COMPARISON OF COBB-DOUGLAS AND TRANSLOG FRONTIER MODELS IN THE ANALYSIS OF TECHNICAL EFFICIENCY IN DRY-SEASON TOMATO PRODUCTION

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ABSTRACT

There has been contradiction among researchers regarding similarity or otherwise of technical efficiency estimate obtained from Cobb-Douglas and Translog frontier models. While some researchers believe that results obtained from the two functional forms, given the same data, were essentially similar, others disagreed. This study compared both functional forms to analyze technical inefficiency in dry-season tomato production in Jos-South Area of Plateau State. Data were collected from 60 dry-season tomato farmers sampled through three-staged random sampling technique. The analyses of the data were done using both Cobb-Douglas and translog frontier models. The results showed that the estimated elasticities, efficiency scores and inefficiency effects from Cobb-Douglas and Translog functional forms differ significantly. Therefore, the choice of functional form for efficiency analysis should be based on convenience, meeting selection criteria premise on the value of variance-parameters and objective of the study.
Keywords: Efficiency, comparison, Cobb-Douglas and Translog models

INTRODUCTION

Tomato (*Lycopersicon esculentum Mill.)* is one of the most important vegetables grown in Nigeria due to its rich minerals, vitamins, essential amino acids, sugars and dietary fibers. It is also a cash crop for small-holders and medium scale farmers. According to Abolusoro, Ogunjimi and Abulosoro (2014), tomatoes could be grown in a wide altitude range from the sub-tropical plains through to the high hills, depending on the variety and sowing date. In 2013, the estimate of tomato production in Nigeria stood at 1.93 million metric tonnes from total land area of about 517,000 hectares, at an average of 3.7 tons per hectare, while the national tomato consumption was about 2.33 million metric tonnes (Food and Agricultural Organization, 2016). As a result of deficit in domestic supply of tomato, Nigeria imported a total of 407,959 metric tonnes of tomato largely in paste form in 2013 alone, to bridge the

supply and demand gap in the country (Food and Agricultural Organization, 2016). The importation of processed tomato, which cost the country US dollars equivalent of 16 billion naira annually, is mainly from China and Italy. This trend has not changed; rather it is getting worse occasioned by the rising population, which further necessitated the need for increase of national output to meet ever-increasing demand.

In the Southern part of Nigeria, tomato is usually produced in a small-scale under rain-fed conditions while in the Northern part; it is grown solely or in combination with other crops and mainly in the fadama farm land (Kalu, 2013). Farmers in the Northern Nigeria engage in the production of other crops during raining seasons, while they plant tomatoe in the dry season using the irrigated and/or fadama land (Kalu, 2013). In order to make for its all-year round availability, there is a need for an increased production, especially during the dry season (Oladoja *et al.* 2006).

It is believed that inefficiency in the management of tomato production inputs remains a major factor hindering efforts of meeting the national tomato demand, thereby necessitating its importation in order to bridge supply and demand gap at the expense of hard earned foreign currency. Non-parametric method like Data Envelopment Analysis, DEA, and parametric method like Stochastic Frontier Analysis, SFA, are two common techniques used for estimating production efficiency or inefficiency. However, SFA is applied mostly in efficiency estimation in preference to DEA because the former has ability to deal with stochastic noise and amenable to statistical testing of hypotheses (Coelli et al. 2005). Stochastic frontier models specified in the functional form of Cobb-Douglas or Transcendental logarithm (translog) has been widely applied in estimating farm production efficiency using the Maximum likelihood Estimates. However, all the previous studies (Ogunniyi and Oladejo, 2011; Tsoho, et al. 2012; Adenuga, Mohd and Rotimi, 2013; Aminu, Ayinde, and Ambali, 2013; Zalkuw, et al. 2014; Shettima, Amaza and Iheanacho, 2015) applied Cobb-Douglas functional form in the analysis of tomato production inefficiency without considering translog functional form. According to Ahmad and Bravo-Uretta, (1996) and Thiam, Barvo-Ureta and Rivas, (2001), contrary results on technical efficiency from the two functional forms were observed. While Thiam et al. (2001) observed that the average technical efficiency score from Cobb-Douglas function was significantly different from those of Translog function, Ahmad and Bravo-Ureta (1996) argued that there was no much difference in the results obtained from two functional forms, but suggested that the comparison between functional forms in the efficiency studies was imperative.

It is against this background that this study was designed to compare Cobb-Douglas and Translog stochastic frontier models in estimating technical inefficiency and its determinants in dry season tomato production.

METHODOLOGY

The study was conducted in Jos South Local Government Area of Plateau State, Nigeria. It is located within Latitude 09° 48^1 N and Longitude 8° 52^1 E. The area has distinct wet and dry seasons. It has an area of $510km^2$ and a population of 306,716 (NPC, 2006). The major crops grown in the area include tomato, cabbage, lettuce, beans, Irish potato, carrot etc.

The target population was dry season tomato farmers. A three-stage sampling procedure was employed for this study. Three (3) districts were purposively selected out of the four (4) districts in the Local Government Area. This was based on areas where tomato is predominantly produced during dry season. At the second stage, a random selection of one (1) tomato producing village from each of the three districts was done, and followed by random selection of twenty (20) tomato farming households from each village making a total of 60 respondents for the study. The random selection of 20 tomato farming households was done using sample frame provided by ADP.

This study employed well-structured questionnaire to collect data about farmer's socio-economic characteristics; such as gender, family size, age and educational level, as well as production data such as farm size, farm output, and production inputs, such as quantity of fertilizer applied, labour, planting materials, pesticide and herbicide.

Model Specification:

According to Coelli (1996), the stochastic frontier production function was independently proposed by Meeusen and Broeck (1977) and Aigner, Lovell and Schmidt (1977).The original specification involved production function with composite error terms accounting for random effect as well as technical inefficiency effect both of which could cause production output deviation from frontier. The model is implicitly expressed in matrix form as follow:

$Y_i = X_i\lambda + C_i^r$ (i=1, 2,...., N) i

   Where, Y_i = is the output of the ith farm; Xi = is the K × 1 vector of the inputs used in i^{th} farm; λ= is a vector of parameter to be estimated; C_i^r (composite error term) = $(V_i - U_i)$; V_i = random effect variables which are assumed to be [iid. N (O, σ_v^2)]. The random effect variable, V_i, captured aggregate effects of unobserved factors on production, which are generally

exogenous and beyond the control of the farmer; U_i= non-negative random variables which are assumed to account for technical inefficiency in production, (captured output deviation from the frontier caused by factors under the control of the farmers, which are generally socioeconomic in nature) are independently distributed as truncation at zero of the N (u_i, σ_u^2).

Where, U_i= $Z_i\delta$ ……………………………………………………………………………ii

Z_i = is the P× 1 vector of variables (mainly farmers' socioeconomic factors) which may influence the efficiency of the farm; δ = is a vector of unknown parameter to be estimated.

The frontier or the potential output is defined as the maximum output obtained without inefficiency effect on the production given the input vector, X_i. This can be specified as follows:

Y^*= exp($X_i\lambda$ + V_i)……………………………………………………………………iii

Hence, the technical efficiency, TE, of the ith farm can be defined as the ratio of the observed output to the potential or frontier output, given the available technology. This can be expressed as follow:

TE_i = Y/Y^*= exp($X_i\lambda$ + V_i- U_i)/ exp($X_i\lambda$ + V_i) = esp(-U_i)…………………………………………..iv

Given equation 3, the technical efficiency scores range from zero to 1 and inversely related to the inefficiency effect (Coelli and Battese, 1996).

Aigner, et al (1997) suggested the use of likelihood function to allow for two variance parameters namely Sigma squared (σ^2) and gamma (γ) which have statistical application. They are defined as follows:

$$\sigma_T^2 = \sigma_V^2 + \sigma_U^2; \quad \gamma = \sigma_U^2 \Big/ \sigma_T^2 \qquad \text{……………………………………………………………v}$$

The value of σ^2 measures goodness of fit to the data. The γ value lies between zero to 1, where the value of zero indicate all deviation from the frontier is due to noise effect and the value of 1 is an indicative that all deviation from frontier are due to inefficiency effect.

Specification of Functional form of the Model:

The Cobb-Douglas form of the stochastic frontier production function applied in this study is specified:

$LnY_i = \lambda_0 + \Sigma^5_{i=1} \lambda_i lnX_i + C^r_i$ ……………………………………………………………………..vi

Where; Y_i= output of tomato in i^{th} farm (kg), X_1= Farm size (ha), X_2=Labour (Manday), X_3=Seed (Kg), X_4= Fertilizer (Kg), X_5= Pesticide (litre), Ln= Natural Logarithm, λ_0-λ_5 = Parameters to be estimated, C^r_i = as defined in equation 1

The Translog form of the stochastic frontier production function applied in this study is given as:

$LnY_i = \lambda_0 + \Sigma^5_{i=1} \lambda_i lnX_i + 0.5\Sigma^5_{i=1} \lambda_{ii} lnX_i lnX_i + \Sigma^5_{i=1}\Sigma^5_{j=1} \delta_{ij} lnX_i lnX_j + C^r_i$ …………………….vii

Where, λ_{ii} and λ_{ij} are estimable parameters.

The inefficiency effect model is explicitly specified in its general form as follows:

$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3$……………………………………………………………………..viii

Where, U_i= inefficiency effect of ith farm, Z_1= farming experience, Z_2= education, Z_3= household size, while δ_0 to δ_3 estimable parameters.

RESULTS AND DISCUSSION

Descriptive statistics of the variables:

 The descriptive statistics of variables used in both Cobb-Douglas and Translog production frontier functions are presented in Table 1. The mean of output of dry season tomato production in the study area was 5,349 Kg. The minimum and maximum output recorded were1,850 Kg and 12,580 Kg respectively (Table 1). The standard deviation of the Output was 2,111, which is an indication of wide variability of farmers' output from the average. Table 1 also showed that the minimum farm size devoted to the production of dry season tomato in study area was 0.30 hectare, while the maximum farm land was 3 hectares with mean of 1.02 hectares and standard deviation of 0.68. This implies that all the dry season tomato farmers in the study area were smallholders.   The labour utilization ranges between 20 man-day to 72 man-day with the mean of 47 man-day (Table 1). Based on the value of standard deviation (13.56), there was low variability of labour utilization among the farmers from estimated mean. The averages of seed planted among the farmers and pesticide used were 1.99 Kg and 3.2 litres respectively. There was very low deviation from mean of quantity of seed planted and the litre of pesticide utilized among farmers. Table 1 also showed that fertilizer utilization among the dry-season tomato farmers ranged between 100 kg and 1, 514 with mean of 276 kg. The mean of family size and farming experience were 6 persons and 20

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years respectively (Table 1). The mean of education among the farmers was 8 years spent in attaining education (that is junior secondary education).

Table 1: Descriptive statistics of variables used in Cobb-Douglas and translog frontier models

Variable	Minimum	Maximum	Mean	Std. Deviation
Output (Kg)	1,850	12,580	5,349	2,111
Farm size (Ha)	0.30	3.00	1.02	0.68
Labour (Manday)	20	72	47	13.56
Seed (Kg)	1.00	4	1.99	0.60
Pesticide (litre)	0	8	3.2	1.75
Fertilizer (Kg)	100	1,514	276	293
Education (Year)	1.0	16	8	5.48
Household size (Number)	1	20	6	3.76
Farm Experience (Year)	3	50	20	11.55

Source: Field Survey (2016)

Production frontier estimates:

The maximum likelihood Estimates (MLE) of the stochastic production parameters for both Cobb-Douglas and Translog models are presented in Table 2. The coefficients of variance-parameter for both models show that σ^2 (sigma squared) and Gamma (γ) were significantly different from zero except for the coefficient of σ^2 estimated from Cobb-Douglas function. According to Aigner *et al.* (1997), statistical significance of the variance-parameter (σ^2) is an indication of a good fit for the model and confirmation of distribution assumption of the composite error term. While the Gamma (γ) values show that 72% (based on Cobb-Douglas estimate) and 99% (based on Translog estimate) of deviation from the dry-season tomato output were due to technical inefficiency effects (Table 2).

Table 2 also indicates that the coefficients of farm size (0.65), labour (0.48) and fertilizer (0.16) were statistically significant estimate of Cobb-Douglas function. This implies that 1% increase in the farm size, labour and fertilizer would result in 0.65%, 0.48 % and 0.16 percent increase in the tomato output. The coefficients of seed and pesticide variables, though positively related to tomato output, were insignificantly influencing tomato output variation in the study area. On the other hand, the coefficients of farm size (7.16), seed (4.33) and

pesticide (8.21) were statistically significant estimate of Translog function. Based on this function, coefficient of labour and fertilizer did not influence the output of tomato significantly. This study confirmed earlier position of Thiam *et al.* (2001) that results from two models namely Cobb-Douglas and Translog production Frontier were different.

Elasticities estimate from Cobb-Douglas were generally small and inelastic, while those from Translog model were larger and elastic due largely to interaction effects of the variables (Lira *et al.* 2014). However, elasticities estimate from both models show that dry-season tomato farmers were operating at increasing return to scale. This implies that if the combined inputs used in tomato production increase by 1%, the output will increase by more than 1%.

Table 2: Maximum likelihood estimate of Cobb-Douglas and translog production frontiers

Common Variable	Description Parameter	Cobb-Douglas Frontier			Translog Frontier		
		Coefficient	Std Error	T-ratio	Coefficient	Std. Error	T-ratio
Constant	λ_0	7.77	1.00	7.74***	5.17	1.09	4.71***
Farm size	λ_1	0.65	0.21	3.00***	7.16	3.64	1.97**
labour	λ_2	0.48	0.23	2.09**	3.35	3.67	0.91ns
Seed	λ_3	0.15	0.20	0.70ns	7.98	1.84	4.33***
Fertilizer	λ_4	0.16	0.07	2.44**	2.61	1.79	1.45ns
Pesticide	λ_5	0.03	0.09	0.28ns	8.21	2.34	3.51***
Variance-parameters	σ^2	0.27	0.27	1.00ns	4.22	1.19	3.54***
	γ	0.72	0.28	2.63***	0.99	8.26	12.11***

Note: ***= significant at 1 % level of probability; **= significant at 5% level of probability; ns= not significant statistically.
Source: Field Survey (2016)

Efficiency Score:
 The frequency distribution of efficiency estimates obtained from both Cobb-Douglas and Translog stochastic frontier models are presented in Table 3. The Table shows that no single dry-season tomato farmer operated below efficiency level of 61%, and the farmers had a mean technical efficiency of 89%, based on the estimate from Cobb-Douglas frontier function. However, as much as 68.3% of the dry-season tomato farmers operated below efficiency level of 61%. The mean technical efficiency was observed to be 54% based on the Translog frontier function estimation.   This implies that on the average, tomato farmers require only

11%, or as much as 46% cost saving technology to attain the status of the most efficient farmers given Cobb Douglas and Translog frontier models respectively. These results confirmed the findings of Thiam *et al.* (2001), who observed that the average technical efficiency score from Cobb-Douglas function was significantly different from Translog function. However, the results disagreed with Ahmad and Bravo-Ureta (1996), who observed that there was no significant difference in the results obtained from the two functional forms.

Table 3: Distribution of efficiency scores obtained from Cobb-Douglas and translog frontier models

Efficiency Range	Cobb-Douglas Frontier		Translog Frontier	
	Frequency	%	Frequency	%
0.21-0.30	0	0	02	3.3
0.31-0.40	0	0	10	16.7
0.41-0.50	0	0	17	28.3
0.51-0.60	0	0	12	20
0.61-0.70	02	3.3	12	20
0.71-0.80	04	6.7	04	6.7
0.81-0.91	27	45	01	1.7
0.91-1.00	27	45	02	3.3

Source: Field Survey (2016)

Factors Influencing inefficiency in dry-season tomato production:

The estimate of inefficiency effects model using the two functional forms (Cobb-Douglas and Translog) are presented in Table 4. The sign of coefficient of education implies that educational level of the dry-season tomato farmers has tendency to enhance efficiency of tomato production in the study area given Cobb-Douglas functional form. This result is supported by earlier studies (Adenuga, et al; 2013; Ogunniyi and Oladejo, 2011). However, based on translog functional form, the sign of coefficient of education suggests that education of dry-season tomato farmers would not likely boost their efficiency in production. Table 4 also shows that the estimate from both functional forms imply that household size of dry-season tomato farmers has tendency of increasing their efficiency in tomato production. This result agrees with those of Aminu *et al*. (2013). The coefficient of farming experience, for both models, suggest that it increases inefficiency in tomato production, though insignificant statistically.

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Table 4: Maximum likelihood estimate of inefficiency effects model of Cobb-Douglas and translog production frontiers

Common Variable	Description Parameter	Cobb-Douglas Frontier			Translog Frontier		
		Coefficient	Std Error	T-ratio	Coefficient	Std. Error	T-ratio
Constant	δ_0	-0.04	0.08	-0.47	-2.06	0.94	-2.50**
Farming Experience	δ_1	0.01	0.03	0.45	1.78	0.73	2.42**
Education	δ_2	-0.20	0.60	-0.35	0.57	0.30	1.85
Household size	δ_3	-0.56	0.15	-0.39	-0.60	0.66	-0.91

Source: Field Survey (2016)

CONCLUSION AND RECOMMENDATIONS

Findings from this study showed that estimated elasticities, efficiency scores and inefficiency effects of Cobb-Douglas and Translog functional forms differ given the same data generated from the dry-season tomato farmers in the study area. Therefore the choice of functional form to be used for efficiency analysis should be based on convenience, meeting selection criteria premise on the value of variance-parameter and objectives of the study.

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