TECHNICAL AND RESOURCE USE EFFICIENCY OF URBAN VEGETABLE FARMING IN THE KUMASI METROPOLIS: A STOCHASTIC FRONTIER APPROACH

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ABSTRACT

The changing food demands by the teeming urban population, job search, and sector profitability have made vegetable production indispensable as it contributes to increased incomes and livelihoods of urban dwellers. This study investigated the current level of productive efficiency (technical and allocative) of vegetable farmers in the Kumasi Metropolis using cross-sectional data obtained from 135 sampled farmers using a semi-structured questionnaire. Data analysis was conducted using the stochastic frontier approach to estimate firm-specific technical efficiencies and the factors that influence efficiency levels. The results show that inefficiency exists among the sampled vegetable farmers as they currently achieve an average technical efficiency score of 66.7%. Allocative efficiency estimates for land and labour revealed that both factors of production are over utilised by farmers. The age of the farmer is the main socio-economic determinant of technical efficiency. The study recommends that farmers be educated on the correct use of inputs by extension agents. The government policy of recruiting community extension agents under the 'planting for food and jobs' programme is in line with addressing inefficiency in the production sector and should be promoted.

Contribution/ Originality

The study provides empirical evidence of the existence of inefficiency in urban vegetable production systems in the Kumasi Metropolis of Ghana using robust estimations. The study revealed that technical inefficiency is linked to over utilisation of inputs by farmers. Enhancing urban vegetable production to meet the increasing demand for food, therefore, requires the support and collaboration of all stakeholders (vegetable farmers, researchers, input dealers, and policy makers) at the Municipal and national levels.

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1. INTRODUCTION

Vegetables play an important role in the household economy and occupy a unique position in both domestic and foreign food trade of Ghana. Besides being an integral part of balanced diets that supply minerals and vitamins for healthy growth, economically they create employment for the teeming youth along the crop value chain. Vegetable production is more profitable than cereal production (Adewumi *et al.*, 2005; Weinberger and Lumpkin, 2007) and irrigated vegetable production systems are more profitable than rain-fed vegetable systems (Dittoh, 1992; Ursu, 2014). The agribusiness potential for actors in the vegetable crop value chain exists (Dittoh *et al.,* 2013) and yet research to assess production and resource use efficiency in the sector has remained limited. Furthermore, actors within the vegetable value chain face multiple constraints: limited access to water resources, lack of capital/financing to purchase inputs, high storage losses,lack of proper market infrastructure, poor transportation and effects of climate change (Mashnik *et al.,* 2017; Ekobi and Mboh, 2018).

Empirical studies that focused on analysing vegetable production efficiency largely point to the existence of inefficiency with various determinants (Haji and Andersson, 2008; Shettima *et al.,* 2015). In estimating the technical, allocative and economic efficiency of 300 vegetable farmer in Ethiopia, Haji and Andersson (2008) reported substantial inefficiencies in production with efficiency differentials among farmers. The main socio-economic factors influencing production inefficiency as revealed by the study were illiteracy, large family size, non-farm income, asset ownership, high consumer spending, and small farm size. Singbo (2012) reported that inefficiency in marketing poses a greater challenge to urban vegetable farmers in Benin and that the type of market arrangements has an effect on marketing efficiency. In the Bono state of Nigeria, Shettima *et al.* (2015) found technical inefficiency among irrigated vegetable farmers engaged in various crop enterprises (sole onion, sole tomato, sole pepper, onion-tomato, and onion-pepper).Farm size, agrochemical use, cost of improved seeds, and family labour were reported as the main determinants of technical efficiency. More recently, Ullah *et al.,* (2017) assessed the technical efficiency of 120 broiler farms and reported a mean technical efficiency of 0.85 with minimum and maximum values of 0.61 and 0.99 respectively.

Few known studies have examined input use efficiency in irrigated vegetable production. The general decline in agricultural productivity growth in developing countries has been linked to both under-utilisation and over-utilisation of resources in production (Khan *et al.,* 2014). Fernandez-Cornejo (1994) analysed input use efficiency in vegetable production in Florida using the slack-based model. The findings revealed the over-utilisation of pesticides by farmers with an effect on technical efficiency. This means that inefficiency exists in pesticides use among farmers with likely impact on farm profitability. Singbo (2012) analysed the efficiency of pesticides use and other inputs using boot strapping to compare various irrigated farming systems in Benin. The study found that vegetable farms within lowland farming systems were diverse and inefficient. The mean input use efficiency in the integrated rice-vegetable farming system was significantly higher than of sole vegetable farming system. While there was clear evidence of pesticides overuse, interdependence between pesticides and other productive inputs could not be established technically.

Similarly, Ursu (2014) found that reductions in labour increase with the economic size of holding and decreases as the number of man-hours to incomes increases. This shows that labour is a critical factor in the production process as it impacts on profitability level of farm enterprises. Dlamini and Kongolo (2014) analysed the efficient use of resources in organic vegetable production to show that the use of inputs has decreasing returns to scale. The study revealed that land, labour, organic manure, seeds, soil preparation, age, educational level, and legal status of the farm are significant factors that affect organic vegetable production. Sanusi *et al.* (2016) reported that farmers using stream water has the highest effect (21%) on technical efficiency in vegetable

production than users of other sources of water (wells, boreholes). Seed and fertilizers were found to be important inputs in the efficient production of vegetables. Furthermore, Akamin *et al.* (2017) analysed the technical efficiency of vegetable farming in eight selected sites in Cameroon and found farmyard manure to be the most productive input followed by farm equipment and labour. The mean technical efficiency reported was 67%, revealing production shortfalls. Females and more educated farmers were found to be more technically efficient but the efficiency level of farmers' decreases as farm sizes became larger.

Urban agriculture is said to contribute significantly to urban food security, poverty alleviation, women empowerment, job creation, and improved nutrition. Understanding the level of production efficiency in vegetable production is crucial in influencing resource allocation decisions and in determining the returns on investment. This study contributes to the efficiency literature by examining the current level of production efficiency of urban vegetable farmers and their resource use efficiency in the Kumasi Metropolis of Ghana. The findings have policy implications for the numerous urban cities where urban agriculture (especially vegetable production) is seen as a livelihood strategy.

The study tested two main null hypotheses: (i) All the vegetable production units considered are technically efficient and there is no room for efficiency growth; and (ii) there is no significant relationship between the socio-economic characteristics of urban vegetable farmers and their resource use efficiency.

2. METHODOLOGY

2.1. Study area and data
The study was conducted in Kumasi Metropolis (the second largest and populous city in Ghana after Accra) in March 2015. The Metropolis is one out of the 30 districts that constitute the Ashanti Region and was purposively selected based on its high potential for vegetable crop production and high concentration of urban vegetable farmers. The Metropolis is located in the transition forest zone (Latitude 6.35°N & 6.40°S and Longitude 1.30°W &1.35°E) with an elevation of 250-300 metres above sea level. With an estimated population of 1,730,249 (36.2% of the total population of the Ashanti Region), only 8.5% of households are directly engaged in agriculture (Population and Housing Census, 2010). Increasing urbanisation, changing dietary patterns and immigration has made urban vegetable farming a key feature of the municipality.

Nine vegetable production sites as identified by the International Water Management Institute (IWMI) survey (2005) was used for the study (see Figure 1). Lists of vegetable farmers operating in all the sites were obtained from group executives and a simple random sampling done to select 15 farmers from each production site to constitute a study sample of 135 farmers. The data collection was done using a semi-structured questionnaire and this was complemented with focus group discussions. The data collected covers the production, marketing, socio-economic and demographic characteristics of farmers.
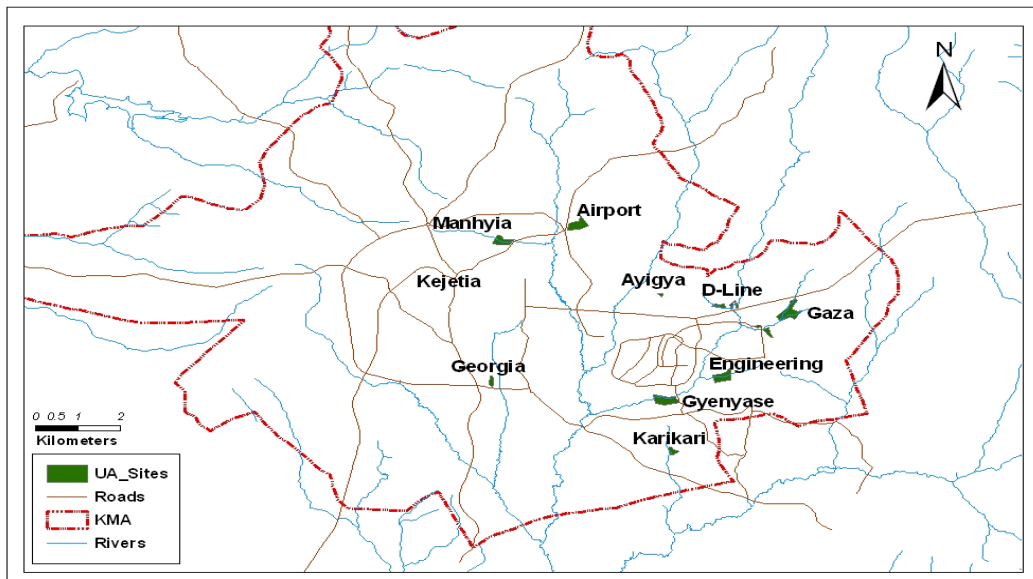
Figure 1: Map of vegetable production sites in Kumasi metropolis

2.2. Analytical framework and empirical specification

This study used the Cobb-Douglas stochastic frontier production function to represent the production technology of vegetable farmers in the Metropolis. This functional form is still very relevant due to the logarithmic nature which makes an econometric estimation of the parameters easy (Murthy, 2002) and recent studies on efficiency favoured its use (Dlamini and Kongolo, 2014; Abdulai and Tewari, 2016; Ullah *et al.,* 2017). However, limitations associated with its use such as the assumptions of unitary elasticity of substitution and constant returns to scale and input elasticity remain (Yin, 2000).The translog functional form which is widely used as an alternative to the Cobb-Douglas in the literature is also without limitations. It is susceptible to multicollinearity and degrees of freedom problems and this renders estimated parameters inaccurate. Kopp and Smith (1980) reported that functional specification has only a small impact on measured efficiency. The use of a Cobb-Douglas functional form is said to be justified in industries characterised by imperfect producers (Coelli and Perelman, 1999). Considering the fact that the vegetable production industry in Kumasi is not perfectly competitive, we applied the Cobb-Douglas functional form in the current study.

The model utilised in this study follows the stochastic frontier analysis (SFA) approach proposed independently by Aigner *et al.* (1977) and Meeusen and van den Broeck (1977) which is defined as:

$$InY_i = In\ f(X_i\ ,\beta) + \ v_i - u_i\ ; i = 1, \dots. N \qquad \qquad \text{......................... (1)}$$

where v_i is the systematic noise assocated with the random factors, and u_i is the one-sided error term that captures technical inefficiency relative to the stochastic frontier. The random errors (v_i and u_i) are assumed to be independently and identically distributed (iid) over each other as random variables. The distributional assumption of u_i followed in this study is the half normal which provides a more useful formulation (Battese and Coelli, 1988) compared to the exponential, truncated normal or the gamma density distribution. Most efficiency studies have relied on either the half-normal or exponential specifications due to ease in interpretation compared to the gamma model parameterisation. There is no established rule or criterion that inform the choice of these specifications, hence, the decision rests with the researchers concerned.

The technical efficiency (TE) of an individual firm is defined as the ratio of the observed output (y) in relation to the frontier output (y*), based on the level of inputs used by the firm in production. The TE of an individual firm is determined empirically as:

$$TE = \ln y_i / ln y^* = (f\ (x_i; \beta)\exp(v_i - u_i)/f(x_i\ ;\beta)\exp(v_i) = \exp(-u_i) \qquad .... (2)$$

such that, $0 \leq TE \leq 1$.

The technical inefficiency effect u_i is unobservable and hence the best predictor is the conditional expectation as proposed by Jondrow *et al.* (1982) as follows:

$$E\left[\frac{u_i}{\varepsilon_i}\right] = \sigma\lambda\frac{[\emptyset(z)-Z]}{1} + \lambda^2\ 1 - \emptyset(z) \qquad .... (3)$$

Where $z = \frac{\varepsilon_i}{\sigma}\lambda$, and ϕ is read from the normal distribution Table. The operational predictor of u_i involves replacing the unknown parameters with the maximum likelihood estimates. Jondrow *et al*. (1982) suggested that the technical efficiency of the ith firm should be predicted using E $[u_i/\varepsilon_i]$. The rationale for this prediction is that $1 - u_i$ is a first order approximation to the equation:

$$Exp\ (u_i) = 1 - u_i + \frac{u_i{}^2}{2} - u_i{}^3/6 + \cdots \qquad .... (4)$$

If u = 0, it means that vegetable production lies on the stochastic frontier and the production unit is technically efficient. If u > 0, it implies vegetable production lies below the frontier and is inefficient. Inefficiency in production could result from the quality and availability of inputs (labour, land, capital, and materials) used in production.

The one-step approach to maximum likelihood estimation was employed in estimating the technical efficiency scores as implemented by previous studies (Battese and Coelli, 1993; Abdulai and Tewari, 2016). The empirical model used is specified as:

$$In\ Y = \beta_0 + \beta_1 InLAD + \beta_2 InLAB + \beta_3 InCAP + \beta_4 InMAT + \beta_5 InPET + \beta_6 InMAF + \varepsilon_i \ .... (5)$$

where,
Y = Output in kilograms
LAD (Land) = Area put under cultivation (ha)
LAB (Labour) = Number of man-days spent on the field (family and hired labour).
CAP (Capital) = Depreciated value of capital equipment in Ghana Cedis (GH¢).
MAT (Materials) = Value of other inputs (fertilizers, manure, seeds, and pesticides) in GH¢
PET (Pesticides) = Volume of pesticides applied in litres
MAF = Quantity of manure and fertilizer used (kg)
ε_i = Composed error term given as $\varepsilon_i = v_i - u_i$
βs = Unknown parameters to be estimated.

All variables were taken in logs for ease of estimation and interpretation of the results. The inefficiency effects model estimated is assumed to be a function of socio-economic and institutional factors (Haji and Andersson, 2008; Ullah *et al.,* 2017) and it is presented as:

$$\mu_{it} = \delta_0 + \delta_1 D_{1it} + \delta_2 D_{2it} + \delta_3 D_{3it} + \delta_4 D_{4it} + \delta_5 D_{5it} + \varepsilon_{it} \qquad .... (6)$$

where μ_{it} is the mean technical inefficiency; D_1, D_2, D_3, D_4, and D_5 represents the age of farmer, level of education, farming experience, access to credit (for inputs and other production requirements), and access to off-farm income respectively. These variables ware selected based on

literature and are assumed to influence the technical efficiency of the farmers. δ_0 to δ_5 are coefficients of the parameters estimated. Both equations (5) and (6) were simultaneously estimated in a one-step approach using LIMDEP version 10 econometric software.

We used the factor elasticities for labour and land obtained from equation (5) to compute the input use efficiency. The allocative efficiency rule is that the marginal physical product should equal the inverse ratio of input price to output price at the point of profit maximisation (Ellis, 1988).The Marginal Product (MP) of the ith factor and the allocative efficiency index (z) was determined as:

$$m = MP_i = \frac{\mu Y_i}{\mu X_i} * E_i \qquad\qquad .... (7)$$

$$z = MP_i = \frac{P_y}{P_x} \qquad\qquad .... (8)$$

where MP_i is the marginal product of the factor (land, labour), μY_i and μX_i are the arithmetic means of the output and inputs used respectively, and P_y and P_x are the price of output and input respectively. The decision criteria are that: z =1, implies efficient utilisation of the input; z > 1, implies an under-utilisation of the factor input; and z < 1, implies an over utilisation of the factor input.

3. RESULTS AND DISCUSSIONS

Table 1 present the results of the OLS estimates from the Cobb-Douglas frontier production function with most variables being statistically significant. The goodness of fit (R^2) for the estimated regression equation is low, suggesting that outliers exist and that some of the variables included do not statistically influence the model output. The low R^2 is not relevant in this study since the focus of analysis is on efficiency. The overall predictive power of the estimated function is what is of great importance in efficiency analysis and the F-statistic is shown to be significant at 1% level. This means that the estimated coefficients can be relied upon.

Table 1: OLS estimates of vegetable production in Kumasi metropolis

Variable	Parameters	Coefficient	Standard Error	t-Value
Constant	B_1	4.1947	0.4472	9.379**
ln (Land)	B_2	0.1373	0.6373	2.155*
ln (Labour)	B_3	0.3615	0.3400	0.915
ln (Capital)	B_4	0.3395	0.2787	4.998
ln (Materials)	B_5	0.3395	0.4537	4.239**
ln (Pesticides)	B_6	0.1109	0.3348	3.316**
In (Manure/fertilizer)	B_7	0.1916	0.3374	0.568
F-Statistic		11.33***		
R-Squared		0.2586		

Note: ***, **, * means significant at 1%, 5% and 10% levels respectively

The coefficient of land is positive and significant at 10% level. This means that access to land and the area put under cultivation has an effect on the vegetable output produced. The coefficients for materials and pesticides are both positive and significant at 5% level. The amount of money invested in purchasing seeds, fertilizers, pesticides, and other inputs and the quality of these inputs thus influence the output obtained by farmers.

Estimates of the firm-specific technical efficiencies using the maximum likelihood procedure for the pooled sample are presented in Table 2. The relative magnitude of the inefficiency in production and the variance associated with the frontier model is depicted by the variance ratio

(γ).The value of the variance ratio (γ) revealed that about 78.5% of the variation in vegetable output is due to technical efficiency differences among the production units considered while 21.5% is due to random factors which are beyond the control of farmers. These random factors may be due to the effects of pest and disease, unfavourable weather conditions, and errors in data aggregation by researchers.

Table 2: Maximum likelihood estimates of the Cobb-Douglas production frontier function

Variable	Parameters	Coefficient	Standard Error	t-Value
Constant	B_1	4.6540	0.3374	13.793**
ln (Land)	B_2	0.1068	0.4740	2.254*
ln (Labour)	B_3	0.1678	0.3205	0.052
ln (Capital)	B_4	0.3452	0.2992	1.154
ln (Materials)	B_5	0.1586	0.3875	4.092**
ln (Pesticides)	B_6	0.1119	0.3687	3.035**
In (Manure/Fertilizer)	B_7	0.3578	0.3254	1.099
Variance-ratio	γ	0.7851		
Total variance	σ^2	0.1218		
Sigma-squared	σ^2_u	0.0956		
Log-likelihood Function		-0.4204		

Note: ***, **, * means significant at 1%, 5% and 10% respectively

3.1. Results of hypothesis tests

The first null hypothesis stipulates that the sampled vegetable farmers are technically efficient and have no room for efficiency growth. Thus, {H_o: There is no difference in technical efficiency among the sampled vegetable farmers ($\gamma = 0$)}. However, $\gamma = 0$ lies on the boundary of the parameter space and is difficult to test. If $\gamma = 0$ is true, then the generalised likelihood ratio statistic (λ) will have a mixture of chi-square distribution (Coelli, 1995). The decision rule for one-sided generalised likelihood ratio test of size (α) is that reject the null hypothesis (H_o) in favour of the alternative hypothesis (H_1: $\gamma > 0$) if γ exceeds $\chi^2 2(\alpha)$. From the test results presented below, the value for the test at 5% is 2.706 (using Table 1 of Kodde and Palm, 1986).

	Log Likelihood function				
	Frontier Function	Average Function	λ	Critical value	Decision
Vegetable	-0.4205	-23.0540	45.2671	2.706	Reject Null Hypothesis

We, therefore, reject the null hypothesis that there is no room for technical efficiency growth and conclude that inefficiency exists among the production units considered in the study. The second null hypothesis {(H_o: there is no significant difference in technical efficiency between the sampled farmers} was tested using the Analysis of Variance (ANOVA) technique. From the test results (see Table 3), F calculated is less than the F critical, so we fail to reject the null hypothesis. This means that there is no significant difference in technical efficiency estimates between production units at 5% level of significance. The absence of variation in technical efficiency among production units in the statistical sense implies that any observed differences are probably due to chance or measurement errors.

Table 3: Hypothesis testing using Analysis of Variance (ANOVA)

Source	df	SS	MS	F	F-critical
Regression	1	0.4533	0.4533	0.9429	3.6800
Error	134	64.4165	0.4807		
Total	135	64.4440			

3.2. Distribution of technical efficiency scores

The farmer-specific technical efficiency estimates showed a great variation in efficiency levels among the production units considered in the study. It is appropriate to question why some producers can achieve relatively high-efficiency levels whilst others are technically less efficient. The variation is probably due to differences in managerial decisions and farm characteristics that may affect the ability of farmers to adequately utilise the existing technology.

Table 4: Distribution of technical efficiency scores

Technical efficiency (%)	Frequency	Percentage (%)	Cumulative (%)
Less than 30	7	5.18	5.18
30 – 40	8	5.92	11.11
41 – 50	7	5.18	16.29
51 – 60	12	8.88	25.18
61 – 70	15	11.11	36.29
71 – 80	67	49.62	85.92
81 – 90	17	12.59	98.51
91 – 100	2	1.48	100
Total	135	100	

Distribution of the efficiency scores revealed that about 50% of farmers operate within the efficiency range of 71-80% while 13% were operating between 81 to 90%. Only a few farmers (1.5%) were operating within the efficiency range of 91-100%. This is reflected in the cumulative percentage as a greater number of farmers (36%) operated below 70% efficiency level.

The study shows that technical efficiency levels achieved by vegetable farmers in the Metropolis range from a minimum of 22% to the highest of 95%. The minimum efficiency score of 22% means that such production units are far below the efficient frontier by 78% and are technically inefficient. The highest level of technical efficiency (95%) suggests that such production units are only 5% away from the frontier. Considering the fact that in reality production units hardly operate at 100% level of efficiency, the performance of such units can be said to be good. The mean technical efficiency of the pooled sample is 66.7%, meaning that on the average, 33.3% more output could be produced using the same level of inputs if farmers were producing on the frontier following best practices. Inefficiency, therefore, exists in the urban vegetable farming system. This outcome compares favourably with findings from previous studies on vegetable production efficiency (Ullah *et al*., 2017; Akamin *et al*., 2017) which reported mean values of 85% and 67% respectively.

3.3. Allocative efficiency estimates

The OLS estimated results alongside the mean values of the variables included in the model were used to establish the allocative efficiency level of factor inputs. The Marginal Value Product (MVP), as well as the Marginal Factor Costs (MFC) obtained for land and labour, were used to compute the allocative efficiency index (R) as presented in Table 5.

Table 5: Allocative efficiency estimates for land and labour

Variable	MVP	MFC	R= MVP/MFC
Land	30,378	63,725	0.4767
Labour	3,645	8,000	0.4556

The allocative efficiency ratios for land and labour are less than one, suggesting over-utilisation (inefficient use) of these inputs by farmers (Table 5). This means that the two factors of production are paid much more than their MVP in the vegetable production process. Nearly all farm operations are done manually by farmers under intensive cultivation and the effects of urbanisation

and scarcity of water resources often restrict farmers. Thus, shifting cultivation can no longer be practiced in urban areas leading to over-utilisation of production lands. This finding is in line with previous studies on resource use efficiency (Singbo, 2012; Khan *et al.*, 2014; Ursu, 2014). For instance, Singbo (2012) found evidence of pesticides overuse among lowland vegetable farmers in Benin. Ursu (2014) reported negative effects of labour on farm profitability. The policy implications of this result for farmers can be seen in high production costs and inefficient utilisation of production resources (reduced profits for farmers). As noted by Khan *et al.* (2014) underutilisation and overutilisation of resources are linked to declining productivity in most developing countries with serious implications for sustainable agriculture.

Table 6 present results of the inefficiency effects model. Almost all the variables included in the model showed insignificant effects except age of the farmers. Farmer contact with extension agents was represented with a dummy variable and is insignificant. This may be interpreted as extension agents not seeing vegetable farmers as a top priority considering the fact that cocoa and other cash crops dominate in the region.

Table 6: Determinants of technical efficiency

Variable	Parameter	Coefficient	Standard error	t-value
Constant	α_1	2.3893	0.7988	2.991
Extension Contact	α_2	-0.2990	0.1558	-0.192
Age	α_3	-0.5870	0.2344	-2.504***
Off-farm income	α_4	-0.5870	0.1196	-0.217
Farmer Experience	α_6	0.7911	0.1143	0.692
Access to Credit	α_7	-0.2241	0.2686	*-0.835*

Note: ***, Means significant at 1% level

The age of the farmer was found to be highly significantly related to productive efficiency at the 1% level of significance. The negative coefficient of age means that increasing age could significantly lead to a decrease in technical inefficiency. The majority (76%) of the respondents covered were youthful in nature (18-39 years) and this could account for the low level of technical efficiency in production observed. This suggests that over time, the performance of firms could likely improve as farmers' age in the business and the potential for efficiency gains exists in the vegetable sector. Policies geared towards improving agricultural productivity should, therefore, target the youth. This finding support sprevious evidence by Dlamini and Kongolo (2014) that age influences the ability of farmers to adopt new technology for efficiency gains.

Farmer access to off-farm income had negative coefficient and is statistically insignificant. Farmer experience has a positive coefficient but statistically insignificant while access to credit showed negative insignificant effects on technical inefficiency. This could be explained by the fact that only a small proportion of the respondents had access to these services. For instance, 93% of the respondents do not have access to any form of credit to invest in the vegetable production business and hence technical efficiency levels are low. The implication is that stakeholders need to turn attention to urban produces by providing the needed extension and financial support.

4. CONCLUSIONS AND POLICY IMPLICATIONS

This study applied the stochastic frontier analysis to predict farmer-specific technical efficiencies using a sample of 135 urban vegetable farmers in the Kumasi Metropolis. The results obtained from the one-step maximum likelihood estimation shows that inefficiency exists among the production units considered in the study. The mean technical efficiency revealed in the study is 66.7%, suggesting that about 33% more output could be produced with the same level of inputs if farmers were following best practices. The likelihood ratio test strongly confirms this outcome.

Considering the rising demand for vegetables in urban centres following the emergence of fast food shops, the policy implication is for the Metropolis and decentralised government agencies in charge of Agriculture and urban development to focus special attention to those engaged in the vegetable value chain by providing the needed technical and financial support.

It was found that about 78.5% of the variation in vegetable output is due to technical efficiency differences among the Decision-Making Units (DMUs) while about 21.5% of the variation is caused by random factors (such as unfavourable weather, water scarcity, pest and disease attacks, errors in data aggregation, etc.) which farmers have no control over.

In urban agriculture, land and labour are critical inputs in the production process. The allocative efficiency ratios for land and labour obtained from the study (0.4556 and 0.4651) respectively showed that both factors of production are over-utilised by farmers in the production process, suggesting a sub-optimal combination of inputs. This has an implication on farm profitability as these enterprises are undervalued with potential negative impacts of limiting investments in the sector.

The age of the farmer was found to be the main determinant of technical efficiency and is significantly related to productive efficiency at the 1% level of significance. Efforts by the government to incentivise and attract the youth to take up agriculture as a business for job creation and improved livelihoods are steps in the right direction. The youth should take advantage of the profitable nature of vegetable production which has hitherto been neglected in terms of both research and extension and invest in the sector. This would have long-term impacts on technical efficiency performance of the sector. Farmer education on the appropriate use of inputs through the strengthening of extension service delivery to urban agriculture production sites needs to be pursued by decentralised agencies at the Municipalities. This will help improve their resource allocation decisions and contribute to increased productivity and profitability. In addition, the government should give priority to Metropolises where urban agriculture activities are intense and access to water resources is limited.

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