Yam Production in Nassarawa State, Nigeria; an Application of the Constant Elasticity of Substitution Production Function

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Abstract: **- This paper examined the Constant Elasticity of Substitution (CES production function in estimating the productivity, efficiency and elasticities of yam production in Nassarawa state, using a multi-stage random sampling procedure. The findings revealed that the mean yam production to be 6776.21kg per farmer, the average land cropped at 2.67 hectare, average capital involved was N44,586.10, the average number of labourers required at 42 manpower and average wage paid to labourers' was N14345.17. The CES Production function estimated revealed a productivity of 17.94 which shows that the farmers are producing at an efficient level, the optimal distribution of input was 0.226031 of capital is required for 0.773 of labour, while our elasticity of production was 1.0699 shows that the factors capital and labour can be substituted since it is constant and implies that for an improved production, an increase capital utilization and reduction of wages paid for labour to reduce human drudgery which is interest in this research. We therefore recommend an intensification of capital inputs (machinery) use rather than human labour in yam production. Also, there is the need to consider other factors when designing policies to encourage an increase in yam production. Thus, for us to increase productivity there is the need to make policies that will encourage technology applications.**

Keywords: **Yam Production, CES production function, Capital, Labour.**

I. INTRODUCTION

Yam is one of the most frequently consumed staple food for most household in Nigeria. It is an important tuber crop of the tropics and some other countries in East Asia, South America and India (Iwueke *et al*, 2003; Idumah, 2014).

Yam (Dioscorea spp) is one of the world's recorded oldest foods, ranking second after cassava in the study of carbohydrate sources in research (Agwu and Alu, 2005). It has over 600 species, however six species are frequently consumed and termed edible in the tropics. It can be eaten boiled, roasted, fried, baked, pounded or converted into other edible sources such as yam flour as in the case of Amala a well consumed Nigerian dish among the youruba tribe. According to Ayanwuyi *et al* 2011, the most commonly grown species in Nigeria are white yam (Dioscorea rutundata) and water yam (Dioscorea alata) (Brand-Miller, *et al*., 2003; Osunde, 2008). Yam is one of the major staple food in Nigeria and is a great potential source of livestock feed and industrial production of starch. When we consider the land area under cultivation, the volume and value of production we can term it as one of the principal tuber crops in the Nigeria economy (Bamire & Amujoyegbe, 2005). The usefulness of yam in Nigeria cannot be overemphasized as it plays an important role in the religious heritage of several tribes and often plays a key role in religious ceremony and cultural values (Sanusi & Salimonu, 2006; Idumah, Owombo, & Ighodaro, 2014).

Nigeria as a nation is by far the world's largest producer of yams, accounting for over 70 to 76 percent of the world production. Statistically in 2004, the global yam production stood at about 47 million metric tons, and 95 percent of this was produced in Africa, having Nigeria alone accounted for about 70 percent of this world production (FAO, 2006).

According to FAO 2008, Nigeria, was the world's largest yam producer in the year 2007, and considered it to be a "man's property". However, according to FAO statistics, Nigeria is the largest producer of this crop, with a production rate of about 38.92 million metric tonnes annually (FAO, 2008), which is an indication of growth because yam production in Nigeria has more than tripled over the past 45 years from a starting point of 6.7 million tonnes 1961, up to 39.3 million in 2006 (FAO, 2007). According to Nwosu & Okoli, (2010), the large area cultivated with yam rather than increase in the productivity is the major contributor to this increase in output. However, recently there has been a decline in yam production over the years in Nigeria according to a research conducted by the International Institute of Tropical Agricultural (2009), in average yield per hectare and this has been more drastic, as it dropped from 14.9% in 1986-1990 to 2.5% in 1996-1999 (CBN, 2002, Agbaje et al, 2005; FAO, 2007), and this has continued and this declining trend may be as a result of underutilization and allocation of resources (Nwosu & Okoli, 2010).

The scarcity of farm labour has impacted negatively on planting precision, better weed control, timely harvesting and crop processing (Oluyole *et. al.*, 2011). The inadequacy of farm labour to facilitate expansion of yam farms and intensify the already selected area for yam production in Eastern Nigeria has been noted (Ugorji, 2013). Empirical evidence has shown that available labour force comprised mostly of aged farmers to the exclusion of men and women within the active working age. This has impacted negatively on yam productivity (Oluyole & Lawal, 2010) The increasing absence of people within the active age could be attributed to drudgery in farm activities, rural-urban migration, and absence of social infrastructure in the rural areas, as well as poor farm income and low life expectancy in rural areas (Gill, 1991). Human labour is about the only main source of labour available to small-holder yam farmers in Nigeria and they are the major producers of yam till recently. Some studies (Echebiri & Mbanasor, 2003; King, 1972) confirm that farm labour supply by humans on the farm is not homogenous and job contents differ. These studies found that in general, men performed heavy farm operations such as land preparation, staking and harvesting with women and children performing lighter operations such as planting, fertilizer application and weeding. Ajibefun *et. al*., (2000) noted that hired labour contributes 88.0% of the total labour use on farms and requires capital use, thus emphasizing its importance in agricultural activities. Other types of labour that could be employed are family labour and exchange labour. Researchers on farm labour supply have observed that total supply of labour depends on such factors such as the size of the population, its age composition and certain institutional factors (Hardwick, 1994).

This study having considered these factors decided to utilize the CES production function to estimate the technical efficiency of yam production in Nasarawa state irrespective of its shortcomings as an analytical tool.

II. METHODOLOGY

Area and Scope of the study

This study was carried out in Nasarawa state Nigeria. A multi-stage simple random sampling technique was employed, and five Local Government Areas were chosen and an agricultural zone was chosen from the list of Agricultural Development Project (ADP) zones in each of the selected village due to its active involvement in yam production. Then we random selected two villages each out of the selected LGA after which a total of 150 producers were sampled and data was cleaned, we got 135 farmers. The data employed here were primary data sourced directly from the farmers.

Data Description and Regression Model (Apriori Expectations)

Our expectations are that we use two inputs at a time since we are not considering the nested CES function and their elasticities should lie between 0 and 1 but most better should be equal to 1, but not negative.

Model Specification: The Constant Elasticity of Substitution:

The functional form of the CES production function is

$$\boldsymbol{Q = A\left[\alpha X_1^{-\rho} + (1-\alpha) X_2^{-\rho}\right]^{\frac{-v}{\rho}}}$$

OR

$$Y = \gamma\left[\delta X_1^{-\rho} + (1-\delta) X_2^{-\rho}\right]^{\frac{-v}{\rho}}$$

Where

Y = Output quantity,

X1 and X2 = Input quantities, where X1=Capital and X2=Labour

$A/\gamma \in [\![0,\infty]\!]$ = Determines the productivity,

$\alpha/\delta \in \{0,1\}$ = Determines the optimal distribution of the inputs,

$\rho \epsilon (-1,0) \cup (0,\infty)$ = Determines the (constant) elasticity of substitution which is $= \frac{1}{1-\rho}$ $v \in (0,\infty)$ = Determines the elasticity of scale.

The CES function focuses on three special cases:

for $\rho \to 0, \sigma$ approaches 1 and the CES turns to the Cobb-Douglas form;

for $\rho \to \infty, \sigma$ approaches 0 and the CES turns Leontief production function;

for $\rho \to -1, \sigma$ approaches infinity and the CES turns to a linear function if v is equal to 1.

While the non least square routine works well in an ideal artificial example, it does not perform well in many applications with real data, either because of non-convergence, convergence to a local minimum, or theoretically unreasonable parameter estimates. Therefore, we show alternative ways of estimating the CES function in the following sections.

$$f(x_1, \dots . x_n) = A\left(\sum_{i=1}^{n} \lambda_i x_i^{\rho}\right)^{k/p}$$

Where X1 andX_2 represent two factors of production, and A, α and ρ are three parameters. The parameter A (the efficiency parameter) plays the same role as the coefficient A in the Cobb-Douglas production function; it serves as an indicator of the state of technology

Since the Cobb Douglas type of production function imposes an elasticity of substitution between input pairs of exactly 1, then if a Cobb Douglas type of production function were estimated, the elasticity of substitution between input pairs would be an assumption underlying the research rather than a result based on the evidence contained in the data this is one reason why we did not be apply the Cobb-Douglass methodology in our research.

The CES function is non-linear in parameters and cannot be linearised analytically; it is not possible to estimate it with the usual linear estimation techniques. Therefore, the CES function is often approximated by the so-called Kmenta approximation" (Kmenta 1967), which can be estimated by linear estimation techniques. Alternatively, it can be estimated by non-linear least-squares using different optimization algorithms.

The problem with the Cobb Douglas type of production function is widely known and is of particular interest to economists engaged in macro-oriented issues, such as the extent to which capital could substitute for labor within an economy.

The study published by Arrow, Chenery, Menhas, and Solow "Capital Labor Substitution and Economic Efficiency" in 1961 was a landmark. The study might also be considered a remake of the 1928 effort by Cobb and Douglas without the assumption that the elasticity of substitution between capital and labor was one (1). In the study the authors first introduced the constant elasticity of substitution (CES) production function.

The statement above discusses is the major limitation of the CES function but then because we want to shed more explanation on the methodology, this research will be using it as its econometric model.

The parametric structure or our model is specified as thus;

$$\boldsymbol{Q = A\left[\,\alpha X_1^{-\rho} + (1-\alpha)X_2^{-\rho}\right]^{\frac{-v}{\rho}}}$$

OR

$$Y = \gamma\left[\,\delta X_1^{-\rho} + (1-\delta)X_2^{-\rho}\right]^{\frac{-v}{\rho}}$$

Where,

Q/Y = Yam output in Kg

X_1 = Capital (Total Cost of production) in Naira

X_2 = Labour (total wages paid) measured in man day per hour in naira for the specified period.

$A/\gamma \in [\![0,\infty]\!]$ = Determines the productivity,

$\alpha/\delta \in \{0,1\}$ = Determines the optimal distribution of the inputs,

$\rho\epsilon(-1,0) \cup (0,\infty)$ = Determines the (constant) elasticity of substitution which is $= \frac{1}{1-\rho}$ $v \in (0,\infty)$ = Determines the elasticity of scale.

Where the two restrictions are δ_1 *and* δ_2, and that $\beta_{12} = -\beta_{11} = -\beta_{22}$

If the constant return to scale is to be imposed, then a third restriction must be enforced. That is;

$$\alpha_1 + \alpha_2 = 1$$

These restrictions must be explored to check if the Kmenta approximation of the CES function is an acceptable simplification of the translog functional form. If this is the case, a simple t-test for the coefficients of $\beta_{12} = -\beta_{11} = -\beta_{22}$ can be used to check. Then with these findings, we estimate our parameters.

III. RESULTS AND DISCUSSION

Table 1: Descriptive statistics of yam producers in Nassarawa state in 2013.

Variables	Mean	Standard deviation	Minimum	Maximum
Output	6776.212	10176.81	100	55000
Land size	2.671918	5.837719	0.3ha	60
Capital	44586.1	51275.64	1000	341000
Labour	42.38356	49.97437	4	295
Labour wages	14345.17	30100.58	0	143000

Source: field survey 2013 by Ayodele

In the year 2013, on the average each farmer in Nassarawa produced about 6776.21kg of yams annually, and the maximum quantity of output by the farmers was 55000kg of yams and the lowest was 100kg. The average land area cropped in the area was 2.67 ha with a highest land size cropped standing at 60ha, and the lowest was 0.3ha area cropped. The average, each farmer employs 42 persons for all the labour involved in yam production from land preparation to disease and pest control to harvesting annually and the highest employer of labour stood at 295 manpower for all the activities involved in the production of yam. On the average the total capital in naira required for yam production stood at ₦ 44,586.1 with the maximum capital at ₦341,000.00 and the minimum at ₦1000. The average amount spent on labourer's wages for all labour involved the production process stood at ₦14345.17, while maximum amount spent stood at N143000.00 and the minimum amount spent was ₦900.00 as indicated by the farmers.

Estimating the CES production function

The CES production function we estimated all had increasing returns to scale, this is because the value of v (elasticity of scale) which according to Kmenta (1967) was positive implying that the farmers irrespective of the combination of input were producing below optimal level. Basically, we can say they were all producing within at the first stage of the neoclassical production stage which is an irrational stage of production for a farmer. This is in line with the findings of other researchers who worked on areas of production.

The CES function generalizes the Cobb-Douglas function and accepts any positive elasticity of substitution. It was first introduced by Solow (1956) and then was developed by Arrow et al. (1961). Our findings revealed that all values of our elasticity of substitution was positive implying that they can be substituted though weakly.

Table 2: Results of our estimated CES production function

CES function	A	v	α	ρ	σ	R^2
capital and lumped labour	17.93817	2.109037	0.226031	-0.0653	1.0699	0.2967
capital and skilled labour	16.74979	1.788211	0.417913	-0.1681	1.2021	0.1756
capital and unskilled labour	17.68663	2.197434	0.293779	-0.0976	1.1081	0.2834

Source: field survey 2013 by Ayodele.

The values of R which shows the level of variation in yam production output in Nasssarawa that is that is explained by our two major inputs keeping land size or area covered constant, the higher the value of our R^2 the better the fitness of the model according to Haji, et al 2004, and the estimate of the (constant) elasticity of substitution (σ) is within the expected range of [0,1] according to Henningen and Heningen 2011, which has economic implication that enables us to select the estimation of capital and variations in labour as our lead model and we eventually narrowed to capital and lumped labour as our independent variable this is because there is no significant difference between lumped labour and unskilled labour but there was a significant difference between it and skilled labour. Therefore, we explain our table below.

We obtained a productivity value of 17.94 which is within the expected value range of [0, ∞] that is zero to infinity, and thus our production level is said to be efficient as the parameter that estimates it explains and with our observed value. Thus we can say that in raising our elasticity of substitution we can raise our growth rate and its effect may be potentially even larger than that traditionally use of crude implements. The formal proof for the conjecture was presented by Klump and de La Grandville (2000), based on a very general normalized CES production function.

v, Our elasticity of scale obtained 2.11 lies within the production function requirement of $\mathbf{v} \in (\mathbf{0}, \infty)$.

We obtained α which is the optimal distribution of inputs to be 0.226031 and it lies within the stated range of [0,1] and as observed it is thus. Implying that 0.226031 of capital is required for 0.773 of labour to obtain an optimal distribution of the input capital and labour for an efficient production within that region. Therefore, we can obtain our [1- α] to be equal to 0.773.

The constant elasticity of substitution was obtained as 1.0699 shows that the factors capital and labour can be easily shifted. Thus the we see that even though we had estimated a constant elasticity of substitution production function, our value obtained is approximately equal to one (1) thus they are constant substitutes or complete substitutes. The result we obtained implies that using more capital as a substitute factor of the shortage of labour is high and indeed recommended. Thus we imply that it is an efficient production to increase capital utilization and reducing wages paid for labour in order to be efficient in yam production in our area of concern/interest. Because our CES is equal to approximately one (1), the findings suggest that it is possible to take increase in capital a substitute factor for labour.

The policy implication here is that in estimating our constant elasticity of substitution for yam production we address the weaknesses farmers encounter in yam production that substitutability of inputs is possible so as to reduce drudgery and intensify yam production using capital inputs (machinery) rather than human labour.

The low value of our R square shows that there are several other factors considered in the production of yam and not basically capital and labour and these factors should be put into consideration when designing policies for yam farmer's production.

IV. CONCLUSION

This study of ours reveals that, yam production factors can be substituted for in Nassarawa state, thus an increase in capital possession of the farmers reduces human drudgery. The factors capital and labour can be easily shifted or substituted since it is constant and this implies that for an improved production, increase capital utilization and reduction of wages paid for labour to reduce human drudgery in the form of labour is a policy recommendation for our findings. Thus, we therefore recommend an intensification of capital inputs (machinery) use rather than human labour in yam production. Also, there is the need to consider other factors when designing policies to encourage an increase in yam production. Thus, for us to increase productivity there is the need to make policies that will encourage technology applications, and finally most analysis have confirmed it that the elasticity of substitution is among the most powerful determinants of capital accumulation and growth when we consider the CES production function according to Grandville, 2010; Arne Henningsen and Geraldine Henningsen, 2012, thereby having a higher a higher effect on social welfare.

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