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Analysis of the Technical Efficiency of Castor Farmers in Oyo and Kwara States, Nigeria

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Abstracts

This study was carried out to evaluate the technical efficiency and production practices of castor farmers in Oyo and Kwara States, Nigeria. Snowballing sampling technique was used. Data on production practices, inputs, and outputs were collected with the aid of a structured questionnaire by trained enumerators and analysed by using data envelopment analysis (DEA). Results showed that the mean technical efficiency was 0.4272 or 42.72%, the maximum efficiency was 1 and the minimum efficiency was 0.1315. Only 14% had a frontier technical efficiency of 1. For the castor farmers to operate on the production frontier, the efficiency needs to be increased by 57.28%. Technically inefficient farms should emulate the operating practices of the most productive farms, to improve their performance. Furthermore, the slacks of the DEA showed that the two most overused variables were seed and labour. The farmers need to use the right quantity of seeds and labour in other to reduce costs without reducing the output. The production practices for castor production were divided into three steps; pre-planting, planting, and post-planting. The list of operations included; land clearing, ploughing, ridging planting, weeding with hoe/machete, herbicide spraying, pesticide spraying, fungicide spraying, fertilizer application, pruning, harvesting, shelling and winnowing. From the study, it can be concluded that if the castor farmers were to operate on the production frontier, the efficiency of input usage would have to increase by 57.28%.

Keywords: farmers' technical efficiency, castor, cultural practices, dea, slacks, Nigeria

1. Introduction

Agriculture is very important to Nigeria's economy. The contribution of agriculture to total GDP was 24.17% in 2021 (NBS, 2022). Nigeria's agricultural resources and potentials are enormous and the wide variation in agro-climatic conditions across the country allows a wide range of crops to be grown and different types of animals to be reared. The wide ranges of crops include tubers, cereals, legumes, tree crops, vegetables, and fruits. Agriculture has also been considered as the backbone of the industrial sector providing raw materials for manufacturing, such raw materials include, starch from cassava, sap from rubber trees, hides from animals, and; vegetable oils from oil palm, groundnut, castor beans and soya bean.

Historical evidence shows that the castor plant has been in existence as far back as 6000 years. Africa is regarded as the origin of the plant because of its usage during the mummification of the late Egyptian Pharaohs. The poisonous ricin must have been used as a preservative ingredient during the burial ceremony. Today, the use of castor as a mummy preservative has gone extinct with the civilization that made use of it.

However, the usage of castor is no longer limited to Africa as other parts of the world are now showing interest in the crop. The top ten countries producing castor seeds in large quantities include, India, Mozambique, China, Brazil, Burma, Ethiopia, Vietnam, Paraguay, South Africa and Angola (FAOSTAT, 2017) Castor oil is used in a variety of industries, including painting and coatings, polyurethane coating, plastics, transportation, cosmetics, textiles, and leather. Castor is used as a raw material in over 700 industrial products including medicine, cosmetics, lubrication, paints, polish, nylon, candle wax, beauty creams, hair cream, beauty soaps, foams, biodiesel, and anti-freeze lubricants and its demand is increasing at a rate of 3-5 % per year. (Anjani, 2011). Rilsan B, developed by Atochem, is one of the major products derived from castor oil in France. This 100% castor-based product has a wide range of applications, including rotating glass car wipers, ski boot fixatives, and use in truck air brake systems (Labalette *et al.,* 1996). In recent years the Raw Materials Research and Development Council (RMRDC), an agency of the Federal Government of Nigeria, started promoting the commercial cultivation of the crop because of its many industrial uses.

Though the commercial cultivation of castor plants is newly being promoted, it is gradually gaining popularity among Nigerian farmers. Due to the plant's tropical nature, the crop is well adapted to Nigeria's climatic conditions. Castor is a drought and heat-resistant shrub that can also thrive in Southern Nigeria as well as semi-arid savannas such as Adamawa and Yobe, where temperatures can reach 45^{o} Celsius from March to May. The castor plant is highly valued for its oil; the oil is the most viscous naturally occurring oil and can remain liquid in sub-zero temperatures (Shaik, *et al*,. 2021).

Companies, entrepreneurs, and governments are waking up to the potential of castor bean, castor oil, and castor oil derivatives. In the past few years, several countries which have little or no land under castor cultivation have started making serious exploratory efforts at growing castor. Companies are conducting cutting-edge research on the use of castor in the production of bioplastics and biopolymers such as polyurethane, nylon, and others (Zhang, 2013). In the coming years, therefore, more countries and companies will be involved in the production and processing of castor leading to increasing competition. In other words, for the governments to maximize the benefits from the numerous potentials of castor production, it is not enough to just encourage production, they must ensure efficient production.

There are two definitions of technical efficiency reported in the literature (Farrel, 1957). The first of these is Farrell's radial definition (1957). The difference between unity (100% efficiency) and the maximum equi-proportional reduction in inputs is defined as the input-reducing radial measure of technical efficiency for a unit (while maintaining the production of originally specified output levels). If this difference is zero, the unit is efficient; otherwise, the unit is inefficient. The difference between unity (100% efficiency) and the maximum augmentation of outputs is defined as the output-increasing radial measure of technical efficiency (while still utilizing the originally specified input levels). Koopmans' (1951) definition of technical efficiency is the second. The firm is technically efficient if and only if an increase in one output results in a decrease in another output so that the input level is not compromised, or if it results in an increase in at least one input. In other words, a decrease in one input must result in an increase in another input to avoid compromising the output, or else must result in a decrease in at least one output. Technical efficiency, according to Esparon and Sturgess (1989), is concerned with efficiency in relation to factor-product transformation. To be considered technically efficient, a farm must produce at the production frontier level. A farmer's technical efficiency is critical because resources are scarce and, in most cases, expensive for farmers to purchase pesticides and labour as factors of production. Productive factors of production are those that are efficient in both technical and physical terms. Several authors, including (Chirwa 2007), (Tchale 2009), and (Wadud 2003), have attempted to estimate Technical Efficiency (TE) and its potential determinants in the agricultural sector.

There are two common methods for measuring technical efficiency, Data Envelopment Analysis and Stochastic Frontier Analysis. Aigner *et al*., (1977) and Meeusen & Vanden-Broeck (1977) proposed stochastic frontier analysis, which has a wide range of applications in the literature. Battese and Coelli (1995) proposed a stochastic production function with firm effects as a truncated normal random variable, with inefficiency effects influenced directly by some variables. While Data Envelopment Analysis (DEA) was originally designed by Charnes, *et al.* (1978) to measure the relative efficiencies of organizational or decision-making units (DMUs). It is a non-parametric performance assessment methodology. Here, the technical efficiency measurement generally involves comparing a decision-making unit's (DMU's) production plan to a production plan that lies on the efficient production frontier or isoquant (Charnes *et al*,. 1978).

Even though the castor plant is said to have originated from Africa, it is newly being promoted as a commercial enterprise in Nigeria. Knowledge of optimal production practices among farmers appears to be inadequate. Thus, this research has been focused on describing the cultural practices in castor production and analysing the efficiency of the castor farmers in Nigeria.

2. Materials and Methods

2.1 Study Area

The study was conducted among castor farmers in Kwara and Oyo States, Nigeria. Kwara State is in the North-central of Nigeria and Oyo State is in the Southwestern region. The climates of both states are highly favourable for the agrarian activities of its teeming population who grow tree crops such as cocoa, oil palm, cashew, oil palm, and arable crops like maize, guinea corn and cassava. The majority of the population consists of smallholder farmers cultivating food and cash crops at a small-scale level. Livestock farming is also an important occupation of the populations of Kwara and Oyo States who rear pigs, goats, sheep, rabbits, and chickens. Adeyonu, (2016), Oyegbami, *et al*,. (2016).

2.2 Sampling Procedure and Data Collection Methods

According to Ghaljaie *et al*,. (2017) snowball sampling is a purposeful method of sampling which is used when samples with the desired characteristics are difficult to obtain. Snowball sampling was employed in this study because castor farmers were not easily accessible since the government has just started promoting the enterprise. In Oyo State, five Local Government Areas (LGAs) were sampled, namely Ogbomoso South, Ogbomoso North, Ibarapa East, Orire, and Iddo. In Kwara State, the five LGAs chosen were Oyun, Asa, Offa, Ilorin West, and Ilorin South LGAs. Data were collected from 100 farmers spread across 28 villages.

2.3 Method of Data Analysis

Descriptive analysis (measures of central tendency and dispersion) was used to present the inputs and outputs data used for the DEA. In addition, the distribution of castor farmers' technical efficiencies was presented as frequency distribution and a histogram.

In this study, technical efficiency was analysed using the Data Envelopment Analysis (DEA) method. DEA is a multi-factor productivity analysis model for measuring the relative efficiencies of a homogenous set of decision-making units (DMUs), which in this case, is castor farmers. According to (Coelli 1995), the two main benefits of DEA are that it does not require the assumption of a functional form to specify the relationship between inputs and outputs and that it does not require the distributional assumption of the inefficiency term. The former implies that unnecessary constraints on the functional form can affect analysis and distort efficiency measures (Fraser & Cordina, 1999). According to Coelli *et al.*, (1998), the constant returns to scale (CRS) DEA model is only appropriate when the farm is operating at an optimal scale. This is however assumed to be impossible in a developing country such as Nigeria due to many reasons which include financial constraints, imperfect competition, inadequate farm inputs, etc. A variable return to scale (VRS) DEA is more flexible and envelops the data more tightly than the CRS DEA. The VRS DEA model was developed by Banker, et al., (1984).

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An input-oriented VRS DEA model was used in this study to estimate the technical efficiency of castor farms in the study area. Following Coelli *et al*.,1998), an input-oriented variable return to scale DEA model for estimation of technical efficiency is specified as:

$\text{Min.}\Theta,\lambda\ \Theta,$

Subject to: $-yi + Y\lambda \geq 0$

$\Theta\ xi - X\lambda \geq 0$

$N1/\lambda = 1$

$\lambda \geq 0$

where,

Y = castor output matrix for N farms.

Θ = the input technical efficiency score having a value $0 \leq \Theta \leq 1$.

X = an input matrix for N farms.

λ = N by1 vector of weights which defines the linear combination of the peers of i^{th} farm.

yi = quantity of castor output of i^{th} farm (kg)

The inputs (X) considered are;

X_1 = Amount of pesticide (Litres)

X_2 = Amount of fertilizer (kg)

X_3 = Size of castor farm (Hectares)

X_4 = Amount labour used (Mandays)

X_5 = Castor seed (kg)

U_i = Technical inefficiency

3. Results and Discussions

3.1 Summary of Input and Output Variable

The summary of the variables used in estimating the technical efficiency is presented in Table 1. The mean seed planted was 9.2kg, the planted seed was the most important variable to the farmer. The mean man-day of labour used in castor farming was 59.13 indicating that the cultivation of castor was labour intensive for the farmers. Most of the farmers were involved in the cultivation of arable crops most of which were food crops that were meant for household consumption or sales in the local markets. Castor was being cultivated as a commercial crop which was mostly sold to processors without value addition by the farmers. The mean castor farm size was 2.3 hectares which shows that most of the farmers were cultivating castor on small scale.

Table 1. Summary of Input and Output Variable

Variable	**Mean**	**Standard Deviation**	**Mean per Hectare**
Pesticide (Litres)	11.1	15.55	4.8
Fertilizer (Kg)	81.19	40.78	35.3
Castor Farm Size (Ha)	2.3	3.49	1,0
Labour (Man-day)	59.13	62.58	25.7
Castor Seed Input (Kg)	22.04	22.01	9.6
Castor Seed Output (Kg)	1414.04	4821.52	648.3

Source: Field survey, 2020

3.2 Castor Farmers Efficiency Scores

Table 2 contains the DEA result of the technical efficiency of the castor farmers covered by the study. The mean efficiency was 0.4272 or 42.72%. If the castor farmers were to operate on the production frontier, the efficiency of input usage needs to be increased by 57.28%, the maximum efficiency was 1 and the minimum efficiency was 0.1315.

Table 2. Technical Efficiency Scores

Technical Efficiency scores	Frequency	Percent
0.1-0.19	13	13.0
0.2-0.29	35	35.0
0.3-0.39	11	11.0
0.4-0.49	15	15.0
0.5-0.59	6	6.0
0.6-0.69	3	3.0
0.7-0.79	2	2.0

0.8-0.89	0	0.0
0.9-0.99	1	1.0
1	14	14.0
Total	100	100.0
Mean	0.4272	
Min	0.1315	
Max	1	

Source: Field survey, 2020

The distribution of the farmers by their technical efficiency presented in Table 2 indicates that the technical efficiency of the castor farmers ranges from 0.1315 to 1 which is 13.15% to 100%. Up to 13% of the farmers had their efficiencies between 0.1 - 0.199 while another 35% of the farmers had technical efficiencies between 0.2 - 0.29. About 11% and 15% of the farmers had their efficiencies each between 0.3 - 0.39 and 0.4 – 0.49. Also, 6% of the farmers had efficiencies which were between 0.5 and 0.59, while 3% fell between 0.6 and 0.69. Only 14% had a frontier technical efficiency of 1. The histogram of the technical efficiencies in Figure 1 provides a visual representation of the spread of the technical efficiencies. It shows that the efficiencies were not normally distributed, rather they are skewed towards the lower bound of the distribution. The implication of this is that RMRDC, the agency of the Nigerian Government that is promoting castor production, needs to design programs that help the farmers improve their efficiencies. The efficiency gain, the least efficient farmer can target was 0.8685 while the average farmer can strive to achieve an efficiency gain of 0.5728.

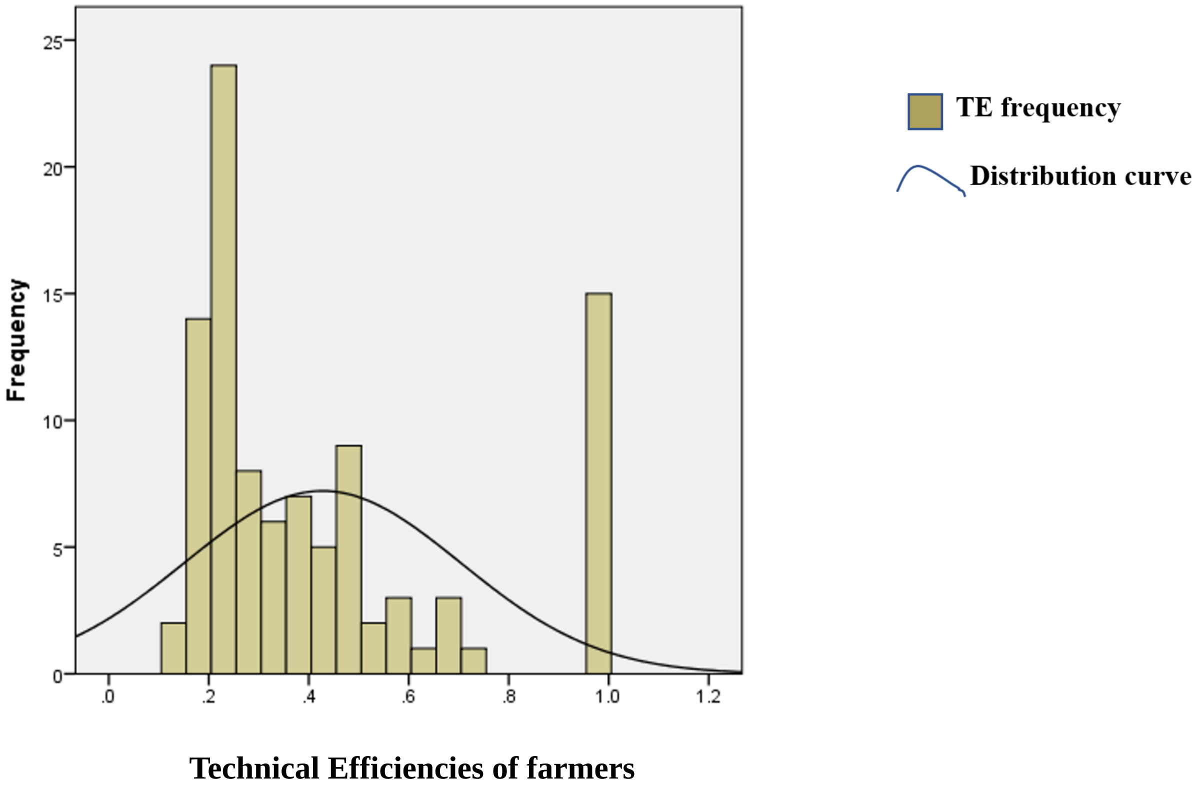

Figure 1. Histogram of Castor Farmers' Technical Efficiencies

Source: Field survey, 2020

3.3 Slack Measure of DEA

The slack measurement of efficiency in DEA is a scalar measure that deals directly with input excesses and output shortfalls of the decisions making units concerned. The slack indicated the excessive usage of the inputs. Thus, the farm can reduce its expenditure on an input by the amount of slack without reducing its output. The five variables represented as the inputs are pesticide, fertilizer, land, labour, and seed as seen in Table 1.

Table 3. Lists of inputs and their mean slacks

Inputs	Mean Slacks
Pesticide	2.8919
Fertilizer	18.274
Land	0.0563
Labour	12.721
Seed	9.9248

Source: Field survey, 2020

When the table above is compared with Table 1, two inputs stand out based on over-usage; seed and Labour (man-day). The production of castor farming in the study area was on a small-scale level and only a few farmers mechanized their production. The farmers need to use the right quantity of seeds and labour in other to reduce costs without reducing input.

3.4 Production Practices among Castor Farmers

Just like Chakrabarty *et al*,. (2020) and Kaur *et al*,. (2020), the production practices of castor in Southeast Asia follow a similar pattern with the study area. Table 4 lists the operations being carried out in the course of castor production The production practice is divided into three steps; pre-planting, planting, and post-planting.

Table 4. Production Practices

Production Practices	
Ridging with hoe	Planting
Harvesting	Shelling and winnowing
Weeding with hoe/machete	Herbicide spraying
Pruning	Ploughing
Pesticide spraying	Ridging
Fungicide spraying	Fertilizer application

Source: Field survey, 2020

Pre-planting Operations

Pre-planting operations are bush clearing, ploughing, and ridging. Bush clearing is done at the end of the agricultural production season in December or shortly before the beginning of the rainy season by March or April. Ploughing is done using tractors for those who have access to tractors while those who do not make use of hoes to make ridges. The time for ridging is between February and March.

Planting Operations

After the land has been prepared the seeds are planted usually at a spacing of 1.5-2m along the ridges and 2 seeds are dropped per hole. The seed rate was 7 – 10 kg/ha. The planting period is between March and April. Some farmers prefer to spray herbicide on the same day they plant the seeds as it is a more efficient method for controlling weeds. Two different types of herbicides are being used; non-selective post-emergence herbicide to kill weeds on the surface immediately after there is contact and a selective pre-emergence herbicide to kill weed seeds in the soil, this method often keeps the farm weed free for three months.

Post-planting Operations

These operations are quite technical and delicate because if a routine is skipped it can have a drastic impact on the yield of the plant. They include;

Herbicide spraying: As earlier stated they are of two types pre and post-emergence. The most used is the post-emergence contact herbicide. The quantity used was 5-7 bottles (litres) per hectare. If the herbicide is not sprayed as part of the planting operation, that is on the day of planting, it is usually sprayed 1-2 months after planting.

Pesticide spraying: This is a very important operation yet delicate because it must be done before flowering so that pollination will not be hindered. The operation is usually carried out between June and August. The pesticide usually applied was cypermethrin.

Fungicide spraying: This operation is also carried out before flowering so that pollination will not be hindered. Fungus is known for attacking the flowers of the castor plant, this often leads to premature fruits which result in fruit abortion. This operation is usually carried out between June to August.

Pruning: This is not a common operation among castor farmers, but the operation is slowly gaining relevance. Pruning is being encouraged due to the result of recent research which indicated that pruning leads to apical growth along the meristem of the plants leading to more vegetative growth, improved flowering, and more fruit production. The operation is done at an early vegetative growth between May and June.

Fertilizer application: there are two types of fertilizer applied to castor plants, namely; granule NPK 15:15:15 (solid) and liquid fertilizer NPK 20:20:20 (Super gro). The first one is applied to the soil about three inches away from the roots of the castor plant while the latter is sprayed on the leaves of the plant. The operation is done between May and August.

Harvesting: This operation is done between August and December when the seeds are matured. The fruit is ready for harvesting when the pods are yellowish-green or when they begin to turn brown as a result of drying although at this stage if the farmer is not observant the pods could easily split due to explosive mechanisms and then be dispersed around the farm.

Shelling and Winnowing: These sun-dried two operations involve removing the seeds from the pods and cleaning them by separating the chaff from the seed. Usually, these operations do not have any time frame. After harvesting the seeds are sun-dried and then shelled either manually or by using a decorticator which is a sheller for castor seeds. Willowing is done manually after shelling. The operations are usually carried out in September and December.

3.5 Limitations of the Study

The main limitation of the study is that castor is an emerging commercial crop in Nigeria even though the plant originates from Africa and there has not been much research done on the crop. It was hence not possible to compare the findings of the study with those of similar studies in other locations in Nigeria.

4. Conclusions and Recommendations

The input-oriented Data Envelopment Analysis, which was used to assess the relationship between castor output and all inputs, namely; pesticide, fertilizer, farmland, labour, and seed, shows that the castor farmers had a mean technical efficiency score of 42.72%. castor farming is a newly introduced enterprise. It is obvious that there was a knowledge gap that needs to be filled in the combination of inputs. Since castor production is an enterprise being promoted by the government, it is important for government extension agents organize programs to train the farmers on the cultural practices of castor production. From the study, it can be concluded that if the castor farmers were to operate on the production frontier, the efficiency of input usage would have to increase by 57.28%.

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