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A TECHNICAL EFFICIENCY ANALYSIS OF CARROT PRODUCTION IN ASANTE-MAMPONG MUNICIPALITY

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Abstract: The Ghanaian agricultural sector, particularly the crops sub-sector, plays a crucial role in the country's economy, contributing significantly to the gross domestic product (GDP) and providing employment opportunities. Among the various agricultural activities, vegetable production, especially non-traditional or exotic vegetables, holds substantial potential for both local consumption and international markets. Despite the global surge in vegetable production over the past decade, vegetable production levels in Ghana and Africa as a whole have not met local market demands. This insufficiency in vegetable production can be attributed to several factors, including poor soil fertility, inadequate utilization of fertilizers, limited access to agricultural inputs, and inefficient input management. Consequently, the socioeconomic benefits that the vegetable sub-sector could bring to farming communities have fallen short of expectations. Mampong Municipality, located in Ghana, is recognized as a prominent producer of vegetables, with a particular focus on carrots. Carrots, as exotic vegetables, are highly sought after and used in various culinary preparations. The demand for carrots, especially in urban areas, remains consistently high. Additionally, the export potential of Ghanaian carrots has been acknowledged by the Ministry of Food and Agriculture. In light of these factors, this study explores the challenges and opportunities in carrot production within the Mampong Municipality, emphasizing the importance of improving agricultural practices, input management, and market access to harness the full potential of carrot farming in the region.

Keywords: Ghana, agriculture, vegetable production, carrot farming, socioeconomic impact

1. Introduction

The Ghanaian economy like other developing economies in Sub-Saharan Africa is relatively dependent on the agricultural sector primarily for its contribution to the gross domestic product (GDP) and employment (ISSER, 2013). In 2017, for instance, the agricultural sector recorded an all-time high contribution of GH¢ 8441 million (18.3%) to the nation's GDP (Ghana Statistical Service [GSS], 2018). In Ghana, the crops sub-sector continues to dominate the agricultural sector and the economy as a whole in its contribution to GDP. It contributed 14.6% and 14.2% of nominal GDP in 2016 and 2017 respectively (GSS, 2018). One of the important production sectors within the crop sub-sector of Ghana's agriculture which has great potential for both local and international markets is vegetables production and non-traditional or exotic vegetables in particular. Global production levels of vegetables have increased significantly over the past decade, from 682.43million in 2000 to 1.09434 billion metric tons in 2017 (Statista, 2019) and as a result, has contributed significantly to consumption, employment and income needs of many people worldwide. However, production levels of vegetable in Ghana and Africa still remain low and have not been able to meet local market demands. Low production levels of vegetables in Africa have been blamed on poor soil fertility (Muendo and Tschirley, 2004) and inability of farmers to optimally and appropriately use fertilizers; poor access to and inefficient management of inputs (Berinyuy and Fontem 2011). Consequently, the contribution of vegetables sub-sector to the socio economic wellbeing of vegetable farming communities falls below expectation. Mampong Municipality is among the leading producers of vegetables and carrots in particular in Ghana. The municipality supplies carrots to major urban centres in Ghana, including Kumasi and Accra. Carrot, one of the exotic vegetables in Ghana, is highly valued and used in combination with other vegetables in preparing soups, stews, salads and drinks. Demand for carrots remains high especially in the urban centres, and its export potential has been recognized by the Ministry of Food and Agriculture since 2002 (MoFA, 2002).

As indicated by Ahmad *et al*. (2005) carrot production can be a lucrative farming activity since it is a short duration crop and can result in higher yields per unit area. While production statistics of carrot is yet to be officially documented for Ghana (MoFA, 2017), its production levels and yield per unit area remain low (Appiah *et al*., 2017). Appropriate inputs and resource utilization is key factor to increasing agricultural productivity, even under technological innovation. In Ghana, most research works in vegetables and carrot production in particular, have centered on production parameters that response to fertilizer or pesticide application and postharvest handling of carrots with the technical efficiency (TE) of carrot production overlooked. Limited data on technical efficiencies of carrot famers constrains policy orientation on productivity improvement. This paper therefore uses the stochastic frontier approach to analyze the levels and determinants of technical efficiency of carrot production in the Ashanti Mampong Municipality of Ghana.

2.0 Theoretical Framework And Related Studies

Efficiency assessment has dominated market and production economics literature since pioneering work of Farrell (1957). In terms of production, a firm's efficiency is measured as the actual productivity the firm achieves relative to its potential productivity. Technical efficiency denotes a maximum output that can be obtained from a combination of a given set of inputs or utilization of minimum input set for a given output level.

2.1 Theoretical and Analytical Framework of Technical Efficiency

Coelli (1995) noted that efficiency of a firm or the maximum potential productivity is defined by the production frontier and measurement of efficiency therefore involves measurement of the distance from observed data point to that of the frontier. This measure therefore implies that efficient firms are those firms operating within the production frontier. However, firms are classified as been inefficient by the magnitude by which they fall below the production frontier (Malinga *et al*., 2015). Approaches to measuring technical efficiency are categorized into parametric and non – parametric measures. The non-parametric frontiers have specific functional forms with nonparametric models based on mathematical programming techniques. The parametric approach uses the stochastic frontier production in the form such as the Cobb-Douglas production function.

This study adopts the Stochastic Frontier Analysis (SFA) to analyze the technical efficiency of carrot production in the Mampong Municipality. Its user friendly and mathematical simplicity made it an obvious choice for use in this study. Another advantage of this model is its ability to provide an inefficiency component that can be used to statistically test for the degree of technical inefficiency among farmers or firms. It also helps to measure both the technical efficiency sources and the impact of measurement errors or factors that are not inherently related to production (Battese *et al.,* 2004). The model however suffers a disadvantage in its imposition of an explicit functional form and distribution assumption of the error term (Coelli, 1995). The general stochastic model for a cross-sectional data as proposed in the works of Aigner *et al.* (1977) and Meeusen and Van den Broeck (1977) is specified as:

$$Y_i \square f(X_i;\square)\exp(\square_i) \square f(X_i;\square)\exp(v_i \square u_i),\ i \square 1,\ldots,N \quad (1)$$

Where i= 1, 2, 3........., N; X_i is a vector of inputs bundle for the ith farmer; .Y_i defines output level of the ith farmer; β_k is a vector of the estimated parameters in the model, $v_i - u_i$ constitutes the composite error term, made up of a random error component that is taken to be independently and identically distributed (*iid*) as $N(0,\square_v^2)$, and independent of u_i, which is a non-negative random component that is attributed to technical inefficiency, (Battesse & Coelli, 1995). The technical inefficiency component is defined by equation (2) as:

$$u_i \square Z'_i \square \square w_i \quad (2)$$

The vector z_i contains explanatory variables to technical inefficiency; □ contain the unknown parameters to

be estimated and w_i represents random errors which are assumed to be independently and normally distributed with zero mean and constant variance. An individual farmer's technical efficiency (TE) is specified in terms (Y*), given on condition of the level of inputs the farmer used. The mathematical expression of TE is:

$$TE \square Y_i / Y_i^* \square f(X_i;\square)\exp(v_i \square u_i) \quad (3)$$

$$TE \square \exp(u_i) \quad (4)$$

Farmers with a value of one are operating on the production frontier and are assumed to be fully technically efficient whilst those farmers with values lying below one and zero are regarded as being technically inefficient. The Maximum likelihood estimation technique estimates the production frontier function which produces estimators for β and γ, where $\gamma = \sigma^2_u / \sigma^2$ and $\sigma^2 = \sigma^2_u + \sigma^2_v$. The total variation of observed output from the frontier output caused by technical inefficiency is represented by the parameter γ which ranges between zero and one; $0<\gamma<1$.

2.2 Related Studies

In vegetable production in general, low and considerable variations in famers' technical efficiency levels, ranging from under 5% to 100%, have been reported in the literature. For instance Amoah *et al.* (2014) estimated average technical efficiency score of 24% with minimum and maximum scores of 2% and 85% respectively in their study of vegetable farming in Kumasi peri-urban area of Ghana. Using the stochastic production frontier model, their predicted efficiencies differed substantially between female and male headed farms, recording mean technical efficiencies of 16.5 and 30.8 % with ranges between 2 and 66%, and 2 and 85% respectively for female and male farmers. Accessibility to credit, levels of fertilizer application, farm size, labour among others explained levels of inefficiency in their study. Julie *et al*. (2017) also used the stochastic frontier analysis to study technical efficiency of vegetable farmers in Cameroon and recorded mean TE score of 86.7%. The main sources of inefficiency in that study were farm size, education, credit and membership to a mutual aid group, while age, sex and access to extension information and services were found to enhance technical efficiency.

In their analysis of resource use efficiency in carrot production and its policy implications in the Punjab, Pakistan, Abedullah *et al*. (2009) estimated average TE score of 46 and explained variations in inefficiencies mainly by education, farming experience and access to input-output markets. They concluded that investment in education and improvement in infrastructure was critical for improving TE. From agronomic efficiency perspective, Favacho *et al*. (2017) and Appiah *et al*. (2017) studied productive and economic efficiency of carrot yield response to green manure and different spatial arrangements in Brazil and Ghana respectively in experimental design setting. In the Brazilian study it was concluded that the use of *Calotropis procera (flor-de-seda)* as green manure is economically viable for the farmer when intercrop carrot with cowpea-vegetable. The study in Ghana concluded that from production as well as economic points of view a combination 10t/ha *Mucuna pruriens* at 25 x 10cm spacing was suggested for maximizing carrot production in the study area. Applying stochastic frontier approach Rajendran *et al*. (2015) assessed technical efficiency of fruit and vegetable producers in Tamil Nadu, India and estimated TE score of 60%. Similar to related studies, factors such as accessibility to irrigation facilities, infrastructure facilities (e.g., road), level of education and access to credit had positive relationship with TE. The review of empirical studies indicated that socio-economic and input factors that have been used in explaining technical efficiency and technical inefficiency levels appear to have mixed influences especially regarding direction of effect.

3.0 Materials And Methods

3.1 Empirical Model of Carrot Farmers

In analyzing the technical efficiency of carrot farmers in the Mampong Municipality, we used the stochastic frontier model with Cobb-Douglas production function (Coelli, 1995). In spite of its limited factors, the Cobb Douglas production function is able to give enough representation of the technology of a given production system (Binam *et al*. 2005). The model is also effective in handling the problems of heteroscedasticity, multicollinearity and autocorrelation especially when modelling multiple inputs. The Cobb-Douglas production function for this study is specified as:

$$ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + e_i, \quad (5)$$

$$e_i = v_i - u_i \quad (6)$$

Where; Y_i is the output of carrot (kilograms) produced in one production cycle by the i^{th} farmer; β_0 denotes the intercept or the constant for the linear regression function; $\beta_1 \ldots \beta_5$ represent the unknown parameters to be estimated; X_1 is hired labour (man-days); X_2 is seed (grams); X_3 is fertilizer (kilograms); X_4 is herbicide (litres); x_5 pesticide (litres) and x_6 is petrol in litres, v_i denotes random shocks; u_i is the one-sided non-negative error representing inefficiency in production. The model for the inefficiency component as specified by Battesse and Coelli (1995) is given as;

$$U_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i} + \delta_7 Z_{7i} \quad (7)$$

Where: U_i is the technical inefficiency of the i[th] farmer; Z_{1i} is the age of respondents in years (AGE); Z_{2i} is the formal education of respondent in years (EDU); Z_{3i} is the farmer experience in years (FME); Z_{4i} is the household size (HHS); Z_{5i} is the farm size in acres (FSA); Z_{6i} is the household labour (man-days) (HLB); Z_{7i} represents credit access (CRD), treated as dummy variable.

3.2 Study Area and Data Collection

The study was conducted in Asante Mampong Municipality of Ghana which is one of the 27 administrative districts of the Ashanti region. Asante Mampong (7° 4N, 10° 22W) lies about 457.5m above sea level and lies in the transitional agro- ecological zone with the forest of the south and Guinea savannah to the north (Meteorological Station, Mampong, 2003). Several communities practice irrigation along the streams that run through the municipality. Based on the intensity of their carrot production, three communities were purposively selected in a multistage sampling to draw farmers for the study. A list of carrot farmers was obtained from MoFA and used as a sampling frame to randomly select 100 farmers for the study. Data were collected through personal interview using well- designed open and close ended questionnaires. The questionnaire covered socioeconomic, inputs and output variables. As specified in the model, age, farming experience, and education of the farmer were measured in years. Household size was measured as the number of people in a household (both adults and children) who provided labour in carrot production. Farmers' farm size was recorded in acres of land used for cultivating carrots. Family labour was measured in man-days as household members who provided free labour to the farmer. Output was recorded in kilograms of total yield harvested within the production cycle. Hired labour measured in man-days for paid labour during production. Seed was measured as quantity of seed in grams used for planting, total fertilizer in kilograms applied to carrot, herbicide referred to the quantity in litres of herbicide used in weed control, pesticide was measured as quantity of all types of pesticide used during production in litres and finally litres of petrol was used as a proxy for quantity of water pumped to irrigate the carrot farm throughout production season.

4.0 Results And Discussion

4.1 Descriptive Statistics of Major Variables of the Study

The descriptive statistics of the variables used in the study are presented in table 1. The results indicate that the mean age of the farmers was 35 years with the youngest and oldest being 20 and 47 years respectively. This means that most of the farmers are in their mid-ages and among the active working class. Similar results were reported in Ayerh (2015). The average years of education was 7.72 (table 1) which is approximately 8 years indicating that an average farmer have schooled up to Junior High School (JHS). This is however lower than the high percentage of farmers in the range of 12 – 17 years of education reported in the study of Ayerh (2015). The farmers have been in the carrot business for quite some time, with the mean of 7.91 years. An average household size of 2 members was recorded. Farm sizes ranged between 0.5 and 6 acres with an average farm size of 1.99 acres. Household labour recorded an average of 110 man-days. The mean carrot yield, hired/paid labour, weight of seed used by farmers and the mean inorganic fertilizer used in the study area were 135.35kg, 232.62 man-days, 22kg and 303.10kg respectively. Herbicide usage was not intensive as the mean litres of herbicide used was only 2. The average pesticide used was 3.79 litres and petrol which was a proxy for quantity of water recorded a mean value of 18.64 litres.

Table 1: Descriptive statistics of variables used in the study

Variables	Minimum	Maximum	Mean	Std. Deviation
Farmers Age	20.00	47.00	35.06	6.156
Farmers Education	0.00	16.00	7.72	3.769
Experience	1.00	20.00	7.91	4.200
Household Size	1.00	12.00	2.27	1.503
Farm Size	0.50	6.00	1.99	1.011
Household Labour	21.00	624.00	110.38	76.721
Credit access-Yes	-	-	66	-
Carrot output	40.00	270.00	135.35	45.287
Hired Labour	38.00	472.00	232.62	80.551
Carrot Seed	2.00	22.00	6.19	2.970
Fertilizer	40.00	600.00	303.10	126.377
Herbicide	0.00	12.00	2.31	3.351
Pesticide	0.00	15.00	3.79	2.253
Petrol	7.00	28.00	18.64	5.492

Source: Authors' computation, 2018

4.2 Estimates from the Stochastic Production Function

As shown in table 2, the maximum likelihood estimation indicates that inputs such as labour in man-days and petrol in litres have significant elasticity values. Labour was significant and positive at 1% significant level. The coefficient of labour, 0.549, indicates that a percentage increase in labour usage would result in about 0.55% increase in carrot yield and this supports the results reported by Etwire *et al*. (2013). Petrol was also significant at 5% level and positively influenced carrot output in that a percentage change in petrol for irrigation will result in 0. 89% increase in carrot output. Similar results were reported in Rahman *et al*. (2012) who found positive relationship between farmers' level of irrigation facilities usage (petrol /irrigation cost) and farm output. The computed variance (δ^2=0.6858) was statistically significant at 5% level of probability and implies a good fit of the model and the appropriateness of the distributional assumption specified for the composite error term. The significant gamma value of 0.6384 indicates that variations in observed carrot yields were not due solely to errors or factors beyond the control of farmers but about 63% is attributable to technical inefficiencies.

Table4.11: Estimates from the production frontier function

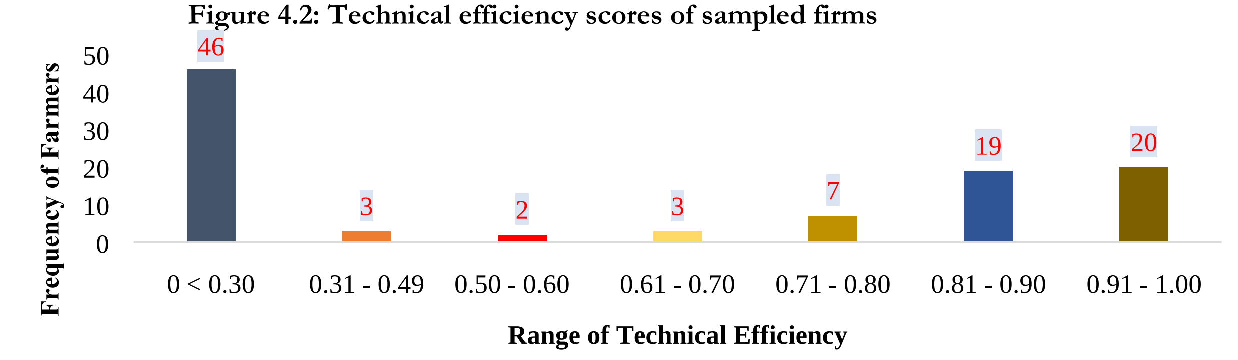
Variables	Coefficient	Standard-Error	t-ratio
Constant	0.296444	0.143320**	2.068401
No. Labour	0.549125	0.172810***	3.177625
Seed Quantity	-0.259082	0.119638	- 2.165540
Fertilizer	0.716067	0.883283	0.810690
Herbicide	-0.667223	0.884518	- 0.754335
Pesticide	0.623938	0.112195	5.561217
Petrol	0.894780	0.415253**	2.154780
Sigma-squared	0.685879	0.335709**	2.043075
Gamma	0.638428	6.91E-02***	9.239190

*Significant Codes '***' 0.001 '**'0.05 '*'0.01* **(source: Authors Computation, 2018)**

4.3 Technical Efficiency Scores

The mean technical efficiency level of the carrot farmers is about 76.5% and this is lower than Julie *et al.* (2017) who also used the stochastic frontier analysis to study technical efficiency of vegetable farmers in Cameroon and recorded mean TE score of 86.7%. However this is far above those of Abedullah *et al.* (2009) and Amoah *et al.* (2014) who estimated average technical efficiency scores of 46 and 24% respectively. Technical efficiency level of 76% shows that carrot farmers could bridge the gap between their observed output and the frontier output by increasing output with same inputs level to about 24%. The technical efficiency scores as displayed by Figure 1. indicate that majority of the farmers representing 51 percent had technical efficiency scores between 0.50 and 1.0 while less than half (49%) of the farmers had a TE score of less than 0.49. This, like previous studies in vegetable production (Abedullah *et al.*, 2009; Amoah *et al.*, 2014; Julie *et al.*, 2017;) shows that a wide variation in output exists among producers of carrot in the study area.

Figure 4.2: Technical efficiency scores of sampled firms



(**Source: Field data, 2018**)

4.4. Factors Affecting Technical Inefficiency

In the technical inefficiency model, a negative coefficient value indicates negative correlation with technical inefficiency but implying positive association with technical efficiency and the vice versa. Estimates from the technical inefficiency model are presented in table 4, where coefficients of age, household size, education and access to credit are positive while those of farming experience, farm size and labour have negative signs.

Farmers' ages, educational levels and accessibility to credit appeared significant at 1%, 1% and 5% levels of significance respectively. Thus, increases in these imply increases in inefficiency. Land size and labour on the other hand were all significant at 5% levels of significance and negatively influenced inefficiency. That is, increasing land size and labour man-days reduce farmers' inefficiencies and intend promote efficient resource use for optimum output. These results compare and contrast with those in the TE literature. The results indicate that as age of farmer increases, technical inefficiency also increases. This implies that younger farmers are more technically efficient than older farmers. This can be explained by the fact that younger farmers are more likely to swiftly adopt new knowledge and skills as well as having physical capabilities demanded by carrots production activities. The finding contradicts the study of Julie *et al.* (2017), Asefa (2011), and Kane *et al.* (2012) but confirms to those of Amoah *et al.* (2014), Ahiale *et al.* (2019) and Yenihebit *et al.* (2019). Unexpectedly accessibility to credit appeared positive and highly significant, implying that farmers who had accessed credit were less technically efficient than their counterparts who did not receive credit. This finding is similar to Julie *et al.* (2017) but contradicts Amoah *et al.* (2014). A possible explanation to this finding could be that farmers who received credits misappropriated them and used the money on other ventures. Again, in the model, education is found to have a positive and significant relationship with technical inefficiency, indicating that less educated farmers are technically less inefficient than the more educated farmers. In Julie *et al.* (2017), who obtained similar results suspected that most educated farmers are usually, involved in part time vegetable farming as they are more likely to have permanent jobs hence, high opportunity cost of time on vegetable farms. This finding contradicts many studies in TE, including Amoah *et al.* (2014) and Abedullah *et al.* (2009). Farm size and labour in man-days showed negative and significant relationship with technical inefficiency. The former contradicts Julie *et al.* (2017), but supports many others (Abudellah *et al.* 2009; Haji, 2006; Haider *et al.,* 2011). Studies of Amoah *et al.* (2014) and Chinwuba *et al.* (2006) had similar results as those obtained for labour, which indicates that inefficiency reduces as man-day of labour increases.

Table 3. Maximum likelihood estimates of factors affecting technical inefficiency

Variables	Co efficient	Std Err	t- stats
_CONS	3.191716	2.342757	1.36
AGE	0.108760***	0.070914	3.53
EDUCATION	0.010912***	0.087977	2.82
EXPERIENCE	-0.138259	0.094526	-1.46
HOUSEH SIZE	0.152988	0.310126	0.49
LAND SIZE	-0.751901**	0.346391	-2.17
LABOUR	-0.785601**	0.264172	-2.97

CREDITACESS	1.264004**	0.607654	2.08

*Significant Codes '***' 0.001 '**'0.05 '*'0.01* **(source: Authors Computation, 2018)**

5.0 Conclusion

This study employed the stochastic frontier model to examine the technical efficiencies of carrot production in Ashanti Mampong Municipality using cross-sectional data of the last cropping season in 2017. The outcome shows that carrot farmers were producing below the production frontier. There was a deviation of 23.5% of carrot output from the frontier since the estimated average technical efficiency score was 76.5%. Labour and petrol for irrigation, were statistically significant and had positive effect on carrot output in the study area. Age, education, farm size, labour and access to credit were the determinants that influenced technical inefficiency in carrot production. There was a negative relationship between technical inefficiency and farm size and household labour; whilst age, education and access to credit influenced technical inefficiency positively. It is recommendable for policies to consider how irrigation facilities could be improved and be made more affordable for vegetable farmers so that they can apply more water to their crops for efficient production. Further assessment of how credits obtained are used is recommended.

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