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Technical and Cost Efficiency of GSM Commercial Call Centers: A Stochastic Frontier Approach

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Abstract

One of the key areas in which science and technology has had profound impact on the Nigerian economy in recent years, is in the area of Global System for Mobile Communication (GSM). The introduction of GSM into Nigeria in 2001 has opened up a lot of opportunities ranging from ease of communication to commerce, industry, trade and tourism; and employment, among others. The Telecommunications industry has attracted considerable investment, providing employment opportunities for several thousands of unemployed school leavers and graduates of tertiary institutions, most especially through the establishment of GSM commercial call centers. This paper is based on an empirical study of GSM commercial call operators in Osogbo, the capital of Osun State, Nigeria. A random sample of twenty out of the 120 Enumeration Areas (EAs) in Osogbo was taken. Also, ten GSM commercial call centers were randomly chosen from the list of GSM commercial call centers in each of the twenty EAs earlier selected. This produced a total of 200 GSM commercial call centers. A structured questionnaire was used to collect data on the technical and cost efficiencies of the centers. In all, 178 questionnaires were duly filled, returned and analyzed. The study employed the use of Stochastic Frontier Package version 4.1 to investigate the presence or otherwise, of technical and/or cost inefficiencies in the operations of the centers. The Stochastic Frontier Analysis revealed that number of handsets, and number of network available affect technical efficiency while education, complimentary services, network quality; and location affect cost efficiency. The study, among others, recommends that government and other stakeholders should channel micro-credit to the GSM commercial call operators so as to enable them invest on those factors that would enhance their technical and cost efficiencies.

Keywords: GSM, telecommunication, technical & cost efficiency.

Introduction

The development of telephone services in Nigeria could be traced back to 1886 when a cable connection was established between Lagos and the colonial office in London. By 1893, government offices in Lagos were provided with telephone service which was later extended to Ilorin and Jebba in the hinterland (http://myprofile.com//gcnwaobi). The purpose of the deployment of these telephone lines was to perform basic administrative functions by the colonial office. Since independence in 1960, successive governments have made several attempts to increase people's access to basic telephone services with little success to show for it. Oluwadare

(2006a), in a recent study, observed that there has been interregnum of doldrums, inefficiency and decay in the nation's telecommunication sector before the advent of the deregulation of the telecommunication sector in 2001.

Statistics released by (NCC, 2004) showed that there were less than 500,000 active fixed telephone lines for Nigeria's estimated population of 130 million as at 2001. Owing to the deregulation of the nation's telecommunication in 2001, as well as innovative regulatory and facilitative framework put in place by the Nigerian Communications Commission (NCC), the number of connected fixed and mobile telephone lines have increased to about 17 million by 2005. The cumulative effect of the increases in the number of connected fixed telephones and the number of mobile phone subscribers have increased the Nigeria's teledensity profile from 1.89 in 2002 to 8.5 in 2005 (Oluwadare, 2006b).

The entrance of multiple operators in the telecommunication sector, particularly the mobile segment, coupled with intensifying competitive rivalry, has had profound effect in the industry in terms of growing subscriber base, decreasing tariff, widening coverage areas, improving quality of service levels, expanding product range and innovativeness; and increasing employment opportunities. Today, there are several GSM commercial call operators all over the country who derive their means of livelihood from rendering telephone services. This paper examined the structure of the GSM commercial call centers in Osogbo, the Osun State capital. It looked at the technical and cost efficiencies of these GSM commercial call centers with a view to proffering recommendations that would enhance their efficiency and viability.

Analytical Technique

Technical Efficiency (TE) is defined as the measure of the ability of a firm to obtain the best production from a given set of inputs (output-increasing oriented), or as the measure of the ability to use the minimum feasible amount of inputs given a level of output (input-saving oriented) (Farell, 1957; Greene, 1980; Atkinson and Cornwell, 1994). Consequently, technical inefficiency is defined as the degree to which firms fail to reach the optimal production.

Farell (1957) proposed a model for measuring TE of a firm by comparing its observed output with output, which could be produced by a fully efficient firm, given the same bundle of input. In the model, inefficiency is measured as the distance from the observed output point to the best production point. In stochastic frontier models, the production frontier is specified which defines output as a function of a given set of input. The presence of stochastic elements makes the models less vulnerable to the influence of outliers than with deterministic frontier models, where the production function frontier is not subject to statistical noise that is,. it is fixed. Examples of deterministic frontier models are found in (Aigner et al, 1968; Timmer, 1971; Afriat, 1972; Richmond, 1974; Schmidt, 1976; and Greene, 1980).

In Stochastic Frontier Analysis (SFA), the error term (ϵ) may be separated into two terms: a random error and a random variable explaining inefficiency effects:

$$y_i = f(x_{i,}\beta) + e^{\varepsilon} \qquad (1)$$

$$\varepsilon = (v_i - u_i)\,, \quad i = 1,2,\ldots N \qquad (2)$$

where y_i denotes the level of output for i^{th} observation, x_i is the row vector of inputs, β is the vector of parameters to be estimated; f (.) is suitable functional form for the frontier (e.g. linear, Cobb-Douglas or translog); v_i is a symmetric random error assumed to account for measurement error and other factors not under the control of the firm; and u_i is an asymmetric non-negative error term assumed to account for technical inefficiency in production. The v_is are usually assumed to be independent and identically distributed (iid) normal random variables with mean zero and variance σ^2:

$$v_i \sim N(0, \sigma_v^2) \qquad i = 1,2,\ldots N \qquad (3)$$

Several distributions have been proposed for u, but u_is are usually assumed to be iid and truncations (at zero) of the normal distribution with mean μ and variance σ_u^2:

$$v_i \sim |N(0, \sigma_u^2)| \qquad i = 1,2,\ldots N \qquad (4)$$

The TE measure is obtained by the ratio of y_i to the maximum achievable level of output:

$$TE = \frac{y_i}{y^*} = e^{-u_i} \qquad (5)$$

where y* is the output that lie on the frontier.

There are basically, two approaches to the estimation of inefficiency effects. The two approaches are the one-stage and two-stage methods. The one-stage method in which the inefficiency effects are modeled in terms of other observable explanatory variables and all parameters (frontier production and inefficiency effects) are estimated simultaneously is generally preferred (Battese and Coelli, 1995). In the one-stage approach,. Battese and Coelli, formulated a functional relationship in which inefficiency effects and the firm-specific factors is directly incorporated into the Maximum Likelihood Estimate (MLE). The inefficiency term u_{it} has a truncated (at zero) normal distribution with mean m_{it}:

$$u_{it} = m_{it} + W_{it} \qquad (6)$$

where W_{it} is a random error term which is assumed to be independently distributed with truncated (at - m_{it}) normal distribution with mean zero and variance σ^2 (i.e. $W_{it} \geq - Z_{it}$ such u_{it} is non-negative). The mean m_{it} is defined as:

$$m_{it} = z(z_{it}, \delta) \quad i = 1,2,\ldots N,\ t = 1,2,..T \qquad (7)$$

where z is the vector (m x 1) of the z_{it} firm – specific variables of inefficiency; and δ is the (1xm) vector of unknown coefficients associated with z_{it}. In this way, we are able to estimate inefficiency effects arising from the z_{it} explanatory variables.

Cost Efficiency Model

The estimation of cost efficiency of a firm follows the same procedure discussed above. Generally, the cost efficiency can be specified as follows:

$$E_i = c(y_i, w_i, \beta) \exp\{v_i + u_i\} \qquad (8)$$

where $c(y_i, w_i, \beta)$ is the deterministic kernel, v_i which is the random noise, takes positive and negative values; u_i captures the inefficiency and it takes only positive values. Under this formulation cost efficiency can be calculated as

$$CE_i = \frac{c(y_i, w_i, \beta)e^{v_i}}{E_i} = e^{-u_i},\ 0 \le CE_i \le 1 \qquad (9)$$

Data and Empirical Model

Data

The data for this study was derived from Osogbo, the capital of Osun State, Nigeria. Twenty out of the 120 EAs in Osogbo were selected randomly using random number table. A listing of all GSM commercial call centers was done in each of the selected EAs. Again, the random number table was used to select 10 GSM commercial call centers from each EA. This produced a total of 200 GSM commercial call centers used for the study. A structured questionnaire was administered to the operators of these centers. At the end of the exercise, 178 questionnaire which represent 89% of the total questionnaire administered were duly filled and returned.

Frontier Model Specification

Stochastic Frontier Production Model

In this study, we assumed a Cobb-Douglas functional form as frontier technology specification for the GSM commercial call centers. Using Battese and Coelli (1995) procedure, the Cobb-Douglas stochastic frontier is specified as follows:

$$\ln Y_i = \beta_0 + \sum\beta_j X_{ji} + (v_i - u_i)\ ,j = 1,2,..N \qquad (10)$$

This could be stated explicitly as follows:

$$\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + (v_i - u_i) \qquad (11)$$

where

$Y =$ output of GSM commercial call centers (measured in average number of calls per day)

$\beta_0 - \beta_7 =$ parameters to be estimated

$v_i =$ is the random error

$u_i =$ inefficiency component

$X_1 =$ capital outlay (Naira)

$X_2 =$ labor (wage rate in Naira)

$X_3 =$ cost of recharge card (Naira)

$X_4 =$ network quality (network coverage, signal quality etc.)

$X_5 =$ complimentary services rendered at the center (e.g. sales of GSM accessories, GSM lines, photocopying, computer services, etc.)

$X_6 =$ location (business district/educational institution/road junction, residential/other areas).

$X_7 =$ population density (high, medium or low).

The inefficiency effects model is specified as follows:

$U = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + w_i$

$U =$ efficiency effect

$Z_1 =$ educational level of respondents

$Z_2 =$ gender of respondents

$Z_3 =$ number of networks available at the centre

$Z_4 =$ number of handsets available at the center

$\delta_0 - \delta_4 =$ parameters to be estimated

$w_i =$ error term

Cost Model

The stochastic frontier cost model for the study is specified as follows:

$$\ln C_i = \beta_0 + \sum \beta_j X_{ji} + (v_i + u_i) ,j = 1,2,..N \quad (12)$$

This could be stated explicitly as follows:

$$\ln Y = \beta_{0} + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + (v_i + u_i) \quad (13)$$

where

C =	Cost of operation (Naira)
X_1 =	average number of calls per day
X_2 =	cost of handset (Naira)
X_3 =	cost of recharge card (Naira)
X_4 =	cost of labor (Naira)
X_5 =	GSM service provider
X_6 =	other costs (Naira)
β_0 - β_6 =	parameters to be estimated
u_i =	is the random error

The inefficiency effects model is specified as follows:

U =	$\alpha_{0} + \alpha_1 Z_1 + \alpha_2 Z_2 + \alpha_3 Z_3 + \alpha_4 Z_4 + w_i$
U =	efficiency effect
Z_1 =	educational level of respondents
Z_2 =	complimentary services rendered at the centre
Z_3 =	network quality
Z_4 =	location of the GSM call centre
α_0 - α_4 =	parameters to be estimated
w_i =	error term

Results of Analysis

The presentation of the results covers the socio-economic characteristics of the GSM commercial call operators and the empirical analysis of the stochastic frontier production and stochastic frontier cost functions.

Socio-Economic Characteristics of Respondents

Age Distribution of Respondents

Table 1 showed that 83.1% of the respondents were below 35years of age. This shows that the GSM commercial call business is dominated by the youth.

Table 1. Age distribution of respondents

Age group	Frequency	Percentage	Cumulative percent
Less than 20	30	16.9	16.9
20 – 24	31	17.4	34.3
25 – 29	54	30.3	64.6
30 – 34	33	18.5	83.1
35 – 39	25	14.1	97.2
40 and above	5	2.8	100
Total	178	100.0	

Source: Field survey, 2006

Distribution of Respondents by Sex

The result presented in Table 2 showed that 53.9% of the respondents are male while 46.1% are female. This showed that GSM commercial call business is not gender biased, that is, both male and female are engaged in it.

Table 2. Sex distribution of respondents

Sex	Frequency	Percentage	Cumulative percent
Male	90	53.9	53.9
Female	82	46.1	100
Total	178	100	

Source: Field survey, 2006

Educational Level of Respondents

The result presented in Table 3 revealed that 7.3% of the respondents had primary school education, 24.7% had secondary school education and 68.0% had post secondary school education. This clearly showed that GSM business is a undertaken by literate people. This may be explained by the fact that GSM is a hi-tech enterprise.

Table 3. Distribution of respondents by education level

Education level	Frequency	Percentage	Cumulative percent
No formal education	0	0	0
Primary	13	7.3	7.3
Secondary	44	24.7	32.0
Post secondary	121	68.0	100
Total	178	100	

Source: Field survey, 2006

Marital Status of Respondents

Table 4 revealed that 77.5% of the respondents are single while 22.5% are married. This further confirmed that GSM commercial call business is dominated by the youth.

Table 4. Distribution of respondents by marital status

Marital status	Frequency	Percentage	Cumulative Percent
Single	138	77.5	77.5
Married	40	22.5	100
Total	178	100	

Source: Field survey, 2006

Initial Capital

The result presented in Table 5 revealed that 51.1% of the respondents started business with less than ₦20,000.00, 34.8% started with between ₦ 20,000.00 and ₦40,000.00 while 14.1% started with above ₦40,000.00. This shows that starting GSM commercial call business requires small capital investment.

Table 5. Initial capital for starting GSM commercial call business

Amount (₦)	Frequency	Frequency	Cumulative percent
Less than ₦20,000	91	57.1	51.1
₦20,000 – 40,000	62	34.8	85.9
Above ₦40,000	25	14.1	100
Total	178	100	

Source: Field survey, 2006

Empirical Results of the Stochastic Frontier Model

Stochastic Frontier Production Model

The result presented in Table 6 showed that all the variables included in the frontier model are significant determinants of output. Also, it was observed that number of GSM networks and number of handsets for use at the GSM call center contribute significantly to the technical efficiency of the call center. On the other hand, education and gender do not contribute significantly to the technical efficiency. This may be due to the fact that majority of the respondents (68.0%) have post secondary education. The coefficients of the variables in the efficiency model are negative, meaning that they lead to decrease in technical inefficiency or increase in technical efficiency. The sigma squared (0.7651) showed that about 76.5% of the variation in output is jointly explained by the independent variables in the model. The gamma coefficient (0.9826) indicates that about 98.26% of the variation in output of the GSM commercial call operators was due to differences in their technical efficiencies. The efficiency of the firms ranges between 26.65% and 87.05%, with mean efficiency of 0.5301. Thus in the short run, there is the scope for increasing output by about 46.99% by adopting the technology and techniques used by best – practice GSM commercial call operators.

Table 6. Maximum Likelihood Estimate for Stochastic Frontier Production Function

Variable	Parameter	Coefficients	S.E	t-ratio
Frontier Model				
Constant	β_0	7.5753	1.0117	7.49**
Capital	β_1	0.2670	0.0511	4.56**
Labour	β_2	0.2166	0.210	6.72**
Cost of recharge card	β_3	0.0670	0.023	3.76*
Network quality	β_4	0.1630	0.072	2.56**
Complimentary Services	β_5	0.4568	0.038	5.85**
Location	β_6	0.2856	0.0612	3.08**
Population density	β_7	0.6231	0.071	5.76**
Efficiency Effects				
Constant	δ_0	0.0246	0.8926	2.36**
Educational level	δ_1	0.0010	0.000	1.52
Gender	δ_2	0.0340	0.1626	1.22
Number of networks	δ_3	0.5445	0.2356	2.86**
Number of handsets	δ_4	0.0841	0.3618	2.85**
Sigma squared		0.7651		
Gamma		0.9826		
Log likelihood function		0.6856		
Mean Technical Efficiency		0.5301		

* Significant at 0.05 level
** Significant at 0.01 level
S.E. = Standard Error

Stochastic Frontier Cost Function

Results presented in Table 7 revealed that all the variables in the frontier cost model except cost of handset are significant determinants of the cost of production of GSM commercial call operators. The result of the inefficiency model indicates that all the variables except education level have significant effect on cost efficiency of the operators. However, the coefficients of all the variables are negative, indicating that they lead to decrease in technical inefficiency or increased in technical efficiency. The sigma squared (0.83612) indicates that about 83.6% of the variations in cost of production are jointly explained by the variables in the frontier cost model. The gamma coefficient (0.982) indicates that about 98.2% of the variation in the cost of production of the GSM commercial call operators was due to differences in their cost efficiencies.

Finally, the efficiency of the firms ranges from between 0.248 and 0.958, with a mean of 0.728. Hence, in the short run there is the scope of the cost of production being reduced by about 27.2% by adopting the technology and techniques used by the best-practiced GSM commercial call operators.

Table 7. Maximum Likelihood Estimate for Stochastic Frontier Cost Function

Variable	Parameter	Coefficients	S.E	t-ratio
Frontier Model				
Constant	β_0	0.6439	0.861	8.123**
Average number of calls	β_1	1.6984	0.001	5.821**
Cost of handsets	β_2	0.5620	0.034	1.023
Cost of recharge card	β_3	2.812	0.396	6.865*
Cost of labour	β_4	3.261	0.002	4.816*
GSM service provider	β_5	0.786	0.031	7.826**
Other costs	β_6	0.345	0.045	6.123**
Efficiency Effects				
Constant	α_0	0.9324	0.026	2.215*
Educational level	α_1	0.2392	0.052	1.061
Gender	α_2	0.5896	0.021	3.027**
Number of networks	α_3	0.2810	0.012	2.967**
Number of handsets	α_4	0.3261	0.034	3.823**
Sigma squared		0.83612		8.625*
Gamma		0.982		256.42**
Log likelihood function		0.826		
Mean Technical Efficiency		0.728		

* Significant at 0.05 level
** Significant at 0.01 level
S.E. = Standard Error

Conclusion

The study revealed that technical and cost efficiencies of GSM commercial call operators varied due to technical and cost inefficiency effects. Number of networks and number of handsets available at the call centers increase technical efficiency. Also, education level, complimentary services, network quality and location contribute to efficiency. Since the study also revealed that GSM commercial call business requires little capital investment, it is recommended that government at all levels, Non-Governmental Organisations (NGOs), financial institutions, micro-credit agencies; and other stakeholders should channel micro-credit to the GSM commercial call operators so as to enable them invest more on those variables that would enhance their technical and cost efficiencies. Since the study showed that most GSM commercial call operators operate below technical and cost frontiers, efforts should be made by all stakeholders to address the issues raised in this research in order to enable the telecommunication sector of the nation's economy realize fully, one of its roles namely, the provision of sustainable employment for the growing army of unemployed citizens.

Finally, there should be further research into the structure, cost-benefit analysis, cash flow analysis and productivity of GSM call business in Nigeria. This would promote growth of the telecommunication sector with its attendant multiplier effect on the nation's economy.

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