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THE APPLICATION OF DATA ENVELOPMENT ANALYSIS ON SWEET POTATO PRODUCTION IN THE IN-LAND VALLEYS OF CROSS RIVER STATE, NIGERIA

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ABSTRACT: This study on the application of data envelopment analysis (DEA) on sweet potato production in the in-land valley of Cross River state was undertaken to demonstrate the potentials that exist in this economic sub-sector. The nature of input-output relationship and returns to scale efficiency were the major objectives. Data were collected from 60 sweet potatoes farmers using structured questionnaire and analyzed using DEA model. Results revealed that 12 farms out of 60 representing 20% are operating under increasing returns to scale. Also, 20 farmers representing 33.3% operated under deceasing return to scale. While 28 farms representing 46.7% exhibited constant returns to scale. It is recommended that potato farmers producing at increasing returns to scale needs expansion by adding more of the variable inputs to the fixed inputs. Those producing at decreasing return to scale are to reduce variable cost. For sweet potato farmers exhibiting constant returns to scale, they still need to do more by moving between the extensive and intensive margins where production is justifiable and profit margins are maximized. To improve production and to bring sweet potato farmers to optimal production level, effort should be directed by farmers toward sound farm management practices and efficient resource allocation.

Keywords: Data envelopment analysis, potato production, scale efficiency

INTRODUCTION

Despite the dominant role of the petroleum sector as the major foreign exchange earner, agriculture remains the mainstay of Nigeria's economy (Ubigbi, 2001). Apart from contributing to gross domestic product (GDP), it is the largest non-oil export earner, the largest employer of labour and a key contributor to wealth creation and poverty alleviation, as larger population derives its income from agriculture and related activities (NEED, 2014). Food production in Nigeria has been increasing tremendously for the past two decades, although, such increase has not been meeting with the rising food demand due to high population pressure. A contributor to this trend in food production includes the root and tuber crops sector with increasing annual output and growth rates. Agricultural projects monitoring and evaluation units (APMEU, 1996) estimated a yearly output of 33.2 Mt for cassava and 25.2 Mt for yam, 1.3 Mt for sweet potato, 1.3Mt for potato, 3.0 Mt for cocoyam and 0.223Mt for ginger in Nigeria.

Sweet potato (*Ipomoea batatas* L.) is the fourth among the major root and tuber crops accounting for 2.14% of the total production of the four crops with about 62.7Mt (Tewe and Nwokocha, 1998). The traditional utilization of sweet potato in Nigeria consists of the following (Tewe, 1992):

Sweet potato is boiled and eaten with stew

Sweet potato is boiled and pounded with either boiled or fermented cassava as fufu or boiled yam as pounded yam.

Sweet potato is dried and milled for sweetening of gruel or *Ogi* porridge.

Sweet potato are sliced into chips and then fried in vegetable oil, or dried and boiled with beans or vegetables.

The low output realized by small, medium and large scale farmers is an indication that resources used in the production of root and tuber crops are not produced at optimal levels (Nweze, 2002; Panwale *et al.,* 2006). Some of the major reasons for low productivity in sweet potato production centred on low capacity utilization of resources and technical/allocative inefficiency of resource used. Therefore, the needs to use resources efficiently in the production of sweet potato become a significant factor in increasing production.

The resource poor farmers must be assisted to rise beyond subsistence level to increase their income through more efficient use of resources. They must be guided on what level of inputs combination that would ensure optimum production.

There is need to increase sweet potato production in the study area and the country at large using resources efficiently. Resource use efficiently, adoption of new technologies and improve farm management techniques are the most effective ways in increasing productivity of sweet potato in the short and long terms, so that farmers will produce with better efficiency.

The objective of this study, is aimed at estimating the scale efficiency of sweet potato production among farmers by this, identify farms facing increasing, constant and decreasing return to scale, using the input orientation of DEA.

Theoretical framework

Farm efficiency measurement is very important both in developed and developing agriculture. Its role in increasing agricultural output is wildly recognized by researchers and policy makers, for example Bravo-Ureta and Evenson (1994), stated that efficiency measurement is important for three main reasons; firstly, it is success indicator and performance measure by which production unit are evaluated. Secondly, the exploring of hypothesis concerning the source of efficiency differential can only be possible by measuring its efficiency and separating its effects from the effects of the production environment, thirdly, identification of sources of inefficiency is important to institution of both public and private policies designed to improve performance (Ogunjobi 1999).

A number of commonly used efficiency measures are generally represented by some form of frontier functions. Frontiers have been estimated by using many different methods over the past 40 years. The two principal methods are: DEA and Stochastic frontiers, which involves mathematical programming and econometric methods. Modern efficiency measurement begins with Farrel (1957) who drew upon the work of Debreu (1951) and Koopmans (1951) to define a simple measure of firm efficiency which could account for multiple inputs. He proposed that the efficiency of a firm consist of two components: technical efficiency, which reflects the ability maximal output from a given set of inputs, and allocative efficiency, which reflects the ability of a firm to use the inputs in optimal proportions giving their respective prices. These two measures are then combined to provide a measure of total economic efficiency.

In studying the efficiency resource- use, several researchers have posited different views on the efficiency of resources used for maximum possible output; Van Zyle *et al.* (1996) analyzed the productivity and efficiency of farms in two regions of Poland using data from 1993, the authors argued that there was a negative relationship between farm and the total factor productivity (TFP), as well as between size and technical efficiency estimated by DEA. They reported that differences in scale efficiency between size and groups where statistically significant.

Davidona *et al.* (2002) analyzed TFP of polish farms in 1999. They reported a significantly higher mean size for farms with TFPs above 1, relative to those with TFPs below 1. All these studies used panel data collected by the polish Institute of Agricultural and Food Economics. The exception of Lerman (2002) who used rural household survey data from 2000. Lerman’s DEA technical efficiency scores were higher for larger farms. However, he argued that there was a quadratic pattern efficiency, varying with farm size. The highest scores were achieved by the smallest farms, up to 2 hectares, and the largest farms, over 30 hectares.

Landsink *et al.* (2002) studied technically efficiency of Funnish farms using DEA and found that the conventional livestock farms had technological efficiency scores up to 69%. Jonasson (1996) measured various output efficiencies of a sample of Swedish farms during 1989-1991, using DEA. He found that the average technical and allocative output efficiencies were 0.95 and 0.92 respectively. DEA is a non-parametric method in frontiers. It is used to empirically measure productive efficiency of decision making units (DMUs). The techniques involved in DEA is a linear programming methodology to measure the efficiency of multiple DMUs when the production or process presents a structure of multiple inputs and outputs. DEA has been used for both production and cost data utilizing the selected variables, such as unit cost and output. DEA software searches for the points with the lowest unit cost for any given output connecting those points to form the efficiency frontier. Any company not on the frontier is considered inefficient. A numerical coefficient is given to each firm defining its relative efficiency (Berg, 2010).

In the DEA methodology, formally developed by Charnes *et al.* (1978), efficiency is defined as a ratio of weighted sum of output to a weights structure as calculated by means of mathematical programming and constant returns to scale (CRS) are assumed. In 1984, Banker *et al.* developed a model with variable returns to scale. This research therefore, is aimed to determine the scale efficiency of sweet potato production in the study area and to identify farms facing increasing, decreasing and constant returns to scale with a view to recommend implementable policies to improve potato production in the study area.

METHODOLOGY

The study was conducted in Obubra local government area (LGA) of Cross River state, Nigeria. Obubra lies between. Longitude 7^0.55 and 8^0.10E of the Greenwich meridians and Latitude $5^{0.}$40 and 6^0 10N of the equator. It has a total land of 1086.27sq.km (Enya and Agba, 2006). The LGA has a mean temperature range of between 21 and 29^0 C and annual rainfall between 2250 and 2500mm and relative humidity of 60 - 80%. Ecologically, Obubra falls within the tropical rainforest zone which favours the cultivation of many types of crops such as potato, yam, cassava, rice, maize, plantain, banana, fruits, vegetables, oil palm, cocoa, oranges etc. Obeten (2011) reported that sweet potato, yam, cassava and rice are the mainstay of the economy of the study area.

A random sample of active potato farmers were drawn from villages in the LGA. The villages were purposefully selected because they are the main producers of sweet potato in the area. Thus total of 60 potato farmers consisting of 26 in Ofadua, 14 in Ovonum and 20 in Ofatura were used in the study during the 2014 cropping season. The instrument used for data collection was a structured questionnaire and personal interview.

The analytical procedure employed in order to achieve the objectives was the DEA which is a linear programming system where for the ith farm, the estimated input-oriented efficiency scale α_i, under constant returns to scale is given by solving the following linear programming model.

Min α_i ……………………………………………………………………i

Ω, α_i……………………………………………………………………ii

Subject to $Y_i + Y\Omega \geq 0$……………………………………………………iii

$\alpha i\ Xi - X\ \Omega \geq 0$……………………………………………………...iv

$\Omega \geq 0$ (non-negative property)………………………………………………v

Where X and Y are matrices of the inputs and outputs respectively, of all observed (N) farms; Xi and Yi are the input and output vectors of the ith farm respectively, Ω as a Nx1 vector of constraints

The α is the technical efficiency of the ith farm, bounded by 0 and 1 with a value of 1 indicating a technically efficiency firm.

The variables return to scale (VRS) DEA model was obtained by adding the constraint N1 Ω = 1, where N1 is a NX 1 vector of ones. This is a convexity constraint ensuring that a firm is benchmarked against firms of similar size.

DEA under decreasing returns to scale (DRS) was obtained by adding the constraint N1 Ω≥1. If the two scores are different, the ith farm operates under increasing returns to scale (IRS). Where: Ω = Lamba; X = inputs; α = technical efficiency; VRS = Variable return to scale and CRS = Constant returns to scale.

VRS is obtained by

VRS = N1 Ω = 1……………………………………………………………………………vi

Where: N1 = Nx 1 = ith farm

Scale efficiency is obtained as a ratio of the CRS to VRS

C

$$\text{Scale efficiency} = \frac{CRS}{VRS} \quad \text{……vii}$$

Where, VRS = Variable return to scale

CRS = Constant return to scale

RESULTS AND DISCUSSION

Table 1 shows the farmers exhibiting increasing returns to scale for sweet potato farmers in Cross River state. Farmers in this category becomes smaller and smaller in space between their isoquant as one moves to higher levels of output, implying efficiency in the level of production as less inputs generate higher production or the same level of inputs gives a higher production. This set of farmers, their inefficiency gap is 1 – 0.623 i.e. 0.377 representing 38% inefficiency gap. The economic implication is that when a firm is operating under increasing return to scale, the firm is in the stage one of the production stages. The elasticity of production ∑EP is greater than 1; implying increasing returns to scale (Figure 1). The firm fixed input is still contributing more to production. So, the firms need expansion to maximize. Furthermore, in stage one, the APP is increasing while the MPP reaches a maximum and begins to drop depicting that TPP is increasing at an increasing rate. In the study area, for the potato farmers under this stage of production, there is need to still adding variable inputs to cover the inefficiency gap.

The graph depict decreasing return to scale (Figure 2) showing that farms in this category exhibited a wider space in between the isoquant as one moves to higher level of output. This also means that inefficiency in their level of production, because in stage 3 of the production process at this point, MPP is less than zero, TPP is at maximum and it is declining, the average variable cost is over-stretched, farms are operating at loss. Economic decisions at this level are to reduce variable cost. The elasticity of production ∑EP is less than 1, implying decreasing return to scale in the study area. At this level of operation, the ratio of the variable input to the fixed inputs is at maximum and the overstretched variable inputs gives a decreasing outputs, and the MPP becomes negative. Additional variable input into the production process do not make economic sense anymore as the variable input is beyond the intensive margin.

The graph in Fiqure 3 depicts constant return to scale, revealing that farms under this category, their output increases by equal amount of input used. This takes place in stage 11 of the production process where breakeven point is expressed as MC = MR and the elasticity of production ∑EP =1 showing a constant return to scale. The economic implication is that production is justifiably restricted to stage 11 of the production process and it is where profit margin are maximized because stage 11 is bounded by the extensive and intensive margins. The ratio of the variable input to the fixed inputs is high and adjustment of both the fixed and variable input is feasible to maximize profit. If the fixed input is expensive relative to the variable input the tendency is to move to the intensive margin. While if otherwise, there is the tendency to move to the extensive margin, this is the rational stage of production.

Measurement of scale efficiencies of sweet potato farmers Cross River state

The variable returns to scale (VRS) and the constant return to scale (CRS) model was used in measuring the scale efficiency of sweet potato farmers in Cross River state (Tables 2 and 3). The constant returns to scale assumptions is only appropriate when the decision making units (DMUs) i.e. the farms are operating at an optimal scale (full capacity). Imperfect competition, constraints or finance etc. may cause a farm not to operate optimally. Banker *et al.* (1984) suggested an extension of the constant return to scale. DEA model to account for variable returns to scale (VRS) situations. The implication is that technical efficiency of a firm is decomposed into two components one is due to scale inefficiency and one is due to "pure" technical inefficiency. This may be done by conducting both the CRS and VRS DEA upon the same data if there is a difference in the two TE scores for a particular farm, then this means that farm has scale inefficiency, and that the scale inefficiency can be calculate from the difference between the VRS TE score and The CRS TE score.

The scale efficiency for the sweet potato farmers in Cross River state revealed that 12 farms out of the 60 farms representing 20% are operating under increasing return to scale. Also, the study revealed that 20 farms representing 33.3% are operating under decreasing return to scale. In addition, 28 farms representing 46.7% exhibited constant return to scale. Summarily, the scale efficiency study of the potato farmers can be seen in Table 4.

CONCLUSION

The finding of the study shows that 28 farms were fully technically efficient of the 60 farmers representing 47%, while 53% of the farms are technically inefficient in the production of sweet potato in the study area. The mean technical inefficiency was 0.463, the mean technical efficiency of the farm was 1.000, the mean of efficiency gap was 0.540, the mean allocative efficiency was 0.182 and the total economic efficiency was 6.544. The study also revealed that 53% of potato farmers in the study area operate below full capacity due to some constraints while, 47% operate within stage 11 of the production stages where production is rational and profit is maximized.

RECOMMENDATIONS

Highly improved potato varieties should be provided to ensure high yield and increase income, and more so, formation of potato farmers association should be encourage. Such as cooperative societies their sources could be pooled together to purchase inputs at lower cost and their output equally pooled together to have better market prices, making more income and improved standard of living.

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Table 1: Farmers exhibiting increasing returns to scale for sweet potato farmers in Cross River state

S/N	Farm (DMU)	Scale efficiency
1	26	0.828
2	34	0.906
3	36	0.359
4	37	0.514
5	38	0.939
6	40	0.153
7	44	0.923
8	50	0.576
9	51	0.273
10	53	0.783
11	55	0.282
12	58	0.936
Mean	43.5	0.623

Source: Survey data, 2014

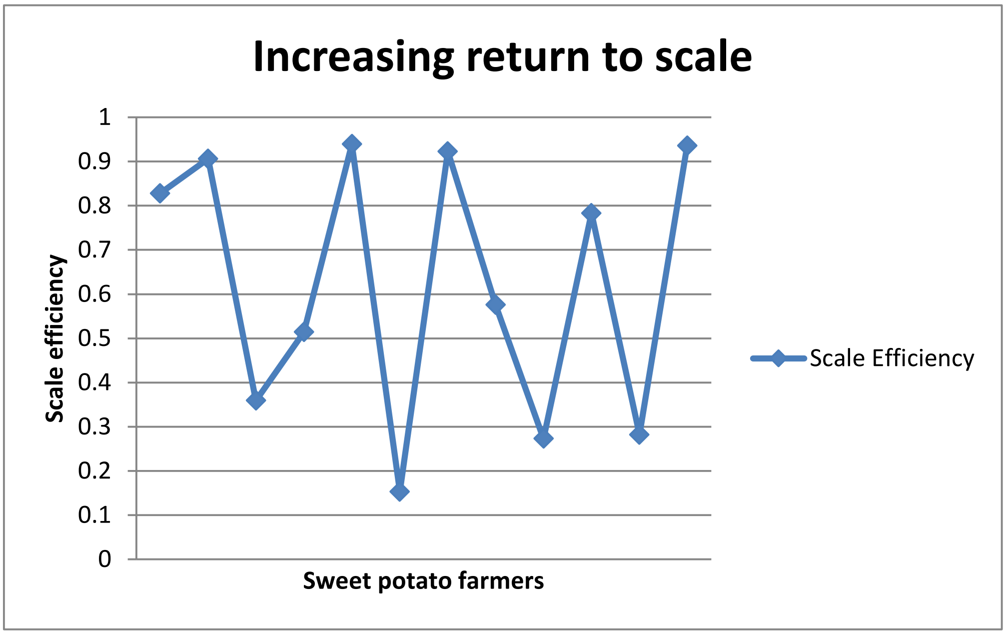

Figure 1: shows graph of increasing return to scale that is farmers exhibiting increasing return to scale

Table 2: Decreasing Return to Scale for sweet potato farmers in Cross River State

SN	Farm(DMU)	Scale Efficiency
	1	0.511
	2	0.823
	3	0.924
	5	0.516
	6	0.726
	9	0.639
	10	0.549
	12	0.496
	13	0.799
	15	0.868
	23	0.976
	25	0.977
	28	0.803
	29	0.849
	31	0.920
	35	0.600
	41	0.620
	43	0.952
	56	0.904
	60	0.907
Mean	22.35	0.773

Source: Survey data 2014

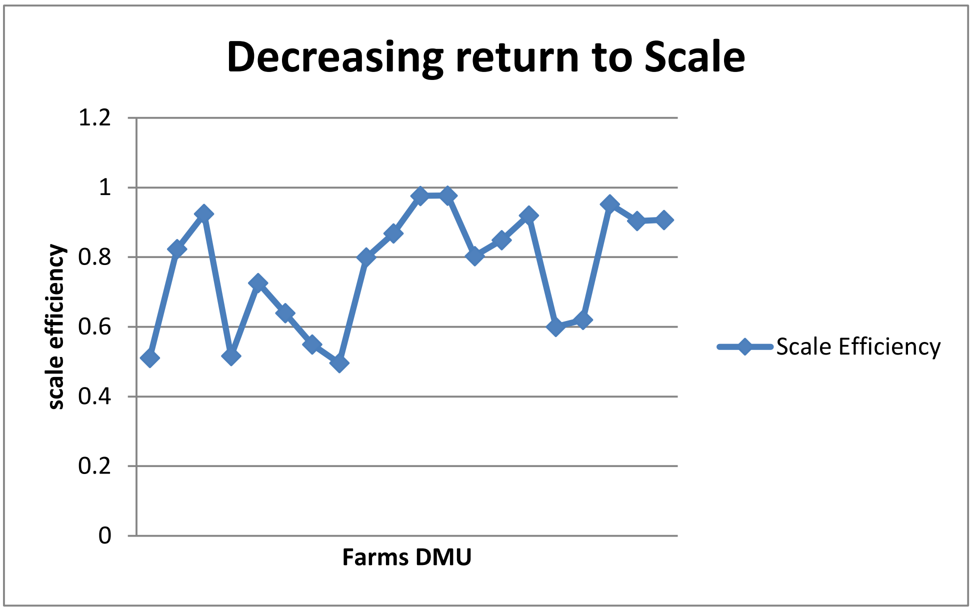

Figure 2: Decreasing return to scale

Table 3: Constant Return to scale for sweet potato farmers in Cross River State

SN	Farm (DMU)	Scale Efficiency
1	4	1.000
2	7	1.000
3	8	1.000
4	11	1.000
5	14	1.000
6	16	1.000
7	17	1.000
8	18	1.000
9	19	1.000
10	20	1.000
11	21	1.000
12	22	1.000
13	24	1.000
14	27	1.000
15	30	1.000
16	32	1.000
17	33	1.000
18	39	1.000
19	42	1.000
20	45	1.000
21	46	1.000
22	47	1.000
23	48	1.000
24	49	1.000
25	52	1.000
26	54	1.000
27	57	1.000
Mean	30.714	1.000

Source: Survey data 2014

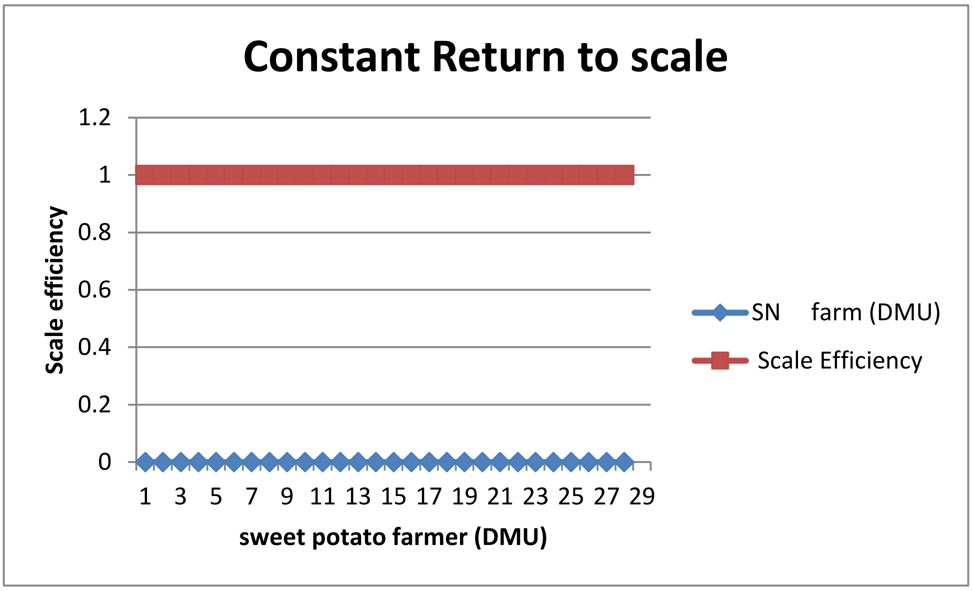

Figure 3: graph showing constant return to scale

Table 4: Summary of Farms Scale Efficiency

SN	No of Farm	%	Scale Efficiency
1	12	20	irs
2	20	33.3	drs
3	28	46.7	crs
	60	100	

Source: Survey data 2014