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Stochastic Estimation of Technical Efficiency and Productivity of Granite Stone Production in Edo State, Nigeria

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Abstract: *The quarry firm – level of efficiency of resource use has important implication on mining in Nigeria, since efficient quarry firms make better use of existing and available resources, producing maximum output at lowest possible cost. This study therefore focused on estimating the technical efficiency and productivity of granite stone production in Edo State, Nigeria. The data for this study were primary data collected from ten (10) selected granite quarries in Edo state. Data were collected using interview method with sets of structured questionnaire, which was designed to collect information on output and input. The study revealed that the technical efficiencies of the quarry firms varied closely between 0.9461 and 0.9993 with a mean of 0.9889. the study further revealed that significant positive determinants of technical inefficiency were mean age of productive equipment ($p<0.05$) and quantity of diesel fuel used ($p <0.01$), while number of skilled labour was the only significant negative determinant of technical inefficiency ($p<0.05$). the mean productivity per skilled labour in tons/person is approximately 2,611 while that of unskilled labour is approximately 1,139 tons/person. Mean productivity per day is approximately 3,817 tons/day. The productivity per mean age of equipment and productivity per years of quarry age are approximately 8,280 tons/year and 4,054 tons/year respectively while the mean productivity per diesel use is 0.57 tons/litre. It is concluded that granite stone production in the study area need policies that will encourage regular replacement of granite stone productive equipment at cheaper amount, while this also has a tendency of reducing diesel fuel use. Access to credit should be focused in policy making to improve affordability of quarry management to regularly replace the leading productive equipment; since age of equipment increases technical inefficiency.*

***Key Words**: Nigeria, productivity, quarry, stochastic frontier production technical efficiency,*

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I. Introduction And Statement Of Problem

The mining of minerals in Nigeria accounts for only 0.3% of her Gross Domestic Product (GDP) due to the influence of her vast oil reservoirs (National Beareau of Statistics [NBS], 2011). GDP from mining in Nigeria averages 1.79 trillion Naira from 2010 until 2017, reaching an all-time high of 2.4 trillion Naira in the first quarter of 2011 and a record low of 1.22 trillion naira in the fourth quarter of 2011 (NBS, 2011).Granite is one of the most commonly found minerals in Nigeria. It is produced as aggregates or dimensional stones. Aggregates are defined as inert, granular, and inorganic materials that normally consist of stone or stone-like solids. They can be used alone (in road bases and various types of fill) or can be used with cementing materials (such as asphalt cement or Portland cement) to form composite materials or concrete (Guimaraes*et al.*, 2007). The sustainability of mining firms (granite quarries) depends on the ability of the firm to maintain a revenue which will sufficiently cater for the working capital, operational cost and other expenses of the firm. Hence, the need for estimating the technical efficiency and productivity in granite quarries.

Technically efficient production of aggregates has great implication for overall national development as it will also lead to rise in Gross National Product (GNP) and per capital income will increase (Amos, 2007). The following reason could be adduced for measuring technical efficiency in granite quarries. It is firstly a success indicator and performance measure (Amos, 2007). Secondly, it is only by measure of technical efficiency and separating its effects from the effects of the production environment that one can explore hypotheses concerning the sources of efficiency differentials (Ajibefun and Daramola, 2003). Thirdly, the ability to quantify efficiency helps decision-making monitor the performance of the units under study. In some cases, the use of theory will not give clear picture of the impact of some factors on the performance level. The use of empirical measurement will provide both qualitative and quantitative evidence (Coelli, 1995).

Empirical evidences suggest that inefficiency oneof the great concerns to industries (including mining) in developing countries as it encourages wastage of resources employed in production, decline in production level and low profit generation (World Bank Development Report,1990). With mining offering great potential in poverty eradication, employment generation and great national economic growth, however this potential will not be achieved if productivity and efficiency are not increasing in the mining sector. Increasing productivity and efficiency in granite quarrying requires a good knowledge of the current efficiency or inefficiency inherent in production as well as factors responsible for this level of efficiency and inefficiency. The need to efficiently allocate productive resources for development purpose cannot be over-emphasized. In that case, every factor of production should be efficiently and effectively mobilised to reduce the gap between actual and potential outputs (Amos, 2007). Therefore, the attempt at studying the productivity and efficiency of granite stones production represents a veritable source of achieving growth in the mining sector and the economy of Nigeria.

The ability of granite quarries to efficiently carry out mining operations with a certain level of input to generate maximum output has been a major concern for quarry operators/owners and the mining industry at large regardless of the mineral or ore being mined. This study specifically focusses on the technical efficiency and productivity of granite stone production while the aims and objectives are to:

i. Estimate the technical efficiency of some selected granite quarries.
ii. Identify the determinants of technical inefficiencies in granite stone production.evaluate the productivity of granite stone quarries.
iii. Assess the level of productivity of granite stone quarries in the study area

II. Theoretical Framework

Production is the process of transforming inputs such as capital, labour and land into goods and services called outputs Ogunbo (2015). The analysis of the efficiency of a production unit dates back to the scholarly work of Koopmans (1951) in which efficiency was defined as the relationship between input-use and output, and use of coefficients of resource utilization as measurement of efficiency. However, Farrel (1957) explained that efficiency of a production firm consists of technical, allocative and economic components. Technical efficiency is the ability to produce a given level of output with a minimum quantity of inputs under certain technology; allocative efficiency refers to the ability to choose optimum input levels for given factor prices while, economic or total efficiency is the product of both technical and allocative efficiencies. A granite stone producing firm is technically efficient when it combines the optimal combination of inputs (labour, capital/ machinery, energy) to produce a given quantity of granite stone. On the other hand, such firm may be technically inefficient if it fails to produce maximum output of granite stone from a given bundle of inputs; in which case, it operates beneath the stochastic production function frontier (Dzever*et al*. 2016). The model is characterized by error term comprising two components; the stochastic component (Vi) and the inefficiency of the producer (Ui). While the stochastic error term represents random shocks such as adverse weather and other factors beyond the control of a producer, the inefficiency component constitutes a deviation from the production frontier as a result of the producer's inefficiency. Battese and Coelli (1995) extended the stochastic production frontier model by suggesting that the inefficiency effects can be expressed as a linear function of the explanatory variables, reflecting individual producer's characteristics. The advantage of this model is that it allows estimation of the firm-specific efficiency scores and the factors explaining efficiency differentials among quarries in a single stage estimation procedure. Assuming that the production function of the granite stone producers in the study area is given by

$$Yi = f(Xi,\beta) + Vi - Ui \text{--} (1)$$

Where Yi is granite stone output for ith quarry; Xi represents the physical inputs, βs are the parameter estimates to be estimated; Vi is the stochastic error term that is assumed to be normally, independently and identically distributed (idd), with zero mean and unknown variance (σ2v), while Ui is the inefficiency component of the error term. A producer (quarry) is efficient if he or she operates on the frontier, that is, the optimum output that could be realized from a given set of inputs. A producer who fails to produce on the frontier is therefore inefficient. Technical efficiency (TE) measures the ratio of an observed output to the optimum output that could be produced by a fully-efficient quarry using the same inputs vector. Technical efficiency takes a value between zero and one. As expressed by Coeli*et al*. (2005), output oriented technical efficiency can be represented by:

$$TE = \frac{\text{Yi}}{\text{Ymax}} = \frac{\exp{(Xi\beta + vi - ui)}}{\exp{(Xi\beta + vi)}} = exp(-ui) \text{ --} (2)$$

III. Methodology, Data Analysis And Results

Data Collection

Data for this study were collected from granite stone quarry in Edo state, Nigeria. Edo state is located in the southern part of Nigeria. It lies between longitude 6.5438° North and latitude 5.8987° East. It is bounded by the Kogi state to the Northeast and east, Anambra to the east, Delta to the southeast and south, and Ondo to the west and Northwest. The Niger River flows along the state's eastern bound (Reyment, 1965). Edo state lies at elevation between 500 feet (150) in the south more than 1500 feet (550) in the north. The data for this study were primary data collected from ten (10) selected granite quarries in Edo state. Data were collected using interview method with sets of structured questionnaire, which was designed to collect information on output and input, and some major socio-economic characteristics of the granite quarries in the area. The input data collected include: labour, capital, age and number of equipment, land area of quarry etc. while output data collected includes granite production in tonnes in previous five (5) months.

Empirical Model Specification

Transcendental logarithm production function (Christensen *et al*., 1971) to estimate the production parameters. The model is implicitly specified as follows

$$LnYi = \beta o + \sum_{n=1}^{8} \beta\, nlnXn + \frac{1}{2} \sum_{n=1}^{8} \sum_{n=1}^{8} \beta nmlnXn\, lnXm \text{ ----------------------------- (3)}$$

Where:
Y = Output (tons)
x1 = Sum of productive equipment
x2 = Mean age of productive equipment (years)
x3 = Hours of daily use of equipment (hours)
x4 = Number of skilled labour (persons)
x5 = Number of unskilled labour (persons)
x6 = Mean working hours per day (hours)
x7 = Mean working days per week (days)
x8 = Diesel quantity (Litre)
Vi and Ui are assumed to be independently distributed of each other and uncorrelated with Xi, while Ui follows half normal distribution. Factors explaining the farmer's inefficiency are implicitly expressed as

$$Ui = \delta o + \sum_{n=1}^{8} \delta n\, Zn \text{ --- (4)}$$

Where,
z1 = Availability of engineer for repairs (available=1; not-available=0)
z2 = Years of establishment (years)
z3 = Number of subsidiaries
z4 = Number of Downtimes

IV. Data Analysis And Results

4.1 Technical Efficiency Assessment

Table 1: Statistics of some production variables

Production variables	Min	Max	Mean	Std. Dev.
Total number of major equipment	7.00	21.00	13.50	4.33
Mean equipment age (years)	2.35	7.00	4.36	1.49
Mean equipment use per day(hours)	6.00	12.00	7.90	1.97
Age of quarry(years)	5.00	16.00	7.90	3.31
Number of skilled workers (persons)	6.00	51.00	15.30	13.35
Number of unskilled workers (persons)	15.00	202.00	43.20	56.84
Days of work per week	6.00	18.00	4.50	3.78
Hours of work per day	8.00	21.00	10.60	4.79
Area of land (Acres)	2.00	7.00	4.50	3.54
Number of subsidiaries	0.00	6.00	2.40	1.90
Quantity of diesel used per month (liters)	30,000.00	90,000.00	57,600.00	23,684.03
Mean monthly production (tonnage)	21,600.00	51,600.00	30,818.00	9,488.64

Source: Authors data analysis, (2018)

The statistics of some production variables were presented in Table 1. The study reveal that the mean number of equipment is 14 with an average age of 4 years used for an average of 8 hours per day. The mean number of skilled labour and unskilled labour across the quarries are 14 and 43 persons respectively. These workers work for an average of approximately 5 days per week and about 11 hours per day. The selected quarries have an average of 4.5 acres of land occupied by the companies with the mean number of subsidiaries of about 2. The average quantity of diesel used is 57,600 liters per month for the production of an average of 30,818 tonnes of granite from September 2017 to January 2018 across the quarries.

4.2. Determinants of Technical Inefficiency of Granite Stone Production

Table 2: Maximum likelihood estimates of stochastic frontier for granite stone production

Variable	Parameter	Coefficient	Std. Error	t-value
Constant	β_o	4.5890	0.9065	5.0621
Sum of productive equipment	β_1	0.1153	0.1091	1.0564
Mean age of productive equipment (years)	β_2	0.1951	0.0775	2.5171**
Hours of daily use of equipment (hours)	β_3	1.0106	0.5380	1.8782
Number of skilled labour (persons)	β_4	-0.3346	0.1373	-2.4354**
Number of unskilled labour (persons)	β_5	0.2827	0.1634	1.7308
Mean working hours per day (hours)	β_6	0.0381	0.1800	0.2117
Mean working days per week (days)	β_7	0.1282	0.2584	0.4961
Diesel quantity (liter)	β_8	0.2445	0.0731	3.3460***
Sigma squared	σ^2	0.00007	0.0002	0.3468
Gamma	γ	0.4921	2.0199	0.2436

Source: Author's data analysis, (2018)
*** and ** = significant at 1% and 5% levels respectively
Log-likelihood function = 30.9067Linear Regression (LR) of the one sided error = 6.34978

Maximum likelihood estimate of the Cobb–Douglas Stochastic Frontier Production was carried out to determine the technical efficiencies of granite quarries as well as their mean technical efficiency in the study area. The result is as tabulated above (Table 2). The sigma square (σ^2) and gamma (γ) estimated were 0.00007 and 0.4921, respectively, and they are significant at 5.0% level. The sigma square (σ^2) shows the goodness of fit of a model while the gamma (γ) shows the proportion of total deviation from frontier attributable to inefficiency of the quarries and the 0.84 observed in this study indicates presence of inefficiency in granite stone production quarries.The study further reveals that a group of variables; sum of productive equipment, mean age of productive equipment, hour of daily use of equipment, number of unskilled labour, mean working hours per day, mean working days per week and quantity of diesel fuel, all have a positive impact on inefficiency. While technical efficiency increases as number of skilled labour increases. Significant determinants were mean age of productive equipment ($p<0.05$), number of skilled labour ($p<0.05$) and quantity of diesel fuel used ($p <0.01$).

Table 3: Maximum Likelihood Estimates of the Parameters of the Inefficiency Factors

Variable	Parameter	Coefficient	Std. Error	t - value
Constant	δ_0	-0.3515	0.2317	-0.1517
Availability of engineers for repairs	δ_1	-0.0082	0.0212	-0.3846
Years of establishment	δ_2	-0.0043	0.0138	-0.3107
Number of subsidiaries	δ_3	0.0028	0.0028	0.1913
Number of downtimes	δ_4	0.0166	0.0428	0.3490

Source: Authors data analysis, (2018)

Table 3 above describes the inefficiency factors such as the availability of engineers for repairs, the year of establishment of quarries, the number of downtimes and the number of subsidiaries of firms. Results showed that the coefficients on availability of engineers for equipment repairs and years of establishment of quarry were insignificant and negatively influencing technical inefficiency of HQCF processors; this implies that technical efficiency increases as these number of engineers available for equipment repairs increases, technical efficiency of production of granite stones increases; while older quarries are more technically efficient than newly established quarries. The coefficients on number of subsidiary and number of downtimes were positive and insignificant at all levels of probability.

Table 6: Level of Technical Efficiency Estimate of Granite Stone Quarries used for this Study

Quarry	Efficiency Estimates
1	0.9993
2	0.9461
3	0.9870
4	0.9918
5	0.9912
6	0.9992
7	0.9975
8	0.9787
9	0.9993
10	0.9991

Maximum Technical Efficiency = **0.9993**
Minimum Technical Efficiency = **0.9461**
Mean Technical Efficiency = **0.9889**

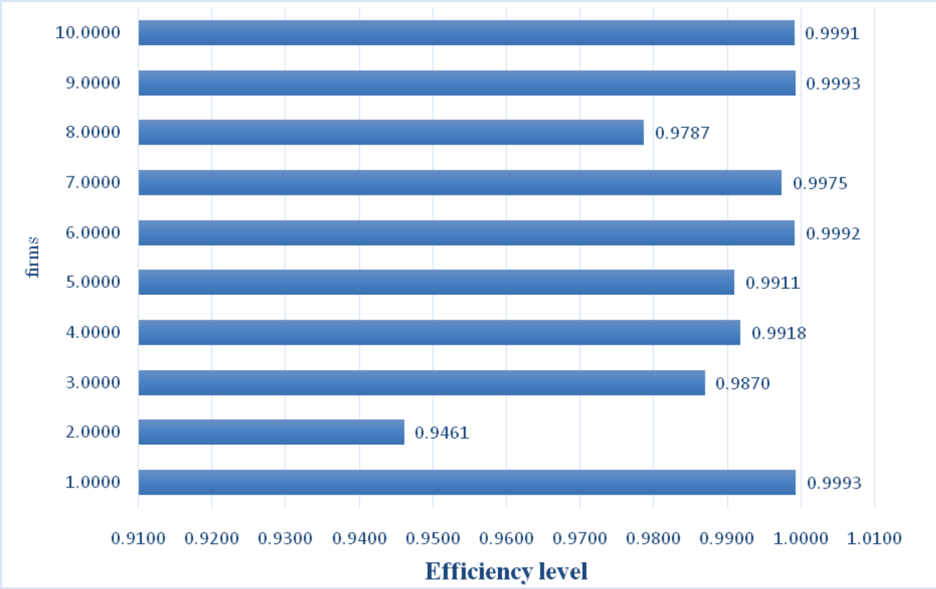

Fig. 6: Technical Efficiency Estimates of quarries

The Fig. 6 above describes the technical efficiency level of 10 quarries. The technical efficiency of the quarries is below 1.0 which means the quarries are operating below the frontier. It is found that firms 1, 6, 9 and10 are the most efficient quarries and firms 3,4,5,7 and 8 can be described as fairly efficient while firm 2 is the least efficient. The maximum and minimum efficiencies are 0.9993 and 0.9461 respectively. The mean efficiency is found to be 0.9889.

4.3 Granite stone quarries' level of productivity

Measurements of productivity

Table 4: Statistics of some productivity measurements

Productivity measurements	Min.	Max.	Mean	Std. Dev.
Productivity per skilled labour (tons/pers.)	1,011.76	3,966.67	2,611.03	940.80
Productivity per unskilled (tons/pers.)	255.45	1,787.50	1,139.64	464.44
Productivity per day (tons/day)	2,866.67	4,766.67	3,817.61	543.78
Productivity per mean equipment age (tons/yr.)	3,771.43	18,763.64	8,279.55	5,091.04
Productivity per years of quarry age (tons/yr.)	3,142.86	5,040.00	4,053.71	727.37
Productivity per diesel use ((tons/lt.)	0.42	0.73	0.57	0.12

Source: Authors data analysis, (2018)

Table 4 shows that the mean productivity per skilled labour in tons/person is approximately 2,611 while that of unskilled labour is approximately 1,139 tons/person. Mean productivity per day is approximately 3,817 tons/day. The productivity per mean age of equipment and productivity per years of quarry age are approximately 8,280 tons/year and 4,054 tons/year respectively while the mean productivity per diesel use is 0.57 tons/litre.

V. Conclusion And Recommendations

This study examined the technical efficiency and productivity granite stone quarries in Edo State, Nigeria. Specific objectives were to estimate the technical efficiency granite stone production of some selected quarries in the study area, determine factors that affect efficiency and to evaluate the productivity of production. The study revealed closeness in the technical efficiencies of the quarry firms. The study further revealed that significant positive determinants of technical inefficiency were mean age of productive equipment and quantity of diesel fuel used, while number of skilled labour was the only significant negative determinant of technical inefficiency. It is concluded that granite stone production in the study area need policies that will encourage regular replacement of granite stone productive equipment at cheaper amount, while this also has a tendency of reducing diesel fuel use.

Based on the above conclusion, the following recommendations were made;

i. Access to credit should be focused in policy making to improve affordability of quarry management to regularly replace the leading productive equipment; since age of equipment increases technical inefficiency.

ii. Quarry firm management should consider employing more skilled staff who have adequate training to manage quarry workers and equipment. This is because number of skilled persons in quarry firms increases technical efficiency.
iii. Adequate policy measures should aim at reducing quantity of diesel fuel use avoiding wastage through regular replacement of equipment part and training of staff, should be

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