforms to the fact that most farms operate at different scale of operation. Analysis of cost variables of the farms shows that cost of labour accounts for about 41.03% of the total cost, fertilizer cost accounts for 24.24% of the total cost, seed cost accounts for 3.01%, agrochemical cost accounts for 16.42% while annual depreciation cost accounts for 15.30%. Variables representing the demographic characteristics of the sampled farmers employed in the analysis of the determinant of cost efficiency include farm size, family size, age of the farmers, educational level of the farmers and years of farming experience. The average farm size, family size ,age of the farmers, year of schooling and years of experience were 1.04, 4.31, 41.80, 5.33 and 7.34 respectively, meaning that the farmers were relatively young and uneducated.

The stochastic cost frontier model estimates of irrigated tomato producers in the Niger State are presented in Table 2 The Table showed that the coefficients of labour cost, fertilizer cost, seed cost, agrochemical cost and depreciation cost had the expected positive sign and were all significant at 1% level of probability meaning that these factors were significantly different from zero and thus were important in irrigated tomato in the study area. The positive sign of cost elasticities with respect to all input variables used in the analysis imply that an increase in labour cost, fertilizer cost, seed cost, agrochemical cost and depreciation cost will lead to 0.38%, 0.24%, 0.05%, 0.18% and 0.15% in total production cost respectively. The result of the presence of economies of scale among the irrigated tomato farmers showed that economies of scale prevailed among the sampled farm, judging by the fact that Es computed is greater than one, that is Es = 1.00503. This showed that the farms were experiencing decreasing but positive return to scale (stage II of production surface), since return to scale and economies are equivalent measures (Chambers, 1983).

**Table2: Maximum likelihood estimates of parameters of the cobb-douglas frontier function for small scale irrigated tomato production in Niger State.**

| Variables | Parameters | Coefficients | t-ratio |
|---|---|---|---|
| ***General Model*** | | | |
| Constant | $ß_0$ | 1.525 | 21.624*** |
| Labour Cost (₦) ($X_1$) | $ß_1$ | 0.380 | 26.787*** |
| Fertilizer Cost (₦) ($X_2$) | $ß_2$ | 0.242 | 18.720*** |
| Seed Cost (₦) ($X_3$) | $ß_3$ | 0.045 | 4.053*** |
| Agrochemical cost (₦) ($X_4$) | $ß_4$ | 0.177 | 14.604*** |
| Annual depreciation (₦) ($X_5$) | $ß_5$ | 0.151 | 16.364*** |
| Irrigated tomato output ($X_6$) | $ß_6$ | -0.033 | $-0.367^{N.S}$ |
| ***Inefficiency Functions*** | | | |
| Constant | $\delta_0$ | -0.394 | -3.243*** |
| Farm Size (ha) | $\delta_1$ | -0.022 | $-0.430^{N.S}$ |
| Family Size | $\delta_2$ | 0.007 | $0.563^{N.S}$ |
| Age (years) | $\delta_3$ | 0.001 | 3.976*** |
| Education Level (years) | $\delta_4$ | -0.003 | -1.924** |
| Farming Experience (years) | $\delta_5$ | -0.031 | -1.733** |
| Diagnosis Statistics | | | |
| Sigma-square $\delta^2$ | | 0.3082 | 7.821*** |
| Gamma $\gamma$ | | 0.9687 | 16.197*** |
| Log likelihood function | | 146.984 | |
| LR Test | | 69.947 | |
| Economies of scale (Es) | | 1.00503 | |

Source: Computed from MLE Results

** = Significant at 5% level; *** = Significant at 1% level; NS = Not significant

The estimated coefficient in the explanatory variables in the model is presented in the lower part of Table 2 for the cost inefficiency effects are of interest and have important implication.

The negative coefficients for farm size, education level and farming experience imply that farmers with large farm size, high education level and most farming experience in irrigated tomato production were more cost efficient than the farmers with small farm size, low education level and low farming experience. The positive sign of family size and age of the farmers indicated that farmers' level of cost efficiency tends to decline with large family size and high age.

The gamma ($\gamma$) ratio of 0.9687 which is significant at 1% level implied that about 96.87 percent variation in the total cost of production among the sampled farmers was due to differences in their cost efficiencies.

***Test of Hypotheses and Diagnostic Statistics***

The result of the generalized likelihood ratio which is defined by the chi square distribution is presented in Table 3. The null hypothesis in the table is Ho: $\gamma = 0$, which specifies that the inefficiency effects in the stochastic frontier production are not stochastic. The null hypothesis is rejected. This implies that the traditional response function (OLS) is not an adequate representation of the data

**Table 3: Generalized likelihood ratio test of hypothesis for parameters of the stochastic cost function for irrigated tomato production in Niger State.**

| Null Hypothesis | Log likelihood | No. of Restrictions | $\chi^2$ Statistics | Critical value | Decision |
|---|---|---|---|---|---|
| Ho: $\gamma = 0$ | 146.98 | 7 | 69.95 | 14.07 | Rejected |

Source: Computed from MLE Results

Table 4 showed summary of cost efficiency scores the small scale irrigated tomato farms in the study area. Cost efficiency is estimated as $C_{EE} = \exp(U_i)$. The mean cost efficiency of the farms was estimated as 1.091. This means that an average irrigated tomato farm in the sampled area has costs that are about 9% above the minimum defined by the frontier. In other words, 9% of their costs are wasted relative to the best practiced farms producing the same output (tomato) and facing the same technology. The higher the value of $C_{EE}$, the more inefficient the irrigated tomato is.

**Table 4: Cost efficiencies of the sampled small scale irrigated tomato farmers in Niger State**.

| Efficiency level | Frequency | Relative Efficiency (%) |
|---|---|---|
| 1.00 - 1.19 | 88 | 88 |
| 1.20 - 1.29 | 7 | 7 |
| 1.30 - 1.39 | 3 | 3 |
| 1.40 - 1.49 | 1 | 1 |
| 1. 50 - 1.59 | 0 | 0 |
| 1.60 - 1. 69 | 1 | 1 |

| | | |
|---|---|---|
| Total | 100 | 100 |
| Mean | 1.091 | |
| Minimum | 1.000 | |
| Maximum | 1.687 | |
| Standard Deviation | 1.061 | |

Source: Computed from MLE Results

**SUMMARY AND CONCLUSION**

This empirical study is on analysis of cost efficiency in small scale irrigated tomato production in Niger State using stochastic frontier cost function. The empirical evidence indicates that the existence of relative economies of scale despite the fact that the farms operate at small level. Relative economies of scale in the sense that the small scale irrigated tomato farmers are currently expanding their present level of production, which in long run will enable them to experience decrease in the cost of production per output.

Further outcome of this analysis showed that 88% of the farms included in the sample operated close to the frontier level, achieving scores of 9% or lower in termsof cost difference in the relation for the best practiced technology. However, the level of the observed cost efficiency has been shown to be significantly influenced by farm size, education level and years of farming experience.

In conclusion, the relative closeness of the computed overall economies of scale (Es) of 1.0053 and average cost efficiency ($C_{EE}$) of 1.091 from unity, is an indication that although the farmers are small scale resource poor, but they are fairly efficient in the use of their resources and that any expansion in their present level of production would bring down the cost of production per out, given the prevailing but fairly economies of scale obtained for the study which is in accordance with results from earlier studies that higher relative efficiency for small farms (Ogundari *et al,* 2007, Yotopolous and Lau, 1973; Khan and Maki, 1979).

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