

ANALYSES OF PRODUCTIVITY AND TECHNICAL EFFICIENCY OF SAWMILL INDUSTRIES IN NIGERIA

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OJO, S. O. & OBALOKUN, B. M. 2005. Analyses of productivity and technical efficiency of sawmill industries in Nigeria. This study examined the productivity and technical efficiency of sawmill industry in Nigeria using the stochastic frontier production function analysis. A total of 86 sawmills were sampled in Ondo state using multi-stage sampling technique. Results showed that Nigerian sawmills were in three scale economies, that is, small, medium and large. The productivity estimates of three of the four variables involved in sawmill operations were efficiently allocated as confirmed by their positive elasticities of production, which were between zero and unity. However, the returns to scale (RTS) of 1.26 implied that sawmill operation was in the increasing RTS stage of the production function. The technical efficiency analysis showed that there was presence of technical inefficiency in Nigerian sawmill operations. The technical efficiency varied significantly between 0.113 and 0.978 with a mean of 0.898. The technical efficiency was higher with medium/large scale sawmills and also much better with sawmill operators without access to government reserved forests.

Key words: Scale-economies – elasticities-of-production – stochastic frontier production function

OJO, S. O. & OBALOKUN, B. M. 2005. Analisis produktiviti dan kecekapan teknikal industri kilang papan di Nigeria. Kertas kerja ini mengkaji produktiviti dan kecekapan teknikal industri kilang papan di Nigeria menggunakan analisis fungsi penghasilan sempadan stokastik. Sebanyak 86 kilang papan di Ondo disampel menggunakan teknik pensampelan berbilang tahap. Keputusan menunjukkan bahawa kilang papan Nigeria tergolong dalam tiga skala ekonomi, iaitu kecil, sederhana dan besar. Anggaran produktiviti tiga atau empat pemboleh ubah yang terlibat dalam operasi kilang papan ditempatkan dengan efisien seperti yang ditunjukkan oleh keanjalan positif bagi pengeluaran, iaitu antara 0 hingga uniti. Bagaimanapun, skala pulangan ikut bidang (RTS) sebanyak 1.26 menunjukkan bahawa operasi kilang papan adalah dalam peringkat RTS yang meningkat dalam fungsi pengeluaran. Kecekapan teknikal menunjukkan bahawa terdapat ketidakcekapan teknikal dalam operasi kilang papan Nigeria. Kecekapan teknikal berbeza dengan signifikan antara 0.113 hingga 0.978 dengan purata 0.898. Kecekapan teknikal lebih tinggi dalam kilang papan skala sederhana/besar dan lebih baik bagi kilang papan yang tiada lesen beroperasi di hutan simpan kerajaan.

Introduction

The number of sawmills in Nigeria has been on the increase lately. It rose from 130 in 1970 to 1220 in 1985 (Badejo & Giwa 1985) and 1349 in 1998 (Akindele & Fuwape 1998). These sawmills are located mostly in the south-west zone of the

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country with Ondo State having the largest number. The concentration of sawmills in this region is influenced by the climatic distribution of vegetation which is responsible for the high concentration of trees in this area. Nigerian sawmill industry processes about 96.6% of the total volume of wood processed in the country and its contribution to the gross domestic product (GDP) surpasses that from other subsectors of the wood-based industries.

The sawmill industry provides wood requirement for constructional development in the areas of residential and commercial buildings, engineering works, home and office furniture, and road construction works, while the products of sawmills serve as raw materials for other wood industries. The industry is important in providing employment opportunities and income.

Nigerian sawmills are categorized as small, medium and large, based on the capacity of equipment used, type of saw (bandmill) and labour utilization (Sanwo 1982, Alviar 1983). Small-scale sawmills are the commonest in Nigeria where most of the wood processing is done with the use of primary conversion machines such as French-made CD horizontal handsaw. The circular band saw is a secondary conversion equipment to reprocess slabs and offcuts. It is mainly used in the medium and large sawmills. Studies have shown that the types of bandmill used have direct relationship with mill efficiency and productivity. The inefficiency and low productivity experienced in the sawmill industry are largely due to a host of problems such as dwindling supply of raw materials caused by the activities of illegal tree fellers, official corruption and destruction of forest resources by fire and unethical agricultural activities of many Nigerian farmers.

The dearth of wood raw materials has led to the use of undersized logs in the mills. This only brought about other problems such as high quantity of wood waste and wastage of time, labour and other resources that have high opportunity costs due the conversion of such small size logs. This phenomenon has led to low capacity utilization of equipment and low extraction efficiency of sawmills. Another equally important cause of inefficiency in the sawmill industry is the low level of education of human resources in the industry. In most Nigerian sawmills, the management staff lacks required education, technical skills and knowledge of administration. Most of the mill managers have less than secondary school education and secured managerial jobs purely on the basis of long years in service.

It is interesting to note that the categorization of Nigerian sawmill industry into small-, medium- and large-scale mills does not imply market differentiation. While medium and large mills handle wood products for both domestic needs and for export, the small mills equally perform these functions. The only difference is that medium and large mills have adequate capital for investment of higher-end production processes and are able to utilize scarce resources efficiently. The small mills, on the other hand, performed at suboptimal level and are thus inefficient in the allocation and utilization of scarce resources.

This study looked at the Nigerian sawmill industry with a view to analyse the productivity of inputs used in the industry. It also predicted the technical efficiency of mills in the industry, conducted tests for the presence of technical inefficiency effects and examined the factors affecting technical efficiency in the industry.

Materials and methods

Analytical framework

The econometric technique used is the stochastic frontier production function. The measurement of the level of technical efficiency in farms using the stochastic frontier production function is now common in agriculture and other fields (Ojo & Ajibefun 2000, Ojo 2003), but it remains a relatively new methodology in forestry research.

The stochastic frontier production function was independently proposed by Aigner *et al.* (1997), and Meeusen and Vanden Broeck (1977). It involves a production function which has an error term with two components, one to account for random effects (V_i) and the other to account for technical inefficiency (U_i) (Coelli 1994). The model can be expressed in the following form:

$$Y_i = X_i\beta + (V_i - U_i)$$

where

Y_i = output of firm i

X_i = vector of input quantities used by firm i

β = vector of parameters to be estimated

V_i = random variable that is assumed to be independently and identically normally distributed and independent of U_i

U_i = non-negative random variable that is assumed to account for technical inefficiency in production and is often assumed to be independently and identically normally distributed. The U_i measures the technical inefficiency relative to the frontier and describes the distance of sawmill i to the frontier output (Y_i^*):

$$Y_i^* = X_i\beta + V_i$$

where

Y_i^* = maximum output achievable given the existing technology and assuming 100% efficiency

The technical efficiency (TE) of the individual sawmill given the specification of the model is estimated using the expectation of U_i conditional on the random variable $(V_i - U_i)$ as shown by Battese and Coelli (1988). Given the available technology, the technical efficiency can also be estimated by finding the ratio of the observed output (Y_i) to the corresponding frontier output (Y_i^*):

$$TE = Y_i / Y_i^*$$

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

The variances of the parameters V_i (σ_v^2) and U_i (σ_u^2) and the overall model variance (σ^2) were used to measure the total variation of output from the frontier under these relationships:

$$\sigma^2 = \sigma_v^2 + \sigma_u^2$$

and

$$\gamma = \sigma_u^2 / \sigma^2$$

where

γ = total variation of output from the frontier, which can be attributed to technical inefficiency (Jondrow *et al.* 1982).

Study area

The study area is Ondo State, Nigeria. The state has three distinct ecological zones. The mangrove forest is situated in the south, the rain forest in the middle and the guinea savannah in the north. The mangrove and rain forest zones have large hectareage of forest reserves that are well stocked with various species of economically important trees such as obeche, iroko and mahogany. The major occupation of the people of the state is farming while lumbering and sawmilling activities thrive well as a result of abundance of economic trees in the individual people's land, government reserved forest and government afforestation projects.

Data collection and sampling techniques

The data, mainly from primary sources, were collected from 86 sawmills selected from six local government areas (LGA) in the state. The LGA are Akure South, Akoko North East, Ose, Idanre, Odigbo and Ondo West. The sampling technique used was the multi-stage sampling method. It involved the purposive sampling method to select the six LGA where sawmilling activities were prominent. The second stage of the sampling involved selection of the sample. A simple random sampling method was used to select the sampled sawmills from the population of sawmills in the six sampled LGA. Information was collected with the use of a set of structured questionnaire on the following variables: output of processed wood in m³, log processed in m³, labour used in man-days, operating expenses in Naira, fixed costs in Naira, and years of schooling and sawmilling experience of sawmill operators. Other variables include scale of operation based on the type of equipment used and accessibility to government reserved forests.

Method of data analysis

The data collected were analysed using descriptive statistics and the stochastic frontier production function. For the study, the production technology of the sawmill operators was assumed by the Cobb-Douglas function linearised in the form:

$$\ln Y_i = \beta_0 + \sum \beta_j \ln X_{ij} + V_i - U_i$$

where

Y_i = output of processed wood (m³)

X_1 = log processed (m³)

X_2 = labour used (man-days)

X_3 = operating expenses (₦)

X_4 = fixed costs (₦)

X_5 = years of schooling of sawmill operators

X_6 = years of sawmilling experience of sawmill operators

The U_i was also assumed with a linear function of the form:

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2$$

where

Z_1 = scale of operation of sawmill (dummied as 0 for small scale and 1 for medium or large scale)

Z_2 = accessibility to government reserved forest (dummied as 0 for non-accessibility and 1 for accessibility of government reserved forest)

Z_1 and Z_2 were included in the model to indicate the possibility of their influence on the technical efficiencies of the sawmill operators. β , δ , γ , σ^2 , σ were scalar parameters obtained using the program FRONTIER 4.1 (Coelli 1994).

Various tests of hypotheses for the parameters of the frontier model were conducted using the generalized likelihood ratio test, which was defined by the chi-square distribution, χ^2 (Battese & Coelli 1993):

$$\chi^2 = -2 \ln (LH_0 / LH_1)$$

where,

LH_0 = the value of the likelihood function for the frontier model in which parameters restrictions specified by the null hypothesis (H_0) were imposed such that:

$H_0: \gamma = 0$, that is, there was no technical inefficiency effects in the production operations of the sawmillers and

LH_1 = the likelihood function for the general model in which there were no restrictions, that is, $H_a: \gamma \neq 0$, indicating there were technical inefficiency effects in the production operations of the sawmillers.

The χ^2 has a mixed chi-square distribution with the degree of freedom (df) equal to the number of parameter restrictions.

Results and discussion

Production performance

The results for sawmill production and socio-economic characteristics of sawmill operators are presented in Table 1. The mean output of processed wood was 8645.87 m³. There was a wide variation in the output of processed wood, consistent with the three scales of the sawmill industry in Nigeria, i.e. small, medium and large. The volume of log brought to the sawmill for processing was 13727.36 m³. The average sawn wood recovered, a measure of extraction efficiency of sawmills, was 62.98%. This showed that the sawmill extraction efficiency was low. The mean labour utilization was 1967.79 man-days. The average output of processed wood per man-day was 4.39 m³, which is regarded as quite fair. The mean operating expenses was ₦311767.71 or about ₦36.10 m⁻³.

Table 1 also shows that sawmill operators were quite well educated with 12 years of schooling. This implies that an average sawmill operator attended secondary school before going into the sawmill industry. With 9.12 years of work, the operators were considered well experienced.

Table 1 Summary statistics of variables of the stochastic frontier model

Variable	Min value	Max value	Mean \pm SD
Wood output (m ³)	1960	44 000	8645.87 \pm 8824.35
Log processed (m ³)	2080	55 000	13 727.36 \pm 10 862.4
Labour (man-days)	840	4216	1967.79 \pm 710.77
Operating expenses (₦)	21 960	549 810	311 767.71 \pm 99305.18
Other cost (₦)	32 541	699 667	251 115.94 \pm 131 484.34
Education (years)	6	17	12 \pm 2.36
Experience (years)	3	20	9.12 \pm 3.55

Small-scale sawmills = 43; medium/large-scale sawmills = 43

Sawmills with access to forest reserves = 73

Sawmills without access to forest reserves = 13

USD1 = ₦142

Of the 86 sawmills studied, 43 were small-scale operators. In all, 73 had access to government reserved forests (results not shown). Small-scale operators could only handle small forest hectareage compared with large-scale operators who were handling over 20 ha of forest areas. Nevertheless, accounting for 50% of the total sampled sawmills in the country, the small-scale operators were significant in the Nigerian sawmill industry.

Estimates of stochastic frontier production function

The summary of the stochastic frontier production function estimates is presented in Table 2.

Presence of technical inefficiency effects and choice of model

The results for the generalized likelihood ratio test for presence of technical inefficiency effects in the sawmill operations as presented in Table 3 rejected the null hypothesis. Thus at $p = 0.05$, about 99% of the variations in the output of finished products of the sampled sawmills were due mainly to technical inefficiency effects, with only 1% variation in the output due to white noise (random effects).

With this finding, the traditional response function (ordinary least squares) was found not appropriate for the estimation of the productivity analysis. Based on this finding, model 1 of Table 2 was not employed for further econometric and economic analyses and, therefore, model 2 was used instead.

Table 2 Estimates of stochastic frontier production function analysis

Variable	Parameter	Model 1	Model 2
General model			
Constant	β_0	-1.89 (-1.91)	-2.15 (-4.6)
Log processed	β_1	*0.92 (13.75)	*0.95 (23.32)
Labour	β_2	0.20 (1.79)	0.12 (1.68)
Operating expenses	β_3	0.05 (0.90)	*0.07 (2.76)
Other costs	β_4	-0.001 (0.02)	0.03 (1.07)
Education	β_5	0.05 (0.38)	0.06 (0.81)
Experience	β_6	-0.07 (0.47)	-0.03 (-0.66)
Inefficiency model			
Constant	δ_0	0	-0.03 (-2.74)
Scale of operation	δ_1	0	*- 2.05 (-2.65)
Accessibility to reserved forest	δ_2	0	0.69 (1.04)
Variance parameters			
Sigma squared	σ^2	0.07	*0.64 (3.52)
Gamma	γ	0	*0.99 (233.78)
Log likelihood function	LLF	-3.47	46.80
Mean technical efficiency	TE		0.898

*Significant at 5%

Figures in parentheses are *t*-ratios.

Productivity analysis

The results for the productivity estimates of sawmill operations are given in Table 2. The estimated elasticity of variables in this study showed positive decreasing function to each of the factors except that of experience of sawmill operators (Table 4).

The positive estimated coefficients and their being between zero and unity implied that the allocation of variables, and their utilization were in the rational stage (stage II) of the production function, that is, they were efficiently allocated and used. Only log processed and operating expenses were significant (Table 2). The negative estimated coefficient of experience of sawmill operators implied that the more years the sawmill operators put into the business the less the output of processed products. This could be explained by the fact that the more years in sawmill business the more opportunities for the operators to go into other businesses and thus less time is devoted for the day-to-day operations of the sawmill business.

The computation of the RTS which is the summation of the elasticity of production of variables involved in the sawmill production is presented in Table 4. The RTS of 1.26 indicated that the sawmill production is in the increasing RTS or stage 1 of the production function, i.e. the inefficient stage. Therefore, the only

Table 3 Generalized likelihood ratio test for presence of inefficiency effects

Hypothesis	L (H ₀)	L (H _a)	χ^2	df	$\chi^2_{(0.05,4)}$	Decision
H ₀ : $\gamma = 0$	-3.47	46.80	100.54	4	9.488	Reject H ₀

Table 4 Elasticity of production and returns to scale (RTS)

Variable	X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	RTS
Elasticity	0.95	0.12	0.07	0.03	0.06	-0.03	1.26

X₁ = log processed (m³); X₂ = labour used (man-days); X₃ = operating expenses (₦); X₄ = fixed costs (₦); X₅ = years of schooling of sawmill operators; X₆ = years of sawmilling experience of sawmill operators

option feasible to increase output of the sawmill industry is to embark on technological growth by expanding the scale of operations.

Analysis of the inefficiency model

The estimated coefficients of the explanatory variables in the inefficiency model as given in Table 2 have important implications. The significant negative coefficients of scale of operation indicated that as the scale of operation moved from small scale to large scale the sawmills became more technically efficient in the allocation of resources. For example, extraction efficiency of sawmills (average sawn wood recovered) improved with scale of operation. Alviar (1983) reported that small-scale sawmills using horizontal band mill machine recovered an average of about 47% of sawn wood while the remainder was residue (slabs, sawdust and barks). On the other hand large-scale sawmills that used circular band mills achieved about 75% extraction efficiency. Small-scale operators have poor resource base and low output. Poor resource base, low income, and limitations of having inefficient institutional framework for sourcing small and medium capital requirements for investment in the sawmill industry are significant factors that inhibit small mills to be selective in the choice of raw materials; they have to contend with the cheaper small-size and poorly shaped logs that are rejected by larger mills.

The coefficient of accessibility to government-reserved forest (X₆) was positive indicating that technical inefficiency increased with increase in this variable. We also observed that sawmill operators without access to government forests performed better because the operators were able to decide on the quality (types and sizes) of logs that were brought to the sawmill for processing. On the contrary, sawmill operators with access to government-reserved forests were just harvesting and processing whatever they could obtain in their forest allocation.

Technical efficiency analysis

The technical efficiencies of the sawmill operators varied significantly between 0.113 and 0.978 with a mean of 0.898 (Table 2). About 94% of the sawmill operators had technical efficiencies ≥ 0.80 . This implied that sawmill operators were highly efficient in the allocation and management of resources. The results also noted that the mean technical efficiencies of medium and large mills was higher (0.96) than small mills (0.836).

Conclusions

There were three scale economies of sawmills in Nigeria, small, medium and large, as shown by their production performances. The sawmill operators were fairly well educated, well experienced and majority of them had access to government-reserved forests. The stochastic frontier production function estimates showed that technical inefficiency effects were present in the production processes of sawmills. The productivity analysis of variables involved in sawmill production showed that all variables studied were efficiently allocated except that of experience while the returns to scale (RTS) of 1.26 implied that sawmill operation was in the increasing returns to scale stage of the production function.

The negative estimated coefficient of scale of operation in the inefficiency model implied that technical efficiency increased as scale economies improve. This means, more sawmills are moving towards large-scale category. However, accessibility to government-reserved forest led to decrease in technical efficiency.

Sawmill operators in the study area were technically efficient. The production and productivity of resources used in the production process would improve with positive change in technological growth of the scale of operations.

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