International Journal of Agriculture Innovations and Research
Volume 2, Issue 4, ISSN (Online) 2319-1473
Manuscript Processing Details (dd/mm/yyyy) :
Received : 18/11/2013 | Accepted on : 03/12/2013 | Published : 20/01/2014

Application of Data Envelopment Analysis in Measurement of Technical Efficiency of Cassava Farmers in Imo State, Nigeria

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Abstract **– This study applied cost approach constant returns to scale and variable returns to scale data envelopment analysis models to measure technical efficiency of 276 cassava farmers in Imo State, Nigeria. Technical efficiency among the cassava farmers varied substantially between 0.214 and 0.925 with a mean technical efficiency of 0.622. Scale efficiency of the cassava farmers vaired substantially between 0.103 and 0.916 with a mean of 0.495. The farmers are not all operating at the optimal scale. Most of the cassava farmers operated very far away from the efficiency frontier. The overall technical inefficiency among the cassava farmers resulted more by scale inefficiency compared to pure technical inefficiency.**

Keywords **– Data Envelopment Analysis, Technical Efficiency, Cassava Farmers, Imo State.**

I. INTRODUCTION

Cassava (Manihot esculenta cruntz) is a staple food crop in many Nigerian households, and it is most relevant in boosting incomes of rural farmers through increased productivity and as a strategy for poverty alleviation (1).

As a food crop, cassava has some inherent characteristics which make it attractive to the rural farmers in Nigeria. Firstly, it is rich in carbohydrates especially starch and consequently has multiplicity of end uses, secondly it is available all the year round, making it preferable to other more seasonal crops such as grains, peas, beans and other crops for food security, and lastly, it tolerates of low soil fertility and more resistant to drought (2). Currently, Nigeria is the largest producer of cassava in Africa with an annual production of about 35 million metric tones of tuberous roots (3).

Cassava tubers are mostly processed into cassava flour, garri, fufu, starch and tapioca. It can also be cooked or eaten, pounded and consumed in its raw form, most especially the sweet variety, thereby making cassava a regular food item in household diets in Nigeria (4).

Presently, cassava has achieved an export status because of the increasing demand for cassava as industrial raw materials abroad. To meet the export demand and domestic demand, Nigeria needs about 150 million metric tones of cassava per annum, hence the Federal Government of Nigeria has come out with a policy for cassava production with a view of setting policies that will stimulate domestic production (2).

The role of increased efficiency and productivity of cassava farmers is a great necessity in order to reverse the low technical efficiency of farmers in Nigeria, since cassava has the potential for bridging food shortage gap, as it has been discovered from research that famine rarely occurs where cassava is widely grown (5).

(6) Showed that Imo State dominate cassava production in South East Nigeria, with an annual output of about six million tones. This output level is low, considering the demand for cassava for household consumption and raw materials for industries, which is an indication that cassava farmers in Imo State are not efficient in their use of production resources, since production is a function of land area and yield.

Efficiency is concerned with relative performance of the processes used in transforming given input into output (7). The measurement of efficiency is important because it is a success indicator and performance measure by which production units are monitored and evaluated. Technical efficiency is the ability of a farmer to produce on the maximum possible frontier. A production process may be technically inefficient, in the sense that it fails to produce maximum output from a given bundle of inputs. Technical inefficiency results in an equi-proportionate over-utilization of inputs (8).

This study uses the cost approach constant returns to scale and variable returns to scale data envelopment analysis models. The cost approach data envelopment analysis model has the advantage of allowing estimation of technical efficiency of individual farmers (9). The use of variable returns to scale specification permits the calculation of technical efficiency devoid of scale efficiency effects (9, 10). The Data Envelopment Analysis (DEA) model offers a flexible approach with a considerable scope for the use of diverse data (real and monetary) (11). Furthermore, DEA is deterministic and permits the choice between the constant return to scale (CRTS) specifications and the variable return to scale (VRTS) specifications depending on whether all decision

International Journal of Agriculture Innovations and Research
Volume 2, Issue 4, ISSN (Online) 2319-1473

making units (DMU) are operating at the optimal scale and otherwise respectively.

Using multi stage data envelopment analysis model, (12) evaluated the US State Police performance, and found that most states are technically efficient, but nearly half are operating at less than optimal scale size. Using a variant of data envelopment analysis, slack based measure (SBM), (13) assessed quality management efficiency, and observed that data envelopment analysis is suitable to measure quality management efficiency and give improvement suggestion to the inefficient quality management.

In Nigeria, several studies have been conducted on the analysis of farm efficiency. For example,(14), using the stochastic frontier production function, analyzed policy issues in technical efficiency of Nigerian small scale farmers. (15) applied stochastic frontier production function for technical efficiency analysis of Nigerian cassava farmers as a guide for food security policy. (10) applied stochastic frontier production function and cost function for technical and allocative efficiency analysis of Nigerian rural farmers and its implication for poverty reduction. Of all these studies, none has focused on the application of DEA for the analysis of farm efficiency. (10) applied DEA to evaluate farm resource management of Nigerian farmers, but this study was not on cassava farmers.

The CRTS assumption is only appropriate when all DMU are operating at an optimal scale. Imperfect competition, constraints or finance, etc may cause a DMU to be not operating at optimal scale. (16) suggested an extension of the CRTS data envelopment analysis model to account for variable returns to scale (VRTS) situations. The use of CRTS specification when not all DMU are operating at the optimal scale will result in measures of technical efficiency (TE) which are confounded by scale efficiency (SE). The use of the VRTS specification will permit the calculation of TE devoid of these SE effects. The focus of this paper therefore, is to apply data envelopment analysis in measurement of technical efficiency of cassava farmers in Imo State, Nigeria. It is hypothesized that, there is no significant difference between the constant return to scale (CRTS) and variable return to scale (VRTS) efficiency scores among the cassava farmers in Imo State, Nigeria. This hypothesis is important because the decision making units are expected to operate at optimal scale, and not to have scale inefficiency.

II. Methodology

This study was conducted in Imo State, which is one of the 36 states of Nigeria located in the Southeastern part of Nigeria. Imo State is located between latitudes 5^0 40^1 and 7^0 05^1 North and longitudes 6^0 35^1 and 8^0 30^1 East (17). According to the (18), the population of the state was put at 3.9 million people. The state is divided into three agricultural zones namely; Owerri , Okigwe and Orlu. It is further divided into 27 Local Government Areas (LGAs) and its Headquarters is Owerri.

The topography is generally undulating with conspicuous soil loss due to gully erosion in many areas (19). The state has high agricultural potential with available arable land for the growth of tropical crops such as cassava, rice, sweet potato, groundnut yam, maize, cocoyam, plantains, bananas and vegetables. Tree crops produced include citrus, mango, oil palm, guava, cashew, cocoa and pear.

The multistage simple random sampling technique was used to select the farmers for the study from the three agricultural zones of the state. Owerri agricultural zone is made up of 10 LGAs, while Orlu and Okigwe agricultural zones are made up of 11 LGAs and six LGAs respectively. Using a constant fraction of 45%, five LGAs were purposively selected from Owerri and Orlu, while three LGAs were purposively selected from Okigwe zone under the guide of Imo state Agricultural Development programme. The purposive selection is to ensure that only rural LGAs known for cassava production were selected. From each selected LGA, one community was randomly selected. Finally, from each selected community farm households were randomly selected on the basis of the community's sampling frame of cassava farmers using a constant sampling fraction of 1% so as to make the sampling design to be self-weighting and hence avoid sampling bias (20). Based on the foregoing, 276 farmers were randomly selected from the 27605 farming households in the study area.

Data were obtained through the use of structured and validated questionnaire, which were administered through face to face interview to the selected 276 farmers in Imo State, Nigeria. Production resources were categorized into five groups; land, labour, planting material, fertilizer and pesticides. Land was measured in hectares, labour was measured in mandays (for family and hired labour), planting material was measured in kilograms and pesticide was measured in litres. The unit prices of the resources were measured in Naira.

Data Analysis

The data collected were analysed using the Data Envelopment Analysis Programme (DEAP). Both the constant returns to scale (CRTS) and variable returns to scale (VRTS) DEA models were used for data analsis. Furthermore, t-test was used to test the null hypothesis.

Model Specification

Data Envelopment Analysis (DEA): Before presenting the model, the relevant concepts are presented below:

Overall Technical Efficiency (OTE): This is related to a given farm operating in constant return to scale (CRTS). Overall technically efficient farms fall on the frontier. The overall technical efficiency can be disaggregated into two measures *viz.*, pure technical efficiency and scale efficiency.

Pure Technical Efficiency (PTE): This concept arises when a given farm is operating under variable returns to scale (VRTS). A decisionmaking unit (farm) which is identified as technically not efficient on CRTS frontier can become technically efficient, if it falls on the VRTS frontier. This unit falling on VRTS frontier is technically

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Volume 2, Issue 4, ISSN (Online) 2319-1473

efficient.

Scale Efficiency (SE): A decision–making unit is said to be scale efficient if it operates under constant returns to scale.

Input Congestion: This implies overutilization of resources. This is found in variable returns to scale.

The DEA Model

Given the CRTS assumption, the best way to introduce DEA is via the *ratio* form. For each decision-making unit (DMU) one would like to obtain a measure of the ratio of all outputs over all inputs, such as u'yi/v'xi, where u is an Mx1 DATA ENVELOPMENT ANALYSIS TO EVALUATE FARM RESOURCE MANAGEMENT 11 vector of output weights and v is a Kx1 vector of input weights. To select optimal weights one specifies the mathematical programming problem:

Maxu =v (u'yi/v'xi)
st u'yj/v'yj £ 1
j=1,2,…, N
u, v ³ ≥ 0 .... (1)

This involves finding values for u and v, such that the efficiency measure of the i-th DMU is maximized, subject to the constraint that all efficiency measures must be less than or equal to one. One problem with this particular ratio formulation is that it has an infinite number of solutions. To avoid this one can impose the constraint v'xi = 1, which provides:

maxì =v (ì'yi)
st v'xi = 1, μ'yj – v'xj £ 0
j =1,2, …,N,
μ, v ³≥0, ... (2)

where the notation change from u and v to μ and v reflects the transformation. This form is known as the *multiplier* form of the linear programming problem. Using the duality in linear programming, one can derive an equivalent *envelopment* form of this problem:

minq=l q
st -yi + Yl ³ 0
qxi - Xl ³ 0
l ³≤ 0 .... (3)

where q is a scalar and l is a N x1 vector of constants. This envelopment form involves fewer constraints than the multiplier form (K + M < N + 1), and hence is generally the preferred from to solve. The value of q obtained will be the efficiency score of the i-th DMU. It will satisfy q £ 1, with a value of 1 indicating a point on the frontier and hence a technically efficient DMU, according to the (21) definition. Note that the linear programming problem must be solved N times, once for each DMU in the sample. A value of é is then obtained for each DMU.

The CRTS linear programming problem can be easily modified to account for VRTS by adding the convexity onstraint: N1'l=1 to (3) to provide:

Minq=ëq
st -yi + Yl ³ 0
qxi-Xl ³ 0
N1'l=1 l ³ ≤0, ... (4)

where q is a scalar and l is a N x1 vector of constants, whereas N1 is an Nx1 vector of ones. The value of q obtained will be the efficiency score of the i-th Decision Making Unit (DMU). It will satisfy q £ 1, with a value of Indicating a point on the frontier and hence a technically efficient DMU, according to the (21) definition.

Calculation of Scale Efficiency

Many studies have decomposed the technical efficiency (TE) scores obtained from a CRTS DEA into two components, one due to scale inefficiency and one due to "pure" technical inefficiency. This may be done by conducting both a CRTS and a VRTS DEA upon the same data. If there is difference in the two TE scores for a particular DMU, then this indicates that the DMU has scale inefficiency (SE). The scale inefficiency can be calculated from the difference between the VRTS TE score and the CRTS TE score.

Thus, TEI, CRTS = TEI, VRTS x SEI .... (5)

III. Results and Discussion

Technical Efficiency Estimates

The percentage distribution of the cassava farmers by technical efficiency estimates is presented in Table 1. The result in Table 1 shows that 38% of the cassava farmers operated within a technical efficiency range of 0.71 and 0.85. The implication of this result is that many of the cassava farmers are not technically efficient in the use of production resources. This can result to an equi-proportionate over utilization of inputs (input congestion), and hence low productivity, low output and low income.

Furthermore, technical efficiency among the cassava farmers varied substantially ranging between 0.214 and 0.925, with a mean technical efficiency of 0.622. This wide gap in technical efficiency could be due to the non-homogeneous charactersitics among cassava farmers in the study area. This result implies that the cassava farmers are not utilizing their production resources efficiently, indicating that they are not obtaining maximal output from their given quantum of inputs. Therefore, technical efficiency among the cassava farmers can be increased by 37.8 percent through better use of available production resources, given the current state of technology. This would enable the cassava farmers obtain maximum output from their given quantum of inputs, and hence increase their farm incomes thereby reducing poverty among farming households. This finding is consistent with those of (10), (22, 23, 24, 25, 16 and 10) that Nigerian rural farmers are not obtaining maximum output from their given quantum of inputs.

Table 1: Percentage distribution of the farmers by technical efficiency estimates

Efficiency Estimates	Frequency	Percentage
≤ 0.25	12	4.3
0.26 – 0.40	34	12.3
0.41 – 055	49	17.8
0.56 – 0.70	51	18.5
0.71 – 0.85	105	38.0
≥ 0.86	25	9.1
Total	276	100
Minimum efficiency	0.214	
Maximum efficiency	0.925	
Mean efficiency	0.622	

Source: Field survey 2011

Scale Efficiency Estimates

The percentage distribution of cassava farmers by scale efficiency estimates is presented in Table 2. The result in Table 2 shows that 33% of the cassava farmers operated within a scale efficiency range of 0.56 and 0.70. The implication of this result is that many of the cassava farmers are not scale efficient.

Furthermore, scale efficiency among the cassava farmers varied substantially ranging between 0.103 and 0.916, with a mean scale efficiency of 0.495. This wide gap in scale efficiency could be because of non-homogenous characteristics among Decision making units in the study area. This result suggests that the farmers are operating at less than optimal scale size. Therefore, scale efficiency among the cassava farmers can be increased by 49.5 percent by operating at optimal scale size, given the current state of technology in Imo State, Nigeria.

Table 2: Percentage distribution of cassava farmers by scale efficiency estimates

Efficiency Estimates	Frequency	Percentage
≤ 0.25	37	13.4
0.26 – 0.40	68	24.6
0.41 – 055	39	14.1
0.56 – 0.70	91	33.0
0.71 – 0.85	23	8.4
≥ 0.86	18	6.5
Total	276	100
Minimum efficiency	0.103	
Maximum efficiency	0.916	
Mean efficiency	0.495	

Source: Field survey 2011

This would enable the cassava farmers operate at optimal scale size, and hence increase their farm productivity and incomes thereby reducing poverty. This result is similar to those of (12,10) who found that nearly half of DMUs studied were operating at less than optimal scale size.

Table 3 presents the summary statistics of efficiency measures under CRTS specifications and VRTS specifications. The result of a t-test shows that there is a significant difference between the two groups (CRTS specifications and VRTS specifications) of efficiency scores at 5 percent level of significance (Table 4), leading to the rejection of the null hypothesis. This indicates that some of the decision-making units have scale inefficiency, suggesting that the decision-making units are not all operating at the optimal scale.

The average level of overall technical efficiency (OTE), pure technical efficiency (PTE), and scale efficiency is estimated at 44.3 percent, 62.2 percent and 49.5 percent respectively. This result highlights the level of inefficiency that characterize the farmers in Imo State. The overall technical inefficiency among the farmers resulted more by scale inefficiency compared to pure technical inefficiency. This result supports (13) who observed that data envelopment analysis is suitable to measure DMU's efficiency and give improvement suggestion to the inefficient DMU.

Table 3: Summary statistics of Different Efficiency Measures for the cassava farmers in Imo State

Variable	Minimum efficiency	Maximum efficiency	Mean efficiency
OTE	0.101	0.903	0.443
PTE	0214	0.925	0.622
SE	0.103	0.916	0.495

Source: Field survey 2011

Table 4: Results of t-test of no significant difference between the CRTS and VRTS efficiency scores among cassava farmers in Imo State.

Item	VRTS	CRTS
Mean	0.6905	0.4528
Hypothesized mean difference	0	
Degree of freedom	274	
t-calculated	5.29*	
t-critical	1.97	
Decision	Reject Ho	

* t-calculated significant at 5% level

Source: Field survey 2011

IV. Conclusion

The study applied data envelopment analysis to measure technical efficiency of cassava farmers in Imo State, Nigeria. Results showed that some of the decision making units have scale inefficiency, suggesting that the decision making units are not all operating at the optimal scale. Most of the farmers operated very far away from the efficiency frontier. The overall technical inefficiency among the farmers resulted more by scale inefficiency compared to pure technical inefficiency. Technical inefficiency of cassava farmers would be drastically reduced by solving scale problems of the farmers in Imo State, Nigeria.

Government policies aimed at improving the production efficiency and standard of living of cassava farmers should adequately consider making more farm land available to the farmers so as to increase their scale of production.

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