Research Article

doi:10.25081/jpc.2022.v50.i1.7546
Journal of Plantation Crops, 2022, 50(1): 8-19

Technical efficiency and profitability of small holder natural rubber production in southern Nigeria

Dengle Yuniyus Giroh* and Nathan Nachandiya[1]

Department of Agricultural Economics and Extension, Modibbo Adama University, P.M.B. 2076, Yola, Nigeria
[1]Department of Computer Science, Adamawa State University, P.M.B. 025, Mubi, Nigeria

(Manuscript Received: 22-02-2022, Revised:16-03-2022, Accepted: 20-03-2022)

Abstract

The study measured the technical efficiency and profitability of small holder natural rubber production in southern Nigeria by examining the socio-economic characteristics of respondents, the profitability of latex production and technical efficiency. Multi-stage, purposive and random sampling techniques were employed in the collection of primary data from 300 respondents. Descriptive statistics and stochastic frontier production function were used to analyse the data collected. Results indicated that respondents were educated, married (76%) with a mean family size of seven people and well experienced mean farming experience of 19 years. Latex production was a profitable venture with an average variable cost per ha of ₦ 55,700.94 with total revenue (T.R.) and gross margin (G.M.) per hectare ₦ 163,594.17 and ₦ 107,893.23, respectively. Furthermore, the stochastic frontier production function analysis showed the number of trees per task, labour, farm size and age of plantation, clone, wage and fixed cost items were significantly related to rubber latex. The mean technical efficiency (T.E.) of the respondents was 0.84. Education, extension contact and experience were the significant factors that increased the technical efficiency of the respondents. The resuscitation of extension activities of A.D.P.s in the rubber growing states of the country through adequate funding by the government to improve the efficiencies of farmers, use of improved planting materials during replanting old plantations and the formation of cooperative societies by farmers to enhance access to production credit amongst others are recommended in the study.

Keywords: Gross margin, production, profitability, rubber clones, southern Nigeria, stochastic frontier, technical efficiency

Introduction

The rubber tree produces natural rubber in the form of latex. The tree has the ability to renew its bark, and the production of latex can last for 35 years. Wild species of natural rubber can grow up to 40 metres in height, while improved clones for about 25 metres due to latex harvesting for a long period of its life. Natural rubber was introduced into Nigeria from England in 1895. The first plantation was established by the Division of Agriculture in Sapele in 1906 in the defunct Bendel State. The second was by Pamol at Ikot-Mbo (Cross-River State) in the former eastern region of the country in 1912. The first major Nigerian owned plantation was established at Sapele between 1909 and 1917. The then Midwestern region (Bendel State) area had 2000 hectares. About 35 per cent of the rubber production in the country was from 250,000 hectares of rubber cultivation by Bendel State (Edo and Delta States).

The early plantations were raised from unselected seeds with latex yields ranging from 300 to 400 kg ha^{-1} yr^{-1} (Omokhafe and Nasiru,2004; Mesike *et al.,* 2010). Natural rubber, an economic tree crop in Nigeria, has diverse uses, including providing raw materials for agro-based industries, foreign exchange earnings, and employment to a sizeable segment of the rural Nigerian farming population. The tyre industry is the major consumer of natural rubber. It is well suited for the manufacture of tyres, especially radial, heavy-duty and high-speed tyres, because of its dynamic qualities such as good tear strength and low heat buildup. Beyond this, rubber is used to manufacture

**Corresponding Author: girohydengle@mautech.edu.ng*

specific products such as flexible oil resistance pipelines for offshore oil fields, inner tubes of tyres, footwear, seismic bearings in bridges and building foundations in earthquake-prone areas. The latex concentrate is used to produce carpet underlay, adhesives, foam, balloons, condoms, and medical accessories such as gloves and catheters. The rubber seed is also used to manufacture rubber seed oil, putty and alkyds resins, which find application in the paint and leather industry, manufacture of soap, skin cream, hair shampoo *etc.* Furthermore, rubber seed cake after oil extraction is used for manufacturing livestock feeds, while rubber wood is used for furniture, particle boards and fuel (Umar *et al.,* 2017).

Trends of natural rubber (Table 1) showed increased production in 1990-2009, with exports reaching their peak during the 1990-1999 period while local consumption was highest in 2000-2009. The increase in output was not a result of an increase in hectarage cultivated but the resumption of tapping from abandoned plantations because of the high prices of rubber and favourable government policies.

Table 1. Rubber production trend (export and local consumption) in Nigeria

Year	Total production (tonnes)	Export (tonnes)	Local consumption (tonnes)
1970-1979	656,949	414,255	242,473
1980-1989	624,172	314,300	309,872
1990-1999	1,315,300	718,300	597,700
2000-2009	1,470,000	225,333	1,244,667

Source: Abolagba *et al.,* (2003) CBN Statistical Bulletin various issues

The stochastic frontier production function, referred to as the 'best-practice' technology, differs from the normal average production function. It was initially developed by Farrell (1957), and Aigner *et al.* (1977) used it in their studies on efficiency. Stochastic frontier analysis (S.F.A.) has gained wider use in efficiency studies by scholars where the choice could be the S.F.A. or the nonparametric data envelopment analysis (D.E.A.), which is basically a linear programming technique. Both techniques are exposed to strengths and weaknesses. The stochastic frontier parameters are statistically testable as their confidence levels, and the accuracy of the estimated models are known. Data envelopment analysis allows the estimation of several outputs with ease against multiple inputs. However, researchers with little statistical applications on the multi-collinearity problem might be misled by estimating highly-correlated inputs against correlated outputs. The drawback encountered in the application of S.F.A. and D.E.A. depends very much on the accuracy and availability of data. The advantage of using the stochastic frontier production function is that the error term can be decomposed into random error and inefficiency effects rather than attributing all errors to random effects (Xu and Jeffrey, 1998).

Technical efficiency (T. E.) is the achievement of the maximum potential output from a given quantity of inputs under a given technology (Jondrow *et al.,* 1982; Amaza and Olayemi, 1999). Surakiat *et al.* (2018) conducted a study to measure the technical efficiency of Thai rubber production using the three-stage data envelopment analysis. They reported the average T. E. of the Thai rubber production from 2005 to 2014 was 0.681, the maximum T. E. was 0.962, and the minimum T.E. was 0.515. Kumarasinghe *et al.* (2012) evaluated the role of human capital in technical efficiency increases in smallholdings in the Gampaha district of Sri Lanka.

Empirical studies have been conducted on the profitability of natural rubber production. Tran (2020) and Sarba (2011) reported that an increase in prices of natural rubber has a large impact on farmers' income, while poor prices served as an obstacle to the production of natural rubber in Indonesia.

Suyanto *et al.* (2001) identified the age of rubber plantations to affect the level of profits in Sumatra. Abolagba *et al*. (2003) examined the farm gate marketing of natural rubber in southeast Nigeria. They found a positive correlation between world market prices and local rubber prices in Nigeria, which affects income derivable from rubber by estate owners. Schroth *et al*. (2004) also found out that an increase in the world prices of natural rubber propelled Brazilian rubber tappers to tap for more salaries. Poor field hygiene and deliberate adulteration of latex with sand and bark residue of the tree to increase the weight of the coagula were major factors that affected the pricing of natural rubber at local and international markets. Sajen (2006) attributed the increase in rubber prices to global economic recovery and resultant higher demand for rubber, especially from China. Abolagba *et al.* (2010) examined the determinants of agricultural exports and discovered that increase in producer price led to an increase in rubber export as the farmers were encouraged to maintain their rubber farms leading to increased output.

The decline in natural rubber production can be attributed to the Nigerian civil war (1967-1970) and the oil boom era (1973-1978), resulting in dependence on oil to finance the economy. In reaction to the worrisome performance of the rubber industry, the Federal Government of Nigeria had introduced many policies and programmes, which include the Agricultural Research Institute Decree in 1973, the abolition of the Commodity Board in 1986, National Accelerated Industrial Crops Production Programm (NAICPP) in 1994 and the Presidential Initiative on Natural Rubber (P.I.R.) in 2006 to promote rubber production and to diversify the hitherto mono commodity or monolithic economy with oil as the major source of revenue. With all these policies and programmes, it is expected that the establishment of more rubber plantations should be popularised. Still, empirical evidence revealed only an increase in demand for rubber produce while supply lags (Spore, 2004). This may be attributed to several constraints associated with estate and smallholder development activities, seedlings production and uptake, processing and alternative uses and local marketing and export. About 80 per cent of the current population of the estate and smallholder plantations are over 30 years and have crossed their economic life span of 25 years. Most plantations were planted with unselected planting materials.

Inadequate information, poor marketing facilities, lack of credit facilities and high cost of credit, low yield and under exploitation due to the inability and unaffordability of vital production inputs, and decreased earnings from the rubber business are problems of rubber production (Abolagba *et al.,* 2003; Agwu, 2006). There is a paradigm shift from adopting new technologies for increasing farm productivity and income to improving efficiency rather than introducing new technologies (Bravo-Ureta and Pinheiro, 1997). Shortfalls in efficiency mean that output can be increased without requiring additional conventional inputs and without the need for new technology. If this is the case, then empirical efficiency measures are necessary to determine the magnitude of gains obtained by improving performance in agricultural production with a given technology. Efficiency is an important factor in productivity growth, especially in developing agrarian economies, where resources are meagre, and opportunities for developing and adopting better technologies are dwindling. Such economies can benefit from efficiency studies which show that it is possible to raise productivity by improving efficiency without increasing the resource base or developing new technologies. Raising the productivity and output of small farmers would not only increase their income and food security but also stimulate the rest of the economy. Thus, efforts to increase rubber production will largely depend on the proper understanding of factors influencing farmers to continue to remain in rubber production. Their production efficiency may be influenced by farm-specific characteristics, use of improved seedlings, and production practices. Understanding rubber farmers' production efficiencies are important. A gain in efficiency will lead to increased output.

A study on the harvesting of rubber latex is necessary and gives direction in resource use and allocation to increase output from natural rubber. The main objective of this work is to analyse the technical efficiency and profitability of small holder natural rubber production in southern Nigeria. The specific objectives are to examine the influence of rubber farmers' socio-economic characteristics, determine the profitability of rubber production and determine the technical efficiency of factors employed in latex production.

Materials and methods

The study area

The study was conducted in Edo and Delta States of Nigeria. Edo State lies between Latitudes 5° 44′ and 7° 34′ N of the equator and between Longitudes 5° 04′ and 6° 43′ E of the Greenwich

Meridian. It shares boundaries in the South with Delta State, in the West with Ondo State and in the East with Kogi and Anambra States (Emokaro and Erhabor, 2006a). The state covers a land area of about 17,902 km^2 with a population of 3,218,332. Edo State is divided into 18 Local Government Areas (N.P.C., 2006). The state is characterised by a tropical climate that ranges from humid to sub-humid at different times. Three distinct vegetations identified in the state are mangrove forest, fresh swamp and Savannah vegetations. The mean annual rainfall in the northern part is 1270 mm to 1520 mm, while the southern part of the state receives about 2520 mm to 2540 mm rainfall, respectively. The mean temperature in the state ranges from a minimum of 24 ^{0}C to a maximum of 33 ^{0}C. The people of the state are mostly farmers growing various crops such as cassava, rice, yam, plantain, pineapple and tree crops such as rubber, oil palm and cocoa. Other occupations of the state include small and medium scale businesses and jobs done by artisans and civil servants who engage in farming part-time (Emokaro and Erhabor, 2006b). Delta State lies between latitude 5^0 00′ and 6^0 30′ N of the equator and longitude 5^0 00′ and 6^0 45′E of the Greenwich meridian. The state has a land area of 17,440 km^2; about one-third of this is swampy and waterlogged. The state is bounded in the North by Edo State, in the East by Anambra and Rivers State, and in the South by Bayelsa State. The Atlantic Ocean forms the western boundary, while the North-West boundary is Ondo State. There are 25 Local Government Areas in the state with a population of 4,098,391 (N.P.C., 2006). The state has a tropical climate marked by dry and rainy seasons. The rainy season starts in April and ends in October. The dry season starts in November and ends in March. The rainfall ranges from 1905mm to 2660 mm monthly. The temperature ranges from 24 ^{0}C to 34 ^{0}C, with an average of 30 ^{0}C (Ike, 2010).

The data

Data were collected mainly from primary source on the 2009 and 2010 production activities using a structured interview schedule in a multi-stage sampling technique. The first stage involved the purposive selection of the Tapping Division of the Rubber Research Institute of Nigeria (Main station, Iyanomo, Ikpoba - Okha Local Government Area), Iguoriakhi Farm settlement, Odia Rubber Estates (Ovia South West and Uhunmwode Local Government Areas in Edo State) and Utagba-Uno, Mbiri Farm settlements and Mars Plantation in Ndokwa East, Ika North East and Ndokwa West Local Government Areas of Delta State respectively. The second stage of the sampling was obtaining the list of 407 rubber farmers from the selected locations from Tree Crop Units and the Ministry of Agriculture and Natural Resources in Edo and Delta States. Finally, a total of 300 rubber farmers were randomly selected proportionate to their population.

Methods of data analysis

The data collected were subjected to descriptive statistics and stochastic frontier production function (SFPF).

Descriptive statistics

The descriptive statistics (frequency and percentage) were used to describe variables and their occurrences among respondents. Mean, mode and standard deviation were used to measure central tendency.

The empirical gross margin analysis

The Gross Margin (G.M.) per hectare is expressed as

$$GM = \Sigma Q_y P_y - \Sigma X_i P_{xi} \quad \text{......(1)}$$

Where: Q_y = Output of rubber (kg ha^{-1}); P_y = Unit price of the output (₦ kg^{-1}); $Q_y P_y$ = Total revenue from rubber produced (₦ ha^{-1}); X_i = Quantity of the ith input used in kg ha^{-1}; P_{xi} = Price per kg of the ith input; $X_i P_{xi}$ = Total cost associated with the ith input per hectare.

The empirical stochastic frontier production model

The stochastic frontier production model used is specified as follows:

$$LogY_1 = \beta_o + \beta_1 \log X_1 + \beta_2 \log X_2 + \beta_3 \log X_3 + \beta_4 \log X_4 + \beta_5 \log X_5 + \beta_6 \log X_6 + \beta_7 \log X_7 + V_i - U_i \quad \text{......(2)}$$

Where: Y_1 = Output (litres) of the ith farmer X_1 = Number of trees per task (a task has 450 to 500 tappable trees); X_2 = Wage (in naira); X_3 = Labour use (in man days); X_4 = number of hectares tapped; X_5 = Age of plantation (in years) X_6 = Clone (1 exotic, otherwise zero) X_7 = Depreciation on fixed cost items such as tapping knives, cup hangers, spouts, sharpening stones, buckets, bulking containers, coagulating pans, (in naira).

V = Assumed to account for random factors such as weather, risk and measurement error. It has zero mean, constant variance, normally distributed and independent of U. It covers random effects on the production outside the control of the decision unit.

U = is a non-negative error term having zero mean and constant variance (Xu and Jeffrey, 1998). It measures the technical inefficiency effects that fall within (because the errors could be controlled with effective and adequate managerial control of the firm), the control of the decision unit (Apezteguia and Garate, 1997).

The technical efficiency of rubber tapping for the i^{th} farmer or plantation, defined by the ratio of observed production to the corresponding frontier production associated with no technical inefficiency, is expressed by T.E. = exp $(-u_i)$ so that $0 \leq$T.E. $0 \leq 1$..(3)

Variance parameters are: $\sigma^2 = \sigma^2_v + \sigma^2_u$ and $\gamma = \sigma^2_u / \sigma^2$ .... (4)

so that $0 \leq \gamma\ 0 \leq 1$.

The inefficiency model is defined by: $U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6$ .... (5)

Where: U_i = Technical inefficiency effect; Z_1 = Age of rubber farmer (in years); Z_2 = Literacy level (in years); Z_3 = Farming experience (in years); Z_4 = Extension contact (1 contacted, otherwise zero); Z_5 = Family size (total number of persons in household) and Z_6 = Farm distance (in km).

Results and discussion

Socio-economic characteristics

The socio-economic variables employed in the study (presented in Table 2) show that 76 per cent were within the ages of 45 years and above with a mean age of 51±20.16 years, married with minimum and maximum family sizes of 1 and 12 people, respectively. The mean family size was 7± 2.47, which reflects that many of the farmers were married (76%). Distribution based on educational levels of respondents also revealed that all the respondents were educated and had one form of formal education or the other, with mean years of formal schooling of 10.09±8.26 years. The distribution of respondents by farm size indicated that 52.33 per cent had farm sizes ranging from ≤1.5 to 3.99 hectares, while about 48 per cent had above 4 hectares of farmland. The mean farm size was 1.7±1.12 hectares Distribution of respondents based on the type of land acquisition showed that 33 per cent of the respondents acquired their farmlands through inheritance, 24.33 per cent through purchase, and government allocation accounted for 43 per cent. The farming experience of the respondents revealed that 86 per cent had more than 10 years of experience, with a mean farming experience of 19±9.65 years.

Gross margin analysis

The gross margin was used as the profitability of latex production among farmers and is presented in Table 3. The average variable cost/hectare was ₦ 55,700.94, with labour cost accounting for about 50 per cent of the total tapping cost. The total revenue (T.R.) and gross margin (G.M.) per hectare were ₦ 163,594.17 and ₦ 107,893.23, respectively.

Stochastic frontier production function results

Production factors

Table 4 contains the estimates of the parameters for the frontier production function, the inefficiency model and the variance parameters of the model. The variance parameters of the stochastic frontier production function are represented by sigma squared (δ^2) and gamma (γ). The sigma squared is 0.822 and significantly different from zero at the one per cent level. This indicated a good fit and correctness of the distributional form assumed for the composite error term. Gamma indicates that the systematic influences that are unexplained by the production function are the dominant sources of random error. The gamma estimate, which is 0.923, showed the amount of variation resulting from the technical inefficiencies of the rubber farmers. This means that 92.30 per cent of the variations in farmers' output are due to differences in technical efficiency. This implies that the ordinary least squares estimate (O.L.S.) will not be adequate in explaining the inefficiencies in rubber latex production, thereby justifying the specification of a stochastic frontier production.

Typical of the Cobb-Douglas production function, the estimated coefficients for the specified function can be explained as the elasticities of the explanatory variables. Except for the age of the plantation, the signs of the coefficients of the stochastic production frontier are positive. The returns to scale parameter were 1.726 (increasing return to scale); respondents were operating in stage 1 of the production surface. This suggests that a proportionate increase in all inputs would result in more than a proportionate increase in the output of the respondents. Resources are misallocated with no attainment of optimum efficiency of production. The estimate of the stochastic production frontier parameters indicated that the elasticity of output with respect to the number of trees per task is positive and approximately 0.646, and it is statistically significant ($p \leq 0.001$). The coefficient for wage (0.132) was statistically significant ($p \leq 0.001$). The coefficient of the variable associated with labour was 0.730 and statistically significant ($p \leq 0.01$). The estimated coefficient for farm size was 0.344 and statistically significant ($p \leq 0.001$). The production elasticity of the age of the plantation was -0.339 and statistically significant ($p \leq 0.001$) and inversely related to output. The production elasticity with respect to clones (0.133) was statistically significant ($p \leq 0.001$). The coefficient for depreciation on fixed cost items was 0.080 and was statistically significant ($p \leq 0.001$).

Inefficiency effects

The existence of technical inefficiency provides a good ground to find out the sources of inefficiencies among rubber farmers in the study area. Some variables were considered and estimated in the model, and the result is also contained in Table 4. The signs and coefficients in the inefficiency model are interpreted oppositely, such that a negative sign means the variable increases efficiency. In contrast, positive signs indicated that the variables decreased efficiency. The result of the inefficiency model shows that the coefficients of the efficiency variables, with the exception of the age of the farmers and farm distance, had the expected signs. The estimated coefficient for the age of farmers (0.025) had a positive sign and is statistically significant ($p \leq 0.01$).

Technical efficiency of indices of respondents

Technical efficiency indices derived from the analysis of the stochastic frontier production function in respect of the respondents (Table 5) show that 1.33 per cent of the respondents fell in the range of ≤0.49, 2.34 per cent were in the range of 0.50 - 0.59, followed by 2 per cent (0.60 - 0.69), 13.33 per cent were in the range of 0.70 – 0.79. The majority of the respondents (53 per cent) had T.E. in the range of 0.80 - 0.89, while 28 per cent attained T.E. from 0.90 - 1.00. The analysis further showed that 30.37 per cent of the farmers have technical efficiency (T.E.) index below the mean figure of 0.84, while a majority (69.67 per cent) attained T.E. above the mean.

The study examined the technical efficiency and profitability of small holder rubber estates in southern Nigeria. It estimated the stochastic frontier production function and descriptive statistics in analysing cross-sectional data collected on rubber farmers. The descriptive analysis revealed that older farmers predominate rubber production. The preponderance of older farmers in rubber production portends serious danger to the rubber industry with declining productivity and likely reduction in hectares of rubber production. Farmers in the range 34 to 44 years are usually characterised by increasing productivity, while stability in natural rubber production is experienced at 45 to 54 years, with declining productivity at 55 years and above. Participation of older farmers in production was a consequence of the mass exodus of the youth to the city centres for white-collar jobs leaving rubber production to an elderly population. Nigeria's traditional rubber growing ecology is in the oil-rich belt of the country with oil companies offering brighter job prospects than the rubber industry, which served as a repulsive factor for patronising the rubber industry in Nigeria. Deliberate policy by the Government of Nigeria towards promoting rubber production would serve the twin objective of sustainable livelihood and environmental degradation wrought by oil exploration as plantation establishment would mitigate the negative effects of climate change.

Table 2. Distribution of respondents based on socio-economic characteristics (n=300)

Variable	Frequency	Percentage
Age (years)		
≤ 34	29	9.67
35- 44	43	14.33
45- 54	128	42.66
55- 64	29	9.67
>65	71	23.67
Mean	51	
Minimum	25	
Maximum	62	
Standard deviation	20.16	
Marital status		
Married	229	76.33
Single	57	19.00
Widower	14	4.67
Family size		
1-5	143	47.67
6-10	86	28.67
11 and above	71	23.66
Mean	7	
Minimum	1	
Maximum	12	
Standard deviation	2.47	
Educational level		
Primary education	143	47.67
Secondary education	100	28.67
Tertiary education	57	19.00
Mean	10.09	
Minimum	6	
Maximum	14	
Standard deviation	8.26	
Farm size(hectares)		
≤ 1.5	43	14.33
1.6 – 3.99	114	38.00
4 and above	143	47.67
Mean	1.7	
Minimum	0.5	
Maximum	5.5	
Standard deviation	1.12	
Type of land acquisition		
Inheritance	99	33.00
Purchase	73	24.33
Government allocation	128	42.67
Farming experience (years)		
≤ 10	43	14.33
11 - 20	171	57.00
21 and above	86	28.67
Minimum	8	
Maximum	25	
Standard deviation	9.65	

Source: Author's computation

Rubber production is a male-dominated activity. This result further confirms empirical evidence that suggests gender inequality in employment and agricultural production, where men are more favoured than women. Women are the primary labour force in Sub-Saharan Africa, and their crucial roles in agricultural production have been widely reported in Nigeria (Otene *et al.,* 2011). However, it is regrettable that those women farmers remained one of the most disadvantaged groups in the country. Reij Waters-Bayer (2002) attributed the lack of self-esteem of women with respect to their farming activities to the traditional beliefs and attitudes regarding women's role in the society; the low level of formal education of women; poor access of women to external information, the small size of plot allocation to women that do not attract the attention of extension workers, thus these women have limited access to extension activities. Married people are more into rubber production than those who are single. This is because married people have more family responsibilities such as feeding and educating the children that require means of livelihood, which rubber production provided for them. However, single farmers may face fewer responsibilities than married respondents. The large family size of respondents could be used as a vital source of labour for rubber production and other productive activities. It can put pressure on family heads to obtain income to meet family needs. Government allocation formed the highest form of land acquisition among respondents as farm settlement schemes established in the early 1960s after the Israeli-Moshavian policy formed part of the study area. The settlement schemes served as centres for innovation transfers that could trickle down to neighbouring villages for sustainable agricultural production. Respondents who acquire land through government allocation may be able to make a long-term commitment to the land by obtaining credit for rubber production. Years of farming experience have been reported to provide a measure of managerial ability among farmers in Nigeria. The result showed that the majority of the rubber farmers might have perfected their production of natural rubber with years of experience. The result is in line with the study of Otene *et al.* (2011), who reported the involvement of experienced farmers in rubber production.

The gross margin was used as the profitability of latex production in the short run among respondents, which shows that rubber production is a profitable venture in the short- run in the study area because of the positive gross margin. The age of rubber plantations is critical in determining the productivity and profitability of natural rubber. Productivity is lower in younger plantations (less than 20 years of age) with high productivity between 20 and 30 years, with a likely reduction in production when they approach 35 years. Replanting is required to maintain sustainable production using improved clones.

Table 3. Average cost and return of rubber per hectare

Cost item	Value	Percentage of cost
Safety kits	₦ 5,750.00	10.32
Tapping inputs	₦ 9,500.00	17.06
Transportation	₦ 12,850.00	23.07
Labour cost	₦ 27,600.94	49.55
Total variable cost	₦ 55,700.94	
Total output ha^{-1}	1,649.80 kg	
Price kg^{-1}	₦ 99.16	
Total revenue	₦ 163,594.17	
GM (TR-TVC)	₦ 107,893.23	

Source: Author's computation

The cost of labour was very high, accounting for half of the total cost of production. Labour is one of the most required inputs in operating a rubber estate and constitutes a vital input in agricultural production. The migration of labour to different parts of the country to earn a better livelihood added to the existing imbalance between the demand and supply of labourers. This result is in line with earlier studies that showed that labour was scarce and costly in rubber production in Nigeria. This is a result of the fact that the Nigerian rubber belt corresponds with the oil belt of Nigeria, attracting able-bodied youth to the industry, leaving the older population as a source of labour for the natural rubber industry.

Edirisnghe *et al.* (2014) expressed the same view that variability in labour increases risk in output, requiring policymakers to attempt maintenance of a constant supply of labour. This might entail providing training and extension services to increase labour skills and maintain an adequate level of wages to ensure village labour can engage in rubber tapping. The profitability of rubber production lends credence to Cena (2011), who observed that the huge industrial demand for natural rubber is expected to keep the price of rubber high for decades because of the long period of productivity; environment sustainability; the high value of rubberwood; and allows intercropping of food and cash crops for higher farm income. Jagath *et al.* (2010) also found out that the fluctuation of prices in world markets directly influences the income of rubber growers.

Stochastic frontier production function results

The study established that the number of trees per task is a positive and significant factor that influences the output of rubber farmers. An increase of one per cent in the number of trees per task will increase output by 0.646 per cent. The immediate recognition of an increase in latex output is the number of trees associated with that production. The higher the number of trees, the greater is expected volume of latex depending on the management of the rubber plantations. In their studies, Schroth et al. (2004) established variability in yield levels ranging from low to high on stand structure of rubber trees in the Brazilian Amazon forest. The coefficient for wage is 0.132, which was statistically significant ($p<0.001$). This implies that wage is a positive and significant factor that influences the output of rubber farmers. An increase of one per cent in wage will result in an increase in output by 0.132 *ceteris paribus*. This result is in line with earlier studies that identified wage as a significant factor in natural rubber production in rubber growing countries of the world. A lower wage structure normally experienced in the agricultural sector of the Nigerian economy made the rubber sector unattractive to skilled labour compared to other sectors like the oil and gas industries in the rubber belt of Nigeria that offer fat and attractive salaries to workers. To overcome this challenge, farmers should not be left alone; the government has to intervene by making the sector attractive to skilled labour by making the wages of plantation workers attractive to reflect the prices of rubber. Labour is an important factor of production among small scale farmers. From the analysis, a one per cent increase in the coefficient of labour will lead to a 0.730 per cent increase in output.

Natural rubber production is a labour-intensive activity constrained by skilled labour resources to tap rubber and poses a threat to many other rubber producing countries. Mesike *et al.* (2009) reported that labour had been a critical factor in rubber production in Nigeria, where production is done manually. Inconvenient working conditions (unattractive wages and inadequate medical and housing facilities) may be repulsive. This effect on the rubber industry is likely to reduce the acreage of rubber cultivation; plantations may not be tapped, resulting in low yield and income for the farmers and a reduction in foreign exchange earnings. Farm size is one of the most important factors of production and critical in adopting innovations in agriculture. A unit increase in hectare will lead to an increase of 0.344 kg of rubber production. Mustapha (2011) reported a significant relationship between the cultivated area of rubber smallholdings in Malaysia and an increase in latex production. The importance of farm size as one of the production and technology adoption factors in agriculture was stressed by Mesike *et al.* (2009). The production elasticity of the age of the plantation was statistically significant (≤0.001) and inversely related to output. This shows that output from rubber trees is necessarily a function of age. Age is the single factor determining the yield of a rubber tree for a given clone. While a tree normally attains the required girth for tapping in the seventh year of planting, the yield, which increases from the fourth year, stabilises in the 13th year of tapping. Variations in the economic life span of rubber trees have been reported in many rubber-producing countries of the world. Etherington (1977) found out that the optimal replacement period for natural rubber is in the 32nd year in Malaysia, while Sajen (2006) reported an economic life span of 29-30 years in India. Mesike *et al.* (2010) found that output from rubber trees in Nigeria declines when the trees are beyond their economic life span of 35 years.

The consequence of the old age of rubber plantations was low yield with corresponding low income for the farmers. In the absence of timely replanting by growers, prospects of tapping more rubber from the existing aged trees appear bleak, leading to production decline. Such trees need to be replaced by a replanting programme using improved clones. Tapan *et al.* (2013) emphasised the need for replanting small holder plantations in many rubber-producing countries for sustainable and enhanced livelihoods of farmers. Similarly, Phommexay *et al.* (2011) reported the impact of rubber plantations on environmental diversity. The basic component of any crop production enterprise is the planting material. *Hevea* clones are improved planting materials with potential for high yield, wind and disease resistance. The production elasticity with respect to clones was significant. Spore (2007) reported that rubber farmers need more productive varieties or clones of natural rubber that are adapted to community conditions. Njukeng *et al.* (2011) reported higher yields from rubber plantations where improved clones were used as planting materials. Farmers who adopted improved rubber clones are likely to have increased yields from their plantations, earning more income.

The coefficient for depreciation on fixed cost items was 0.080 and was statistically significant at a one per cent probability level. The farmers' output increases with the increase in operational cost and agrees with the *apriori* that firms incur more cost in production as output increases. This implied that farmers spend more to produce more. The result lends credence to the work of Giroh *et al.* (2010).

The study equally established sources of inefficiencies of production among the respondents. The age of farmers increases technical inefficiency; as the farmer gets older, the productivity and efficiency decline. The elderly population may not easily adopt improved technologies that enhance efficiency. Education increases the technical efficiency of the respondents. Educated farmers are innovative, and the transformation processes by extension agents are likely to be easier. Education obviously will improve production efficiency by enabling farmers to access improved technology and

Table 4. Maximum likelihood estimate of parameters of Cobb-Douglas stochastic frontier production function for rubber farmers

Variable	Parameter	Coefficient	Standard error	t. value
Production factors				
Constant	β_o	0.181	0.388	0.46
No. of trees per task	β_1	0.646 **	0.075	8.60
Wage (naira)	β_2	0.132 ***	0.025	5.12
Labour (SMD)	β_3	0.730 **	0.286	2.55
Hectares	β_4	0.344 ***	0.042	8.13
Age of plantation	β_5	-0.339 ***	0.037	- 8.97
Clone	β_6	0.133 ***	0.031	4.21
Depreciation on fixed cost items	β_7	0.080 ***	0.019	4.04
Inefficiency model				
Constant	δ_0	0.309	0.209	1.47
Age	δ_1	0.038 **	0.014	2.64
Education	δ_2	-0.834 **	0.349	- 2.38
Farming experience	δ_3	-0.875 **	0.355	- 2.46
Extension contact	δ_4	-0.375 *	0.217	- 1.72
Family size	δ_5	-0.116	0.106	- 1.09
Farm distance	δ_6	0.283	0.239	1.18
Variance parameters				
Sigma squared	δ^2	0.822 ***	0.057	14.33
Gamma	Γ	0.923 ***	0.053	17.18
Log-likelihood function	LLF	-0.702		

Source: Author's computation using frontier 4.1 ***,** indicate significance at 1 & 5 per cent

best practices available to them. Farming experience increases the technical efficiency of rubber farmers. The coefficient for extension contact is -0.375 and statistically significant at ten per cent. Extension contact will lead to an increase in the efficiency of the farmers. The implication is that increasing the number of contact with extension agents through an efficient extension delivery system can bridge the gap between the efficient and inefficient rubber farmers in the study area. Such approaches stimulate farmers' adoption of agricultural technologies, which in the long run shifts the farmers' production frontier upward. The main function of extension agents is to disseminate the latest research results to the farmers. They provide farmers with information on planting and processing techniques, pests and disease control and prices of inputs and outputs. Sepien (1979) found a positive correlation between extension visits and the yield of rubber latex among smallholder rubber farmers in Malaysia.

Table 5. Frequency distribution of technical efficiency of rubber farmers

Range of technical efficiency	Frequency	Percentage
≤ 0.49	4	1.33
0.50 - 0.59	7	2.34
0.60 - 0.69	6	2.00
0.70 - 0.79	40	13.33
0.80 - 0.89	159	53.00
0.90 - 1.00	84	28.00
Total	300	100.00
Mean	0.84	
Maximum	0.95	
Minimum	0.23	

Source: Author's computation using Frontier 4.1

Technical efficiency indices were derived from the stochastic frontier production function analysis in respect of the respondents. This result shows an improvement in farmers' efficiency compared to the mean T.E. of 0.59 in Vietnamese rubber farms. Mustapha (2011), who investigated the technical efficiency of smallholder rubber farmers in Malaysia, found out mean technical efficiency score of 0.832. His figures are lower compared to the one obtained in this study. This result suggests that farmers are not utilising their production resources efficiently, indicating that they are not obtaining maximal output from their given input quantities. In other words, the current state of technology can increase technical efficiency among the respondents by 16 per cent (1-0.84) through better use of available production resources. This would enable the farmers to obtain maximum output from rubber production from the given quantum of inputs and increase their income level, improve their family needs and health, and improve their quality of life.

Conclusion

Natural rubber production, a profitable venture, was male-dominated activities, who were literate, older, experienced and mostly smallholder farmers with a mean farm size of 1.67 hectares. The Maximum Likelihood Estimate (MLE) of the parameters of the stochastic frontier production function of rubber farmers revealed that the elasticity of the outputs with respect to inputs showed that the number of trees per task, labour, farm size, and age of plantation, clone and depreciation on fixed cost items were all significantly related with output. The technical efficiency of the entire rubber farmers is less than one, indicating that the farmers were not operating on the efficiency frontier with the mean technical efficiency of 0.84. Education, extension contact and experience were the significant factors that increased the technical efficiency of rubber farmers.

The overall findings in the study have policy implications for enhancing the production of natural rubber in Nigeria, which will improve and sustain livelihoods of farmers and diversify the economy of the country. Increased production through improved planting materials and rehabilitation of old plantations will also help mitigate the effect of climate change through carbon sequestration and biodiversity conservation. Agricultural research policy should be re-invigorated through adequate funding by government and non-governmental organisations to promote rubber production. Farmers should form cooperative societies and associations to enable them to access production credit from financial institutions. The preponderance of the older farmers in rubber production calls for the government to encourage youth participation in rubber production through incentive programmes such as attractive wages and the provision of infrastructural facilities in the rural areas. Farmers' capacity building through effective extension delivery should be put in place by the government to enhance efficiencies in natural rubber production.

References

Abolagba, E.O., Aigbekaen, E.O. and Omokhafe, K.O. 2003. Farm gate marketing of natural rubber in the South East rubber growing zone of Nigeria. *Nigeria Journal of Agriculture and Rural Development* **6:** 40-48.

Abolagba, E.O., Onyekwere, C.N., Agbonkpolor, B.N. and Umar, H.Y. 2010. Determinants of agricultural exports. *Journal of Human Ecology* **29**(3): 181-184.

Aigner, D., Lovell, C.A.K. and Schmidt, P. 1977. Formulation and estimation of stochastic frontier production model. *Journal of Econometrics* **6:** 21-27.

Agwu, A.E. 2006. Enhancing natural rubber production (*Hevea brasiliensis*) production through extension service delivery in south west agricultural zone in Nigeria. *Agricultural Sciences* **5**(2): 7-16.

Amaza, P.S. and Olayemi, J.K. 1999. An investigation of production efficiency in food crop enterprises Gombe State, Nigeria. *Journal of Rural Economics and Development.* **13:** 111-122.

Apezteguia, B.I. and Garate, M.A.P. 1997. Technical efficiency in the Spanish agro-food industry. *Agricultural Economics.* **17:** 179-189.

Bravo-Ureta, B.E. and Pinheiro, R.E. 1997. Technical, economic and allocative efficiency in peasant farming: Evidence from the Dominican Republic. *The Developing Economics* **35**(1): 48-67.

Cena, R.L. 2011. Money-making potentials of rubber. Retrieved September 30, 2011, from http://blog.agriculture.ph/money-making-potentials-of-rubber.html

Edirisnghe, J.C., Waduge, T.D., Fernando, A.P.S., Herath, H.M.L.K. and Jayasinghe-Mudalige, U.K. 2014. Labour and weather related risks in smallholder rubber production: Evidence from Kalutara District. *Tropical Agricultural Research and Extension* **16**(3): 87-91.

Emokaro, C.O. and Erhabor, P.O. 2006a. A comparative Analysis of input use and profitability among cassava farmers in the three Agro ecological Zones of Edo State, Nigeria. *Journal of Sustainable Tropical Agricultural Research* **19:** 15-22.

Emokaro, C.O. and Erhabor, P.O. 2006b. A stochastic frontier analysis of the technical efficiency of cassava farmers in Edo State, Nigeria. *Journal of Sustainable Tropical Agricultural Research* **20:** 15-19.

Etherington, D.M. 1977. A stochastic model for the optimal replacement of rubber trees. *Australian Journal of Agricultural Economics.* **21**(1): 40-58.

Farrel, M.J., 1957. The measurement of productive efficiency. *Journal of the Royal Statistical Society* 120: 253–281.

Giroh, D. Y., Umar, H. Y. and Yakub, W. 2010. Structure, conduct and performance of farm gate marketing of natural rubber in Edo and Delta States, Nigeria. *African Journal of Agricultural Research* **5**(14): 1780-1783.

Ike, P.C. 2010. Access and loan repayment in the Delta State Agricultural loan scheme. *Farm Management Association of Nigeria (FAMAN) Journal* 11(1): 53-61.

Jagath, E., Wasana, W. and Bogahawatte, C. 2010. Profit efficiency of smallholder rubber farmers in Kegalle, Kalutara and Ratnapura districts. *Journal of the Rubber Research Institute of Sri Lanka* **90:** 64-78.

Jondrow, J., Lovell, C.A.K., Materov, I.S. and Schmidt, P. 1982. On the estimation of technical efficiency in the Stochastic Frontier Production function model. *Journal Econometrica* **9:** 233-238.

Kumarasinghe, H., Edirisinghe, J.C. and Patalee, B. 2012. Role of human capital in technical efficiency increases: Evidence from a data envelopment analysis of rubber small holdings in Gampaha district, *Journal of the Rubber Research Institute of Sri Lanka*. **92**: 12-21.

Mesike, S.C., Owie, O.E.D. and Okoh, R.N. 2009. Resource-use efficiency and return to scale in smallholders rubber farming system in Edo State, Nigeria. *Journal of Human Ecology* **28**(3): 183-186.

Mesike, S.C., Sagay, G.A. and Okoh, R.N. 2010. Optimum replacement period for rubber plantation in Nigeria. *Quarterly International Journal of Agriculture* **19**(3): 257- 270.

Mustapha, N.H.N. 2011. Technical efficiency for rubber smallholders under RISDA's supervisory system using stochastic frontier analysis. *Journal of Sustainability Science and Management* **6**(1): 156-168.

NPC (National Population Commission). 2006. National Population Census, Federal Republic of Nigeria, Official Gazette, Vol. **94** Lagos.

Njukeng JN, Muenyi PM, Ngane BK and Ehabe EE 2011. Ethephon stimulation and yield response of some *Hevea* clones in the humid forests of South West Cameroon. *HH International Journal of Agronomy* **2011:** 1-5.

Omokhafe, K.O. and Nasiru, I. 2004. Polygene inheritance for latex yield in *Hevea brasiliensis*: Muell Arg. *Plant Genetic Resource Newsletter* **140:** 48-50.

Otene, F.G., Obinne, C.P.O. and Egwumah, P.O. 2011. Evaluation of the utilisation level of improved rubber management practices among farm settlers in Edo and Delta States. *Journal of Agricultural Science* **2**(1): 53-60.

Phommexay, P.C., Satasook, P., Bates, M. P. and Bumrungsri, S. 2011. The impact of rubber plantations on the diversity and activity of under storey insectivorous bats in Southern Thailand. *Biodiversity Conservation* **20:** 1441-1456.

Reij, C. and Waters-Bayer, A. 2002. Farmer innovation in Africa. A source of inspiration for agricultural development Earthscan publication Ltd. London, Steerling V.A. pp. 155-167.

Sarba, P.R. 2011. Economic efficiency in Indian Rubber Industry. *Contemporary Economics* **5:** 82-89.

Sajen, P. 2006. Aging Indian rubber trees cause concern. Retrieved September 30,2011, from :http://www.deltaplanttechnologies.com/pr_091806.asp.

Schroth, G., Moraes, V.H.F. and da Mota, M.S.S. 2004. Increasing the profitability of traditional, planted rubber agro forest at the Tapajo's river, Brazilian Amazon. *Journal Agriculture, Ecosystems and Environment.* **102:** 319-339.

Sepien, A. 1979. Effects of some management proxies and sociological factors on productivity of rubber smallholdings in Malaysia. *Southeast Asian Studies.* **17**(1): 58-84.

Spore. 2007. Natural Rubber Springs Back. A Bimonthly Bulletin of the Technical Centre for Tropical Agriculture (C.T.A.), pp. 11-12.

Surakiat, P. Kamonthip, M. and Ke-Chung, P. 2018. Measuring technical efficiency of Thai rubber production using the three-stage data envelopment analysis *Agricultural Economics Czech* **64**(5): 227-240. https://doi.org/10.17221/19/2016-AGRICECON

Suyanto, S. Tomich, T.P. and Otsuka, K. 2001. Land demand and land management efficiency: The case of smallholder rubber production in customary areas of Sumatra. *Journal of Agro forestry Systems* **50**(2): 145-160.

Tapan, K.N., Makoto, I. and Mangala, De Zoysa. 2013. Small-scale rubber planting for enhancement of people's livelihoods: A comparative study in three South Asian countries. *Society and Natural Resources: An International Journal* **26**(9): 1066-1081.

Tran, T.L. 2020. Risk assessment of the economic efficiency of rubber production: Case of smallholder rubber production in QuangBinh Province, Vietnam. *African Journal of Agricultural Research* **16**(5): 567-573 DOI: 10.5897/AJAR2020.14825

Umar, H.Y., Okore, N.E., Toryila, M., Asemota, B. and OkoreI, K. 2017. Evaluation of the impact of climatic factors on latex yield of *Hevea Brasiliensis. International Journal of Research Studies in Agricultural Sciences* **3**(5): 28-33.

Xu, X and Jeffrey, S.R.1998. Efficiency and technical progress in traditional and modern agriculture. Evidence from rice production in China. *Agricultural Economics.* **18:** 157-165.