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Economic Efficiency of Organic Farming Adoption by Cocoa Farmers in Southwest, Nigeria

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Abstract: The study was carried out in southwest, Nigeria. The main objective of the study was to determine the level and efficiency of organic farming technology among cocoa farmers in southwest Nigeria. The study ascertained the level of organic farming adoption among cocoa farmers; determined the technical, allocative and economic efficiencies. These were with a view to determining the profitability and efficiencies of organic cocoa farming in Southwest, Nigeria. Primary data were collected from 300 organic cocoa farmers in the study area through multi-stage sampling technique. The data obtained included socio-economic characteristics, level of adoption as well as efficiencies of organic cocoa farmers. Data were analyzed using descriptive statistics, technology adoption index and endogeneity corrected stochastic frontier production function. Results from descriptive analysis showed that the average age of organic cocoa farmers was 52±14.02 years while the average years of schooling was 10±8.72 years. Majority of the farmers were married (85.7%) with average farming experience of 4 years. The results showed that farmers adopted 4 out of 12 organic cocoa farming practices, 39% of organic cocoa farmers were full adopters while 61% were partial adopters. The overall estimated technical, allocative and economic efficiencies for the organic cocoa farmers ranged from a minimum of 0.13, 0.20, and 0.17 to a maximum of 0.94, 0.96 and 0.94 respectively. However, the estimated technical, allocative and economic efficiencies for full adopters ranged from a minimum of 0.44, 0.47 and 0.49 to a maximum of 0.94, 0.96 and 0.94 while partial adopters ranged from 0.13, 0.20 and 0.17 to maximum of 0.92, 0.90 and 0.90 at ($p<0.01$) respectively. The study concluded that efficiency of organic cocoa farmers was influenced by use of organic fertilizer, frequency of weeding and labour in man-days.

Keywords: Organic Farming, Adoption, Cocoa

1. Introduction

The cocoa sub-sector remains critical to the economies of several West African countries, as it produces roughly 80% of the world's cocoa and provides employment for millions of smallholder farmers [14]. At present, Nigeria ranks as the fourth largest cocoa producing nation in the world, responsible for approximately 12% of total global production, trailing behind Cote d'Ivoire, Ghana, and Indonesia [3]. Cocoa has made significant contributions to the development of the economy, and no other agricultural commodity has gained more with regards to foreign exchange earnings than cocoa [6].

Cocoa is commonly grown on small farms, with many of these farms covering less than two hectares [36]. Productivity in the cocoa sub-sector has been regarded as critical to the development of the Nigerian economy [3]. Productivity and efficiency improvements in cocoa production allow a tremendous increase to produce more cocoa at lower cost, but the challenge of constrained availability of resources, combined with difficulties in the suitable use of resources for production, can sometimes inhibit efficient resources utilization. Records from [24] shows that there has been an unsteady flow in cocoa beans produced in Nigeria in the last three years, from 200,000 metric tonnes in 2015/2016 to 245,000 metric tonnes in 2016/2017 followed by a 5% decline in 2017/2018 to 240,000 metric tonnes. Cocoa is produced in six states in Southwest Nigeria, Ondo, Osun, Ekiti, Ogun, Oyo and Edo State with (Ondo and Osun) grouped as high producing states, while the medium producing (Ogun, Oyo and Ekiti) States. Ondo States records an output capacity estimated at

92,200 metric tonnes per annum while Osun State produces 74,100 metric tonnes in 2011/2012 [3]. Nigeria has been unable to sustain its former dominance in the global cocoa market due to several challenges, including stagnant crop size - yields losses and low production, ageing trees and farmlands, pest and disease invasion, irregularity in production patterns, old cocoa trees, old and ageing farmers, lack of new plantations, inconsistent quality of beans and a lack of awareness of good practices [37]. However, incidences of diseases and pests have been a significant contributor to the setback of cocoa production and export. Cocoa farmers use various practices to keep pest infestations under economic control, including the use of pesticides to inhibit attacks on cocoa plantations [15].

Pesticides are a significant component of the modern agricultural technology that has been widely adopted by Nigerian cocoa farmers to control pests, diseases, weed and other plant pathogens, with an effort to reduce or eliminate yield losses and maintain high product quality because of their quick and effective action [10]. According to [34] cocoa pesticides represent approximately 37% of total annual agrochemical usage in Nigeria. Pesticides are toxic by nature and can be dangerous if not managed properly; therefore, limiting their use through registration is extremely beneficial to developing countries [27]. The European Union's regulatory committee has established maximum levels of residue (MRLS) in commercial goods traded on the global market, which include cocoa. Specifically, based on the European Food Safety Authority, the maximum residue limit for cocoa beans is 0.01mg/kg. Still, cocoa beans from Nigeria range from 0.03mg/kg and 4.6mg/kg of dichlorvos pesticide [4]. However, due to challenges inherent from pesticide use, this has led to the development and promotion of healthy, nutritious, and environmentally friendly technology [24].

Organic farming technology is regarded as an appealing substitute for long-term development in agricultural sector in many countries because it provides an important integration of low external input technology, environmental conservation, and input/output efficiency [11]. Several cocoa farmers are concerned about organically resolving pest and disease challenges [37]. The most common cocoa disease, black pod disease, is controlled organically through farm sanitation and the use of neem leaf extract, as well as the planting of resistant varieties. This traditional practice also includes reducing shade, weeding, pruning cocoa trees regularly, removing epiphytes and chupons regularly [19].

Reports shows that a lot of research has been conducted in organic farming technology in other agricultural sub-sector such as rabbit production, fish production as well as vegetable production [9]. However, little research has been carried out on organic cocoa farming in Nigeria. Nigeria's potential to use its agricultural production potential in organic farming is dependent on the level at which cocoa farmers adopt improved agricultural technologies in their production activities [22]. Cocoa farmers do not apply all the recommended technology packages that are introduced to increase productivity resulting in different levels of organic farming technology adoption such as Non-adoption, Partial adoption and Full adoption.

Furthermore, farmers may use resources rationally though not at the optimal economic level resulting in inefficiency in resource utilization. According to [31] for organic cocoa to make the same profit as conventional production, 3.46t of organic cocoa would be produced by farmers (compared to average conventional yield of 4.17t, organic cocoa produces 16.9% less). However, literatures argued that the yield from organic agriculture is lower than the yield from the conventional methods [12]. Surprisingly, the expected organic cocoa yield decreases as the organic premium increases (19.2%, 21.4%, and 29.0% at $50, $100, and $300 per ton organic premium, respectively). The indication of this suggests that farmers will produce organic cocoa at the same or more profit if they sell their organic cocoa at $300 per ton of organic premium, by producing 29% less than conventional cocoa rates. It encourages a thorough assessment of farm efficiency in terms of technical, allocative and economic efficiency to improve productivity among organic cocoa farmers.

As a result, it is necessary to investigate the relationship between input, farm characteristics, socioeconomic factors, and efficiency in organic cocoa production. There is scarcely any literature on the adoption and the efficiency of organic farming among organic cocoa farmers in the study area. In view of this, the study is geared towards answering the following research questions,

i. What is the level of adoption of organic farming among cocoa farmers in the study area?
ii. What are the cocoa farmers' efficiencies in adopting organic farming?
iii. What are the constraints among organic cocoa farmers in the study area?

The main objective of this study is to determine the level and analyze the economics of organic farming technology among organic cocoa farmers in southwest Nigeria. The specific objectives of the study are as follows:

i. ascertain the level of organic farming adoption among cocoa farmers in the study area.
ii. determine the technical, allocative, economic efficiencies of organic farming in cocoa production in the study.
iii. examine the constraints among organic cocoa farmers in the study area.

2. Analytical Techniques

2.1. Technology Adoption Index

Adoption index involves the computation of indices based on the technology adopted by each farmer and the recommended use of technology. The maximum adoption score that can be obtained is fixed at 1, after dividing the number of practices used by cocoa farmers by the total package of technology recommendations. Organic farming practices include the use of organic cocoa seeds, the application of manure, compost, mulching, farm sanitation, regular weeding, the application of organic fertilizer, use of natural pesticides, reduction of shade, removal of epiphytes and chupons, cultivation of nitrogen-fixing crops, and the breeding of resistant varieties. The adoption index adapted from [29] and [32] was used to determine levels of technology adoption among individual farmers. It is used to determine the rate at which each farmer adopts organic farming technology.

$$AIi=\Sigma\{(\frac{ATi}{RTi})\} \quad (1)$$

Where;

AIi is adoption index of ith farmer,

ATi is the number of practices used by a farmer,

RTi is the total number of recommended technology farmers ought to apply,

Farmer's group is estimated by their position in relation to the grand mean adoption score. A farmer with a score equal or higher than the grand mean is referred to as a Full Adopter of Organic Technology. In comparison, those with a score lower than the grand mean are referred to as Partial Adopters of Organic Technology.

2.2. Stochastic Frontier Function

Frontier function was used to analyse SPF, the endogeneity corrected stochastic frontier production function was used and it is specified as:

$$\ln Y_i=\beta_o+\beta_1\ln X_1+\beta_2\ln X_2+\beta_3\ln X_3+\beta_4\ln X_4+(U_iV_i) \quad (2)$$

Where, ln = the natural logarithm;

β_o = the intercept

i = the i-th sample farm;

Y_i = Output of organic cocoa (kg);

X_1 = Total quantity of organic fertilizer (kg);

X_2= Frequency of weeding;

X_3 = Total number of labour (in man-days) both family and hired labour

X_4 = Total number of labour used for harvesting;

$\beta_1, \beta_2, \ldots \beta_4$ = Vectors of unknown parameters.

The inefficiency model is defined by:

$$U_i = \partial_0 + \partial_1 Z_1 + \partial_2 Z_2 + \partial_3 Z_3 + \partial_4 Z_4 + \partial_5 Z_5 + \partial_6 Z_6 + \partial_7 Z_7 \quad (3)$$

Where: U= farmer's technical inefficiency;

∂_s = parameters estimated;

i = i-th farm in the sample;

Z_1= age of the farmers (years)

Z_2= household size (number)

Z_3= farmer's education; (years)

Z_4= experience in organic farming (years)

Z_5= Organic cocoa farm size (hectares)

Z_6= age of cocoa trees (years)

Z_7= numbers of contact and meeting with extension officers

Z_8= organic farm demonstration

Z_9= beneficiary of Government programme

$$Ci = \alpha_0 + \alpha_1 P_{1i} + \alpha_2 P_{2i} + \alpha_3 P_{3i} + \alpha_4 P_{4i} + \alpha_5 P_{5i} + V_i + U_i \quad (4)$$

Here C is the total annual production cost; P_1 is the average price of organic fertilizer; P_2 is the average wage rate per man-day of labour; price per kg of planting materials; P_3 is the average wage rate of harvesting; P_4 is the land rent; P_5 is the cost of transportation and Y is as previously defined. The B's are parameters that must be estimated. Maximum likelihood approach was used to estimate the frontier functions (production and cost). As a result, farm-level economic efficiency (EE) was calculated using the relationship:

$$EE = 1/ \text{Cost efficiency (CE)} \quad (5)$$

$$AE=EE/TE \quad (6)$$

Table 1. *Distribution of respondents by adoption index.*

Adoption index	All Respondents (n=300)		Partial Adopters (n=183)		Full Adopters (n=117)		Cumulative percentage	T-test
	Frequency	%	Frequency	%	Frequency	%		
<0.2	126.0	42.0	126.0	42.0	-	-		
0.2 – 0.4	55.0	18.33	55.0	18.33	-	-	61.0	
0.41–0.60	48.0	16.0	2.0	0.6	46	15.33		
0.61-0.80	52.0	17.33	-	-	52.0	17.33	39.0	
≥0.81	19.0	6.34	-	-	19.0	6.34		
Minimum	0.063		0.063		0.50			
Maximum	0.938		0.438		0.938			
Mean	0.364		0.177		0.657			43.700***
Std. deviation	0.252		0.073		0.117			

Source: Field survey, 2021

*** Significant at 1%.

3. Result and Discussion

3.1. Level of Adoption of Organic Cocoa Farming

Table 1 shows that the adoption index for organic cocoa technology ranged from 0.06 to 0.94, with a mean of 0.364. Based on the mean figure, the adoption level was separated into two categories: partial adopters with indices 0.364 and complete adopters with indices >0.364. There was a significant difference between the mean adoption index of partial adopters (0.177) and full adopters (t = 43.700, p<0.01)

(0.657). 61.0 percent of farmers were partial adopters of organic cocoa technology, while 39.0 percent were complete adopters. This indicates that organic cocoa adoption has made minimal progress in the research area, implying that the majority of farmers continue to utilize conventional farming methods in cocoa production.

3.2. Socio-economic Characteristics of Organic Cocoa Farmers

The levels of organic cocoa technology adoption were examined based on the socio-economic characteristics of the farmers. Gender, age, level of education, household size, organic cocoa farming experience, farm size, and the number of visits by extension agents are among the socioeconomic characteristics considered.

3.2.1. Gender of Organic Cocoa Farmers

According to Table 2, men constitute the majority of farmers in the study area (87.0 percent). According to the findings, the majority of partial and full users of organic cocoa technology in the research area were men (88.0 percent and 85.0 percent, respectively). These findings suggest that men dominate organic cocoa cultivation in the study area. This suggests that men are more actively involved in organic cocoa production than women, which could be explained by cultural norms that offer men more opportunities to own land than women.

3.2.2. Age of Organic Cocoa Farmers

The average age of organic cocoa farmers who were partial or full adopters was approximately 52 years. The t-test result also shows that there was no significant difference in the mean ages of the farmers in the two groups, implying that they are all in the same age group. The findings revealed that the average age of cocoa farmers in the study area was approximately 52 years, suggesting that the average farmer in the study area is older. This could be due to the issue of migration which is being observed in recent times where the youths migrate to the cities in search of greener pastures while leaving the elderly ones in the rural areas. This corroborates the findings of [2] that the average cocoa farmer is over 50 years old. According to [26], a farmer's age mostly correlates with his or her farming experience, indirectly influencing his or her productivity.

3.2.3. Years of Education of Organic Cocoa Farmers

Education is substantial among the total sample (35.0%) of organic cocoa farmers in the study area. Furthermore, partial and full adopters of organic cocoa technology in the study area, respectively, are literate. This indicates that a greater proportion of respondents had a formal education. Cocoa farmers' ability to read and write may aid in the implementation of new technologies. According to [38], education will assist farmers in comprehending the complexities of the factor and product markets, as well as predisposing them to adopt and employ better farming practices.

3.2.4. Years of Farming Experience of Cocoa Farmers

The average farming experience in organic cocoa farming was approximately 4 years. The findings also revealed that the average number of years for partial adopters was three, while full adopters had four. The finding implies that farmers with more years of experience will have a better understanding of improved technology and will be more likely to implement it than farmers with fewer years of experience. This finding backs up [37] assertion that farmers who have been practicing for a long time are more willing to adopt new technologies.

The average household size among cocoa farmers in the study area was six members. However, the results revealed that partial and full adopters of organic cocoa had an average of 5 household members. This could result in increased labour availability, lowering the cost of hiring workers. This finding is consistent with research conducted in Ondo State [36, 5]. This suggests that farmers with large households could act as insurance against a shortage of farm labour and food security.

3.2.5. Total Number of Hectares of Land Used for Organic Cocoa Farming

Table 2 shows that cocoa farmers cultivated an average of 6 hectares. In addition, both partial and full organic cocoa adopters cultivated an average of 6 hectares. This indicates that majority of the respondents were small-scale farmers. This is consistent with the findings of [38], who discovered that a large proportion of Nigerian cocoa farmers operated on a small or medium scale. This could be related to the fact that small-scale farming predominates in Nigeria's agricultural sector. The t-test results show that the average farmland cultivated by partial adopters and full adopters differs significantly.

3.2.6. Frequency of Extension Visits

According to the findings in Table 2, extension agents visited cocoa farmers three times per month on average. The results also indicated that partial adopters of organic cocoa farmers and full adopters were visited an average of two times per month, with a significant difference in the mean frequency of visitation by extension agents to partial and full adopters. Extension agents visiting farmers could help them learn more about a new technology [25]. [34] also confirmed that frequent contact between cocoa farmers and extension agents improves production due to the information accessed and the training program organized.

3.2.7. Yield of Organic Cocoa

The average yield of cocoa farmers in the study was around 636kg/ha. The results also revealed that, while partial adopters made 521kg/ha on average, full adopters made 816kg/ha on average. As a result, it is more advantageous to fully implement organic cocoa technology. The t-test result revealed a significant difference in yield between partial and full organic cocoa technology adopters. The difference in yield between the two levels of adoption was caused by a discrepancy in the application of recommended organic cocoa technology practices.

Table 2. *Distribution of organic cocoa farmers according to socio-economic characteristics.*

Variables	All respondents (300)	Partial Adopters (183)	Full Adopters (117)	T-test
Gender				
Male	87.0	88.0	85.0	
Female	13.0	12.0	15.0	
Age				
<30	6.1	5.5	6.8	
31-40	20.4	21.3	19.7	
41-50	27.3	25.7	28.2	
51-60	22.2	23.5	21.4	
61-70	15.0	14.8	15.4	
>70	9.0	9.3	8.6	
STD	14.02	14.04	14.06	0.09
Years of Education				
0	22.0	25.0	19.0	
1-6	32.0	30.0	34.0	
7-12	35.0	35.0	35.0	
>13	11.0	10.0	12.0	
STD	8.72	6.0	9.7	
Years of Farming Experience				
≤2	14.8	15.9	13.7	
3-4	33.1	31.2	35.0	
5-6	28.8	25.1	32.5	
7-8	10.2	10.9	9.4	
9-10	9.0	12.0	6.0	
>11	4.1	4.9	3.4	
STD	1.49	1.49	1.55	1.19
Household Size				
1-3	23.9	21.3	26.5	
4-6	41.9	43.7	40.2	
7-9	22.4	23.5	21.3	
10-12	9.2	9.8	8.6	
>12	2.6	1.7	3.4	
STD	2.87	2.88	3.12	1.34
Number of hectares of land				
≤6	78.0	82.4	73.6	
7-9	7.6	6.6	8.6	
10-12	7.7	6.0	9.4	
≥13	6.7	4.9	8.4	
STD	3.28	2.15	3.71	1.76
Number of Extension Visit				
0	13.2	15.3	11.1	
1.0-3.0	33.2	27.9	38.5	
4.0-6.0	13.8	13.1	14.5	
7.0-9.0	5.6	7.7	3.4	
10.0-12.0	21.8	24.0	18.8	
≥12	12.9	12.0	13.7	
STD	0.63	0.67	0.51	2.73***
Yield				
≤250	4.7	9.3	-	
251-500	21.9	40.4	3.4	
501-750	38.7	43.2	34.2	
751-1000	28.7	7.1	50.4	
>1000	6.0	-	12.0	
STD	4602.19	2830.39	6171.26	

3.3. Technical, Allocative and Economic Efficiencies of Organic Cocoa Production in Southwest Nigeria

3.3.1. Estimate of Endogeneity Corrected Stochastic Frontier Production Function

The maximum likelihood estimates for the endogeneity corrected stochastic frontier models are shown in Table 3. A Cobb-Douglas production function was estimated using four inputs: the amount of organic fertilizer used, the frequency of weeding, labour, and labour used for harvesting. As proposed, the first-order coefficients are interpreted as partial production elasticities [18]. Endogeneity is ignored in Model EX, which represents a conventional stochastic frontier model, whereas Model EN is an endogeneity-inclusive model. The stochastic production frontier is estimated differently by both methods, and endogeneity issues may arise. According to the endogeneity test, the organic cocoa technology strategy is endogenous. Endogeneity is evident as a result of the model being jointly significant. These parameters represent the percentage change in dependent variables caused by a change in independent variables. The positive coefficients of the estimated parameters indicated a positive relationship with organic cocoa output. This means that a percentage increase in the estimated positive parameters results in a percentage increase in farmer cocoa output, whereas the negative coefficient has a negative relationship with organic cocoa output. As expected, majority of the coefficients are positive.

The quantity of organic fertilizer used by all respondents was related to the amount of cocoa output and was statistically significant at 1%. The quantity of organic fertilizer coefficient was 0.818. The results show that increasing the amount of organic fertilizer by 100% increases organic cocoa output by 81.8%. According to [42], increasing the amount of fertilizer used boosts the yield of the cocoa crop. According to [20], the use of organic fertilizers could increase the technical efficiency of cocoa farmers, resulting in higher productivity. Organic fertilizers may also play an important role in ecosystem preservation and increasing the availability carbon (C) and nitrogen.

Farmers' weeding frequency during organic cocoa production, on the other hand, was positively related to cocoa output and statistically significant at 5%. The frequency of weeding used had a coefficient of 0.096, indicating that increasing the frequency of weeding by one unit increases cocoa output by 9.6%. This means that increasing the frequency of weeding operations on the plantation is a possibility in order to increase organic cocoa output. This significant positive coefficient is consistent with [8] findings in an Analysis of yield gap and some factors of cocoa (Theobroma cacao) yields in Ghana, where he revealed that a unit increase in weeding frequency leads to a 5% increase in yield.

Organic cocoa output was positively related to the number of man-days of labour used for other organic cocoa farming operations such as organic fertilizer application and pruning. The labour coefficient was 0.406, which was statistically significant at 1%; this result indicates that if labour was increased by 100%, organic cocoa output would increase by 40.6%. The feasible inference of labour's significance in organic cocoa output is not surprising. Organic farming technology is labour intensive, and smallholder farmers in resource-constrained developing countries like Nigeria depend heavily on manual labour. This result agrees with [41] findings, which confirmed that labour intensification has a positive effect on farm technical efficiency.

Table 3. *Maximum likelihood estimates of endogeneity corrected stochastic frontier for organic cocoa production in Southwest Nigeria.*

Variables	**All Respondents**			
	Model EN		**Model EX**	
	Coefficients	**Standard errors**	**Coefficients**	**Standard errors**
Organic fertilizer qty (log)	0.818***	0.308	0.119***	0.029
Freq. weeding (log)	0.096**	0.082	0.062**	0.030
Labour in mandays (log)	0.406***	0.295	0.895***	0.029
Harvest (log)	0.072	0.072	0.008	0.035
Constant	2.377***	0.367	-1.346	1.741
Inefficiency model				
Age of farmer	0.032*	0.019	0.018*	0.010
Gender of farmer	0.686	0.864	0.059	0.364
Household size	-0.254**	0.106	-0.088**	0.041
Years of formal education	-0.047	0.049	-0.009	0.024
Access to credit	0.512	0.468	0.150	0.238
Years of org. farming experience	-0.059*	0.026	-0.014**	0.084
Number of extension visits	-0.026*	0.043	-0.045*	0.024
Farm size	-2.340**	0.931	-1.146***	0.329
Organic farm demonstration	-1.154*	0.604	-0.117	0.244
Beneficiary of govt. prog.	-0.651	0.605	-0.027	0.276
Constant	-3.260*	1.962	-1.442**	0.722
	-2.595***	0.267		
			-2.246***	0.149
Eta1 (Organic fertilizer cost (log))	-0.708**	0.312		
Eta2 (Labour in mandays (log))	0.492**	0.192		
Eta endogeneity test	8.09**	p = 0.017		
No of observations	300		300	
Log likelihood	-859.89		-143.06	
Mean production efficiency	0.8153		0.7178	
Median production efficiency	0.8704		0.7688	

Source: Data Analysis, 2021

*** Significant level at 1%, ** Significant level at 5% and * Significant level at 10%

S.Es are robust standard errors, EN = Endogeneity corrected and EX = Endogeneity ignored.

Note: A negative sign of the parameters in the inefficiency function means that the associated variable has a positive effect on technical efficiency, and vice versa.

The exogenous variables in the inefficiency model are selected to examine farmers' managerial capabilities, as well as their access to information and productive resources Technical efficiency estimation is insufficient for deciding on potential policy interventions. Identifying inefficiencies is critical for making farm-level policy recommendations. The estimated coefficients of the determinants of technical inefficiency among organic cocoa farmers in the study area are also included in Table 3. As a result, a positive variable lowers farmer technical efficiency, whereas a negative variable raises it. With the exception of gender, years of formal education, credit access, and government program beneficiary, the results show that six of the eight technical inefficiency variables under the endogeneity corrected inefficiency model are statistically significant. The age of organic cocoa farmers was found to be positively associated with technical inefficiency, with a statistically significant correlation of 10%. Farmers become less efficient as they age, according to the positive coefficient (0.032) of farmer age. This suggests that older farmers are less likely to fully adopt organic farming because they have years of experience using obsolete technology on cocoa farmland. Young farmers are also expected to be energetic and willing not only to work hard, but also to take the risk of investing in innovative farming practices that may increase their production efficiency. Farmers become less efficient in cocoa production as they age [21].

Household size was found to be negatively related to technical inefficiency and was statistically significant at 5%. The size of a household, measured in adult equivalents, is an indicator of labour availability. According to the findings of this study, household size has a negative sign and is statistically significant in reducing the inefficiencies of smallholder rice farmers. This implies that as household size increases, so does respondents' technical inefficiency. A large family size implies the availability of labour by a family that can participate in farming activities and encourage the implementation of organic technology, thereby increasing technical efficiency among organic cocoa farmers in South-west Nigeria. This is consistent with [33] findings which state that as household size increases, technical inefficiency decreases.

Organic farming experience of cocoa farmers was found to be inversely related to technical inefficiency, which was statistically significant at 5%. Organic farming experience has a negative coefficient (-0.059) among cocoa farmers, implying that farmers with more years of farming experience should be more efficient. According to [16], farming experience among organic farmers influences vegetable farmers' production.

At the 10% level, the number of extension visits coefficient (-0.026) was negative and statistically significant, which corresponded to a priori expectations. Farmers who have more contact with extension agents are more efficient, according to the findings, than those who have little or no contact with extension agents. The assumption is that organic cocoa farmers who receive more extension visits will have greater access to information about organic cocoa production. This is consistent with the findings of [17], who discovered that frequent contact with extension agents improves farmer efficiency.

Organic cocoa farm size was negative and statistically significant at the 5% level with a coefficient (-2.340), which corresponded to pre-existing expectations. As a result, as farm size grows, so does technical efficiency. This result is line with the findings of [23, 7], who stated that large farm sizes should have higher efficiency when properly managed. Returns to scale, on the other hand, decrease as farm size increases.

At 10%, the organic farm demonstration was negative and statistically significant. The organic farm demonstration's negative coefficient (-1.154) implies that as a result of organic farm demonstrations, cocoa farmers become more efficient. Farmers who are present at organic technology demonstrations are more efficient than their counterparts. This is consistent with the findings of [1], who discovered that farmers with access to organic farm demonstration are more efficient.

The standard exogenous stochastic frontier model presented in column 4 of Table 3 underestimated the effect of organic cocoa technology on technical efficiency by failing to account for endogeneity. This is consistent with measurement error causing attenuation bias in organic cocoa technology, resulting in a downward bias in estimating the coefficient in the basic SFA model for organic cocoa technology. As a result, assuming that organic cocoa technology is exogenous, the endogenous model's average estimate of technical efficiency is 10% higher than the standard model's estimate (i.e. mean efficiency for exogenous model is 71.8% and 81.5% from the endogenous model).

Dependent on the other covariates, the instrument is strongly correlated with the endogenous variable. At 5%, this correlation is highly statistically significant, which indicates both reliability and a high degree of correlation between this instrument and the endogenous variable. We regressed on the endogenous variable, the instrument and all other covariates (that is, all covariates included in the basic inefficiency model). At the 1% level, the estimated coefficient for the instrumental variable is large (0.77) and statistically significant. According to this study, there are significant technical inefficiencies in South-West Nigeria's cocoa farming, implying that cocoa farm revenues could be increased by 23% by making better use of existing inputs rather than adding resources that raise production costs. Organic cocoa farmers, on average, realize 76.7 percent of potential farm revenues, indicating that revenue potential exists with proper management practices and without the use of additional input resources.

3.3.2. Estimate of Stochastic Frontier Cost Function

Table 4 presents the results of the Cobb–Douglas endogenous and exogenous stochastic frontier cost function estimation. After controlling for endogeneity, the empirical findings show that the production, organic fertilizer price, weeding cost, labour price, land rent cost, and harvesting cost coefficients are all positive and significant, implying that increasing the magnitudes of these variables would result in an increase in the cost of producing organic cocoa beans. This implies that an increase in the estimated positive parameters would result in an increase in the farmers' cost of producing organic cocoa. The negative coefficient, on the other hand, exhibited a negative relationship with the cost of producing organic cocoa. As expected, majority of the coefficients are positive.

Organic cocoa prices, labour prices, and harvesting costs per ha were used as proxies for input prices in the study. After the endogeneity issues were addressed, the mean cost efficiency increased slightly. The average cost efficiency of organic cocoa farmers in Southwest Nigeria, according to the efficiency analysis, was 0.6942. Our test results for the endogenous stochastic cost frontier model show that the hypothesis is accepted and follows a homogeneous of degree one condition.

The cost of organic cocoa fertilizer was positively related to the cost of production and was statistically significant at 1%. The fertilizer cost had a coefficient of 0.480, indicating that increasing the fertilizer cost by N1.00 raises the cost of organic cocoa production by 48%. This means that farmers spend a significant amount of money on organic fertilizer, which increases organic cocoa productivity significantly. This is consistent with the findings of [20], who found that organic fertilizer had the highest elasticity in cocoa production.

Furthermore, the cost of weeding has a positive relationship with the cost of organic cocoa production, which was significant at 5% and had a coefficient of 0.022. According to the findings, increasing the cost of weeding by N1.00 per unit during organic cocoa production results in a 9.6% increase in the cost of organic cocoa production. This is consistent with the findings of [40], who found that weeding improves allocative efficiency.

Labour costs for farming operations such as organic fertilizer application and pruning are positively related to the cost of organic cocoa production and statistically significant at 10%. The labour cost coefficient was 0.414. According to the results, a N1.00 increase in labour costs leads to a 0.414 percent increase in production costs. According to [30], the cost of labour available for farming operations is a factor of supply, which is often less than demand, resulting in a rise in labour costs.

The land rent of an organic cocoa farm had a statistically significant positive relationship with the cost of cocoa production of 1%. The coefficient of land rent was 0.51, which means that a N1.00 increase in land rent raises the cost of organic cocoa production by 51%. This implies that farmers in organic cocoa production spend more money on land rent. This is in line with the findings of [20], who discovered a positive relationship between land rent and cocoa production costs.

Table 4. *Maximum likelihood estimates of endogeneity corrected stochastic frontier for cost function of organic cocoa production in Southwest Nigeria.*

Variables	All Respondents			
	Model EN		**Model EX**	
	Coefficients	**Standard errors**	**Coefficients**	**Standard errors**
Organic fertilizer cost (log)	0.480***	0.303	0.084***	0.048
Weeding cost (log)	0.096**	0.082	0.062**	0.030
Labour in mandays (log)	0.414*	0.199	-0.085*	0.035
Harvest cost (log)	1.754***	0.399	0.936***	0.042
Land rent	0.510***	0.039	1.628***	0.390
Transport cost	0.011	0.040	0.501	0.469
Constant	6.756**	2.053	2.766	0.424
Inefficiency model				
Dep. Var:(In Sigma u-square(σ_u^2)) Constant	-1.448*.	0.654	-2.507	0.964
Age of farmer	0.052*	0.044	0.027*	0.010
Gender of farmer	0.704	0.173	0.207	0.399
Household size	0.050**	0.0429	0.020**	0.061
Years of formal education	-0.976	0.870	-0.043	0.056
Access to credit	-0.256***	0.065	-0.278**	0.291
Years of org. farming experience	-0.083**	0.019	-0.071**	0.052
Number of extension visits	-0.510	0.059	-0.019	0.076
Farm size	-0.091***	0.040	-0.445**	0.095
Organic farm demonstration	-1.466	0.264	-0.358	0.648
Beneficiary of govt. prog.	-0.404	0.635	-0.058	0.078
Constant	-3.260*	1.962	-1.442**	0.722
Dep.Var: (In Sigma v-square (σ_v^2)) Constant	-2.445***	0.251		
Dep. Var (In Sigma w-square (σ_w^2)) Constant			-2.705***	0.244
η_1 (Organic fertilizer cost (log))	-0.555**	0.302		
η_2 (Labour in mandays (log))	0.811**	0.395		
η endogeneity test	4.28**	p = 0.035		
No of observations	300		300	
Log likelihood	-532.13		-105.6	
Mean production efficiency	0.6942		0.6323	
Median production efficiency	0.7199		0.7062	

Source: Data Analysis, 2021

***Significant at 1% level, ** Significant at 5% level and *Significant at 10% level.

The exogenous variables in the inefficiency model explored farmers' managerial capabilities, as well as their access to information and productive resources. Analyzing the estimated coefficients of the inefficiency variables of the efficiency model demonstrates the variables' contribution to allocative efficiency. Except for gender, years of education, credit accessibility, organic farming demonstration, and government beneficiary, the result revealed that five of the endogeneity corrected inefficiency model's allocative inefficiency variables are statistically significant.

The age of organic cocoa farmers was found to be positively related to allocative inefficiency, with a statistically significant correlation of 5%. Farmers' age has a positive coefficient (0.052), implying that organic cocoa farmers are expected to be less efficient as they age. It also claims that younger farmers are more efficient at allocating resources than older farmers. This could be explained by younger farmers being more receptive and less conservative to new agricultural technology, or by taking the risk of resource allocation. This finding contradicts [13] findings that older farmers are more efficient than younger farmers.

Organic cocoa farmers' household size was positively related to allocative inefficiency and statistically significant at 5%. Farmers with more household members are less efficient, as indicated by the positive coefficient of household size. It is widely accepted that household size has an impact on both family and hired labour supply [26]. In smallholder farming, family labour is the most common source of agricultural production labour. Small families, on the other hand, would make better use of their available labour than large families because farm sizes vary less.

Organic cocoa farmers' farming experience was negative in relation to allocative inefficiency and significant at 5%. Organic cocoa experience has a negative coefficient (-0.083) among organic cocoa farmers, implying that the more years of experience a farmer has, the more efficient they will be. This could be attributed to their ability to apply prior experience to current farming conditions. This is consistent with the findings of [6], who discovered that more experienced farmers combined their diverse expertise in farming operations accumulated over time to achieve efficiency.

Cocoa farm size was found to be negatively related to allocative inefficiency and was statistically significant at 1%. The cocoa farm size negative coefficient (-0.091) suggests that farmers with larger farms will be more efficient. This is consistent with the findings of [35], who found that large farms could become significantly more efficient.

Credit availability was significantly and negatively associated with allocative inefficiency, with a coefficient (-0.256) at 1%. This means that farmers who have access to formal credit are more efficient than their counterparts who do not. Credit availability can help farmers afford all of the necessary inputs for maximum output. Similarly, [8] discovered that farmers who self-finance are less efficient than those who obtain funds through other means, including credit.

Failure to account for endogeneity in the standard exogenous stochastic frontier model presented in column 1 of Table 4 depicted the effect of organic cocoa technology on technical efficiency. It agreed with attenuation bias in organic cocoa technology due to measurement inaccuracy, resulting in a downward bias in estimating coefficient in the basic SFA model for organic cocoa technology. The endogenous model's average projected level of allocative efficiency is likewise 6% greater than the conventional model's estimated efficiency, assuming organic cocoa technology is exogenous (i.e. mean efficiency for the exogenous model is 63.2% and 69.42% from the endogenous model).

3.3.3. Technical Efficiency Scores of Organic Cocoa Farmers

The estimated levels of technical, allocative, and economic efficiencies for all organic cocoa farmers are shown on Table 5. Table 5 shows that the projected technical efficiencies (TE) range from 0.1386 to 0.9460, with a mean TE of 0.77. This implies that achieving the TE level of the most efficient farmer in the sample would result in a savings of 18.6 percent [i.e., 1-(77/94.6) x100]. A similar calculation for the least technically efficient farmer results in a cost savings of 85 percent [i.e., 1-(13.9/94.6) x100]. Based on the frequency of occurrences of the anticipated technical efficiencies in decile range, the majority of farmers have technical efficiencies greater than 0.800. The sample frequency distribution clusters technical efficiencies in the 0.80 - 0.99 efficiency ranges, accounting for 66.33 percent of the respondents. This indicates that the farmers are fairly productive.

3.3.4. Allocative Efficiency Scores of Organic Cocoa Farmers

The estimated allocative efficiencies of cocoa growers range from 0.20 to 0.96, with an average AE of 0.69. This means that if the average farmer in the sample achieved the same AE level as the most efficient farmer, the average farmer could save 31% [1-(66.0/96.0) x100]. A comparable computation for the most allocatively inefficient farmer reveals a cost savings of 80% [1-(20.0/96.0) x100]. The probability of occurrence of anticipated allocative efficiencies in decile ranges indicates a clustering of allocative efficiencies in the range of 0.8001 - 0.99 efficiencies, according to the findings. This suggests that the farmers are fairly productive. Farmers are relatively effective at producing organic cocoa at a given output level using the cost-minimizing input ratio, with approximately 53% of respondents having allocative efficiency of 0.80 or higher.

3.3.5. Economic Efficiency Scores of Organic Cocoa Farmers

As shown on Table 5, the estimated allocative efficiencies of cocoa growers range from 0.20 to 0.96, with an average AE of 0.69. This means that if the average farmer in the sample achieved the same AE level as the most efficient farmer, the average farmer could save 31% [1-(66.0/96.0) x100]. A comparable computation for the most allocatively inefficient farmer reveals a cost savings of 80% [1-(20.0/96.0) x100]. According to the findings, the probability of occurrence of anticipated allocative efficiencies in decile ranges indicates a clustering of allocative efficiencies in the range of 0.8001 - 0.99 efficiencies.

3.4. Farm-specific Productive Efficiency of Organic Cocoa Farmers in Southwest Nigeria

After generating the elasticities, the farm-specific efficiency scores were obtained using Frontier 4.1 version as developed by [18]. The results presented in Table 6 shows the differences in means of productive efficiency by organic cocoa farmers based on the level of adoption were analyzed using two-sample t-test. To obtain the economic efficiency, the cost function was first run, and farm-specific cost efficiencies were generated. Economic efficiency was then generated as the inverse of cost efficiency scores. From EE and TE scores, AE was obtained as the quotient of EE/TE [26].

Partial adopters of organic cocoa technology were less efficient with mean TE of 0.74% compared to Full adopters with a mean of 0.79%. The findings show that there was a significant difference in mean TE among organic cocoa farers based on their level of adoption with T-value of 7.25. This plies that for organic cocoa farers to boost their technical efficiency, they should consider fully adopting the organic cocoa faring practices. For a partial organic cocoa farmer with an average TE of 0.74 to achieve the TE level of the most technical efficient (0.94) farmer, he/she would realize proportional inputs 21.7% was given by [1-(74/94) x100]. The implication of this result is that full adopters are more technically efficient than partial adopters. This agrees with the findings of [28] who established that organic farm has higher production efficiency than convectional farm. This suggests that the farmers are fairly productive.

Table 5. *Technical, allocative and economic efficiency scores of respondents.*

Levels	Technical		Allocative		Economic	
	Freq. n=300	%	Freq. n=300	%	Freq. (n=300)	%
≤ 0.2000	3	1.00	5	1.67	4	1.33
0.2001 – 0.3000	5	8.33	17	5.67	26	8.67
0.3001 – 0.4000	19	13.00	15	5.00	22	7.33
0.4001 – 0.5000	12	7.33	39	13.00	37	12.33
0.5001 – 0.6000	24	8.00	20	6.67	39	13.00
0.6001- 0.7000	23	7.67	65	21.66	32	10.67
0.7001-0.8000	15	5.00	10	3.33	38	12.67
≥0.8001	199	66.33	129	43.00	102	34.00
Mean	0.69		0.66		0.62	
Standard deviation	0.021		0.023		0.020	
Minimum	0.1386		0.200		0.1717	
Maximum	0.9460		0.9605		0.9470	

Source: Data Analysis, 2021.

3.5. Farm- Specific Productive Efficiency of Organic Cocoa Farmers in Southwest Nigeria

After generating the elasticities, the farm-specific efficiency scores were obtained using Frontier 4.1 version as developed by [18]. The results presented on Table 6 shows the differences in means of productive efficiency by organic cocoa farmers based on the level of adoption were analyzed using two-sample t-test. To obtain the economic efficiency, the cost function was first run, and farm-specific cost efficiencies were generated. Economic efficiency was then generated as the inverse of cost efficiency scores. From EE and TE scores, AE was obtained as the quotient of EE/TE [26].

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Table 6. *Productive efficiency of organic cocoa farmers based on the level of adoption in Southwest, Nigeria.*

Efficiency	Partial Adopter	Full Adopter	T- value
TE Mean	0.74	0.79	7.25***
Std. Deviation	0.173	0.205	
Min	0.13	0.44	
Max	0.92	0.94	
AE Mean	0.63	0.68	8.70***
Std. Deviation	0.551	0.714	
Min	0.20	0.47	
Max	0.90	0.96	
EE Mean	0.60	0.64	4.57***
Std. Deviation	0.1692	0.1074	
Min	0.17	0.49	
Max	0.90	0.94	

Source: Data Analysis, 2021

***Significant at 1% level, ** Significant at 5% level and *Significant at 10% level.

Table 6 shows that the estimated levels of allocative efficiencies level for partial adopters of organic cocoa technology ranges from 0.20 to 0.90 with average of 0.63 while Full adopters of organic cocoa technology range from 0.47 to 0.96 with average of 0.68. T- value being 8.70 shows that there is significant difference in means of allocative efficiency between full and partial adopters of organic cocoa production. This implies that full adopters are more efficient in the allocation of resources in organic cocoa production.

The estimated levels of economic efficiencies of partial adopters of organic cocoa technology range from 0.17 to 0.90 with average of 0.60 while full adopters of organic technology range from 0.49 to 0.94 with average of 0.64. T-value of 4.57 shows that there is significant difference in means of economic efficiency between full and partial adopters of organic cocoa production. This implies that full adopters are more economically efficient than their counterparts in organic cocoa production.

3.6. Constraints to Organic Cocoa Production

The result on Table 7 revealed the major constraints that partial adopters face was High labour cost (24.0%), Pest and disease infestation (20.0%), Quantity of neem extract (15.5%), Lack of adequate information on organic practices (13.0) and Inadequate capital (7.5%) while for the full adopters, High labour cost (28.0%), Pest and disease infestation (27.0%), Quantity of neem extract (15.0%), Lack of adequate information on organic practices (17.0) and Inadequate capital (9.0%). High labour costs and pest and disease infestation were the most significant challenges faced by farmers in the study. This is due to the fact that organic farming technology is labour intensive, resulting in an increase in the price paid to labour in order to get work done on farmland. According to [31], the main issue confronting cocoa farmers in the study was high labour costs.

4. Conclusion

The study concluded that there were two levels of adopters of organic cocoa technology in South-Western Nigeria – the partial adopters and full adopters. The partial adopters with an index <0.364 and full adopters with indices >0.364. Partial adopters of organic cocoa technology made up 61.0% of farmers, while full adopters made up 39.0 %. Farmers were over 50 years of age, married with average number of farmers having at least primary level of education and cultivating less than 6 hectares of land. The estimated production efficiencies for organic cocoa farmers ranged from a minimum of 0.13 for the least efficient farmer to a maximum of 0.94 for the highest efficient farmer with a mean of 0.77. The partial adopters ranged from 0.13 to 0.92 while full adopters range from 0.44 to 0.94. Furthermore, the result revealed that farmers can increase their organic cocoa output by increasing the quantity of fertilizer, frequency of weeding and labour.

Table 7. *Distribution of Constraints in organic cocoa Production.*

	Levels of Adoption		
Constraints	**All Respondents (n = 300)**	**Partial Adopters (n= 183)**	**Full Adopters (n=117)**
High labour cost	26.0	24.0	28.0
Quantity of neem extract	15.3	15.5	15.0
Lack of adequate information on organic practices	15.0	13.0	17.0
Pest and disease infestation	23.5	20.0	27.0
Price fluctuation	12.0	20.0	4.0
Inadequate capital	8.2	7.5	9.0

Source: Field survey, 2021.

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