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Service Model Estimation for Technical Efficiency of Internet Service Providers in Western Nigeria

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Abstract

This work focuses on the provision of Internet services to the consumers by the Internet service providers in Western Nigeria. The technology of the Internet service providers is assumed to be specified by the Stochastic Translog frontier model as a relationship among certain network characteristics taken in as inputs in the day-to-day provision of services.

Consequently, an 'Internet Service Model Estimation Questionnaire' was designed and administered to a total of 203 randomly sampled Internet service providers in Western Nigeria, in order to collect data about these network characteristics. The collected data were analysed using the Statistical Package for Social Scientists (SPSS) for Windows software and the Stochastic Frontier software. Two models were fitted from the analysed data using the two softwares and sample estimations were made with the models. Finally, a comparative analysis of estimations from the two models was carried out. The hypotheses that the Cobb-Douglas Model adequately represents the data were accepted in both methods. However, it was found that the Frontier estimates perform better because of the capability of the software to isolate the inefficiency errors in the prediction and the generation of firm-level technical efficiency fore each of the service providers. It was found that although the means technical efficiency is high (about 91.2%), wide variation of about 64.9% exists between the lowest and the highest technically efficient service providers. Furthermore, network characteristics such as transmission link and transmission bandwidth have the most effect on the technical efficiency of a service provider in Western Nigeria.

Keywords: Web audience, broadband technologies, telecommunications demand.

Introduction

The Internet is an international network whose origin came from the Federally – funded research that started in the Department of Defense in the early 1960s and was nurtured by the National Science Foundation of the United States until the mid 1990s (Wiseman, 2005). Between that time and now, the Internet has grown in sophistication, resources and services, and is in fact, creating an 'information economy' in developed and developing countries. The driving force for the feat is the provision and utilization of the many Internet services, from simple ones like electronic mail, search engines, file transfer, remote login to advanced and newer functions such as broadband services; all driven by the TCP/IP protocol of the Internet. The Transmission Control Protocol (TCP) and Internet Protocol (IP) define the rule by which packets of data are addressed and transmitted across physical fibers, satellite and Wireless networks (U S Government Working Group, 1998).

The connection and provision of these Internet service to consumers is usually done by the Internet Service Providers, and usually there is a mode of connectivity, a bandwidth for the services, the types and level of services to access (the height of which are broadband services). Simple services such as e-mail are guaranteed to consumers by telephone connections (offering at a rate of 9.6kbps) or at most the digital subscriber line for improved service delivery (Redback, 2003). Broadband services require other more sophisticated modes of connectivity such as the fibre optic cable, microwave and VSAT (Very Small Aperture Terminal). In fact, Gillert (1995) showed that cable medium can provide the same average bandwidth and four times the peak bandwidth of telephone medium.

There is no gain saying that the trend today in Internet services follows that of broadband technologies, and thus, from the ISP point of view, there is the need to ensure that their technical backbone is sufficient and efficient in meeting the requirements of their Internet subscribers. These issues have been largely addressed in the developed worlds where there are possibilities of transmission gateways, the use of fibre optics cables, Internet equipment and infrastructure and the availability of trained and adequate technical personnel are pluses for their operations.

Nigeria is a developing nation where the level of Internet usage is still relatively low owing to inadequate and localized Internet service providers, low level of general infrastructure as well as Internet infrastructure, absence of gateways and absence of trained technical personnel (Nigeria Internet Group, 2005). And as the Internet services grow in usage and complexity, Internet service providers in the country are increasingly faced with the problem of technical inefficiency in managing their services (Caswell and Ramanathan, 1999). Technical inefficiency is their inability to meet the service requirements of their subscribers, owing largely to low technical capability, emanating from the afore-mentioned factors. Monitoring authorities therefore need a guidance in advising and regulating the operation of the Internet service providers, and the task would obviously become easier if it is possible to have a measure of their technical inefficiency (or efficiency) and thus control the Quality of Service (QoS).

Networking literatures abound on measures and estimation of network parameters and pricing schemes using Internet service models (Caswell and Ramanathan, 1999; Taylor et al, 2001; Koucheravy et al, 2004; Cao et al, 2005; Hong et al 1998; Beckert, 2000 and Redback, 2003). In most of these works, statistical methods have been used to build estimation models for their purposes. This thesis shows how to build a stochastic frontier model which would be applicable for the estimation of the technical efficiencies of Internet service providers in our country Nigeria.

Research Motivation

The issue of Quality of Service in the provision of Internet connection and services is worthy of attention in a developing country like Nigeria. Form the Internet Service Providers' viewpoint; this becomes a factor in Internet operations, especially because of the growing realization of the essence of Internet, the increasing demand for services and the emergence and possibility of new broadband services that subscribers desire to enjoy in the country.

The effective and efficient provision of these services would depend on the technical capability and efficiency of the Internet service providers. This parameter would usually be a function of their Internet backbone (especially the sophistication of Internet infrastructure and the expandable limit of the bandwidth they have offerable to their subscribers), occasioned by their mode of connectivity to the Internet. Thus, it would become very tidy if the technical efficiency of an Internet service provider can be estimated from a standardized statistical model to the extent that their Internet loads can be used to determine their effort. An estimation of this sort would guide the regulatory agency, the Internet service providers and indeed the Internet subscribers, towards improvement of services delivered and enjoyed by all and sundry. This is the motivation for this research.

Survey of Internet Services in Nigeria

The Internet is the world's super electronic highway. Djamen et al (1995) defines the Internet as an interconnection of computer networks spanning several countries of the world. Another account of the Internet by the U.S. government working group published in November 1998, puts the Internet as

> *"a vast network of networks that communicate with each other based upon a set of software protocols that direct traffic so information can pass among the networks…and the transmission control protocol (TCP) and Internet Protocol (IP) define the rules by which packets of data are addressed and transmitted across physical fiber, copper, satellite, and wireless networks."*

Other publications in Computers in Africa (1997), an Information Technology magazine in Africa, together with Microbyte Monthly (1997), Nigeria's Business Computer Magazine agree with above notion and add that the world's super electronic highway conjures the images of some super computers linked from Star trek and Space. Jegede's (1995) contribution to the subject of Internet is in his substitution of the word "Internet" with the word "cyberspace", and buttresses this with the fact that;

> *"the conceptual space where words and humans relationships, data, wealth and power are manifested by people using the CMC technology. The cyberspace holds virtual communities together, attempting to mimic real life situation via electronic networking."*

The richness of the Internet is stunning. In fact, in just a few short years, the Internet has become a global phenomenon transforming the way we conduct business, interact and learn. Several authors (Jegede, 1995; Djamen et al, 1995) have all explored avenues for the continent of Africa to enjoy the benefits of the Internet. According to them, the Internet is a tool which Africa may employ for regional integration an development of the people and society. One graphic detail painted by Jegede (1995) has it that the Internet combines the knowledge of universities, libraries, art galleries, government departments, scientists, researchers and up to 30 million individual companies. He stressed further that Africa would be getting linked to the Internet "with a view to joining the Jones and Joneses in the race to and through the superhighway and to communicate, exchange and seek information and educational resources."

Wisemen's (2005) statistics on the growth of the Internet is impressive. For in 1998 alone, Internet related industries led to the creation of over 1.2 million jobs and produced more than $300 billion in revenue in the United State economy alone! Thus, Nigeria as a nation cannot afford not to be part of this information highway.

The Internet usage curve among Nigeria's wired public is indeed a very steep one; what with the fact that international data services is still the preserve of banks, airlines, large organizations and some higher institutions of learning in the country. As Babatunde (1997) pointed out, the establishment of Internet access in a country should first be occasioned by the availability of national networks (Intranet) linking the country, for the facilitation of movement of digital information out of the national communication resources. It is therefore necessary to give an appraisal of data networks available in the country.

NUnet is a Nigerian Universities Network initiated in 1995 by the Nigeria Universities Commission (NUC) to link all federal universities in a wide area network. The main purpose was to address the dearth of educational resources in the institutions and also promote resource sharing among participants. Regrettably, NUnet has not been fully implemented because of communication problems. For instance, NUnet is expected to offer opportunities for collaborative research and computer-assisted instructions, electronic text-handling and associated services as well as access to increased library holdings. The net is even to be developed at the level of departments, units, centres as well as faculties; but is common knowledge that this is not the situation. In fact, only e-mail and remote login services are predominantly available on the net (The Guardian on Sunday, 1997; The Punch, 2005). Thus, the reality of a true intranet in the country is still far-fetched.

Other accesses to the Internet enjoyed in Nigeria all the while are through connectivity to African networks such as the Fidonet and Webnet. The Fidonet network came into existence in 1984 to provide for e-mail facility and news at a low cost among the over 20,000 computers connected to it (Djamen, et al, 1995). Unlike in 1995, when users of Internet enjoy services only through sited at the Yaba College of Technology, Lagos; Obafemi Awolowo University, Ile-Ife and the University of Ilorin, today, the story is different. In fact, more than 80% of Nigerian institutions of learning are connected to the Internet, although through different gateways and Internet service providers both within and outside the country. Further, general Internet education and employment is much greater than what it used to be a decade ago. Today again, cyber cafes spring up to at also every nook and cranny of towns and cities in Nigeria because of the presence of ISPs to provide the needed connectivity to the Internet.

More glaring is the attendant upsurge in web services with institutions and business organizations building their informational websites. For instance, the current wave of eduportal services in educational institutions, registration services with examination bodies (such as WAEC, NECO and JAMB) as well as e-banking and Internet banking offered in Nigeria's financial services sectors are testimonies to Internet embracement and provision in the country. In fact, Wiseman's (2005) statistics that commercial websites were increasing at the rate of 500,000 per month in the U.S.A. may be surpassed in Nigeria in no distant time. Regrettably, however, the relative absence of broadband technologies in Nigeria may limit the attainment of this statistics, although as Vinoski (2002) puts it, web services are still generally evolving around the world with the industry far from reaching consensus.

Survey of ISP Infrastructure in Nigeria

The ISPs are the Internet Services Providers, i.e. the organizations whose objective is to connect Internet users/consumers to the Internet at a subscription fee (Willard, 2005). They provide services such as the electronic mail, remote login, file transfer, news, www, web video, web music, net phone and so on. In the business of providing these services, the service providers influence the choice of hardware and software to be used by their subscribers. For instance, most service providers restrict their subscribers to a choice of e-mail software that they are accustomed to. Further, as connection providers, they determine the mode of connectivity of users to the Internet.

Liu et al (1995) details the mode of connectivity to Internet as follows:

(i) Full-time IP connection, using routers guarantees an always-on connection with possibility of all Internet services.

(ii) Dial-up Access to a computer on the Internet works by providing access to a computer that is directly on the Internet, and using a modem to dial-up the computer Here, terminal emulation programs are used software on the PC and other graphical software that access Internet directly cannot be run due to the absence of Internet protocols.

(iii) Internet protocols over dial-up provides the use of dial-up telephone connection. Here, slower operation is obtained than in full-time connection but Internet protocols are provided. Some of these connections may carry both voice and data in integrated services digital network (ISDN).

Foremost Internet service providers in Nigeria include Direct on PC (DOPC), Broadband Technologies (BT), Cyberspace, Afreenet, Africa On-Line and Pnet limited. Others include Linkserve, Microcom Systems and Skynet. DOPC offers broadband services and has substantial investment in satellite space segments and bandwidth, manpower and other infrastructure. For instance, DOPC offers KU broadband satellite Internet services via the TDMA and SCPC and has huge bandwidth in space and at backbones in Nigeria and abroad, making them very well equipped for video conferencing and other broadband services, with over 1200 subscribers through the country. Their local network infrastructures include Sun servers, Cisco routers and firewalls, Compaq machines, CRM software and call centre management of subscriber's problems. Therefore the provider has the capacity for providing dedicated bandwidth and Net2phone service for users.

For large subscribers, the SCPC technology is appropriate as it allows for the use of a 1.8 KU band satellite dish and makes bandwidth scalable from 200kbps to about 800kbps. Small and medium subscribers, the TDMA satellite (half duplex) which allows for a 1.2metre satellite dish is often used. Whether the subscriber uses the TDMA or SCPC satellite solution, the geostationary satellite, PanamSat, is responsible for the exchange of high speed Internet data, with the DVB (Digital Video Broadcast) and the MPEG (motion Picture Expert group) compatibility (Field Survey, 2005).

Of all the Internet service providers in the country, Broadband Technologies offers the highest dedicated bandwidth of up to 2mbps, fully compatible for DVB and MPEG. Other providers have lesser infrastructure and facilities with some like Microcom Systems and Afrenet having a maximum of 256kbps, therefore doing predominantly e-mail services through their networks. Further, it is also observed that the requirement of providing subscribers with the services on the net, training on the use of the net and offering of technical backup or support is generally great among the subscribers. Moreover, it is noteworthy to record that even with the increasing Internet Provision and usage rate in Nigeria, more than 92% of it still takes place in the state of Lagos.

Internet Service Multipurpose Models

The concept of formulating models to provide solution to relationship problems is generally acceptable, and several authors have since extended this idea to multi-service problems, Internet service pricing problems and estimation issues.

In a technical report by Gillett(1995), an engineering cost model of cable versus ISDN was designed for the effective use of the broadband Internet services from homes. The author derived his model by analyzing data from two service providers – the PSICable deployment in Cambridge (employing the use of cable TV to provide Internet services) and the Internex Inc, San Fransisco (providing Internet service over ISDN telephony). The model revealed several characteristics, including the fact that the cable's shared bandwidth approach has superior economic characteristics because the cable channel has the capacity to provide the same average bandwidth and four times the peak bandwidth of ISDN access for less than half the capital cost.

Hulsen et al (2003) developed a multi-service model for non-pc users to use in accessing any desired service through a mobile phone. Their model provided an annotation for the services semantically in order to find the services with minimal user input. Their method uses the RDF and the OWL metadata and ontology languages in creating a 'device and service reservation' and remote user interfaces, which are necessary for the non-pc users to access context-dependent services on their mobile phones.

Kamppari (2002) proposed a similar business model for mobile Internet services. This m-services model was to dramatically change the technical architecture and the business logic of the communications services, as a way of capturing the commercial value of the technical development. His proposed m-services models were described from the angles of new service business requirements and business model definition and purpose.

Caswell and Ramanathan (1999) demonstrated how Internet service model can be used by service providers for the management of service problems in their operations. The authors made a case for diagnosing service problems by transversing a service model top-down, in order for an operator to assess not only the overall health of a service but also correlate the overall health of all services and service components in order to determine the root cause of any problems that may occur. Further, the authors proposed and implemented a simple-effort approach at creating service models for a target ISP, and capped it up by using a pre-defined service model template specification to generalize a service model for a real-world ISP system.

Internet Service Pricing Models

There are a number of authors who have contributed in the area of building and utilizing pricing models for Internet services. Closely related to the work of Kamppari(2002) is that of Cushnie and Hutchison(2005) who build a charging and billing models for GSM and future mobile Internet services. Their work became significantly important because mobile telephone communications and the Internet are converging and may eventually operate on a common platform – the TCP/IP networks. What the authors did was to apply selected Internet charging models to the mobile telephone network market and determined their relative suitability. Charging and billing models such as the metred charging, fixed price charging, packet charging, expected capacity charging, edge pricing, paris-metro charging and market-based reservation charging were exhaustively weighed by the authors and they concluded by providing a 'unified' flexible model that combines some of these existing charging models for the use of mobile Internet services.

Stiller (1999) earlier published their own common Internet service pricing models from an ISP point of view. Their motivation was their conviction that suitable pricing models for Internet services represent one of the main necessities for a successfully running implementation of a charging and accounting tool. One distinction of the paper lies in its perception of the need to take break these theoretical schemes down real project needs, for that is the only way to evaluate the different approaches with regards to the technical efficiency of the ISPs as well as the economic viability of the venture.

Internet Service Estimation Models

The concept of building estimation models and utilizing such to estimate or predict the values of network parameters or characteristics is not new in networking literature. Many authors (such as Hong et al (1998), Taylor et al (2001), Can et al (2005) have presented estimation models and techniques on demand for switched access, usage, vertical products, services as well as demand for non-switched access.

Taylor et al (2001) published on the specification and estimation of telecommunication demand models for special access on the Internet and bandwidth. Their motivation was the realization of the rising potential for Internet telephony, declining prices of data services and Internet access, the growing role of the Internet in business to business communications and the emergence of e-commerce and e-marketing. Obviously, for the Internet to satisfy some of this demand, the issue of bandwidth estimation becomes crucial, thus, prompting the authors to model the demand for bandwidth using both survey and non-survey information, and link an industry-specific occupation matrix with estimated occupation specific indices of Internet intensity. The authors then compared the bandwidth estimates from their model with that from other measures of bandwidth for validity.

Another dimension to bandwidth estimation was conducted by Cao et al (2005). Their estimation of bandwidth focused on Best-Effort Internet traffic, for the case where the quality criteria specify negligible packet loss. Their model is a simple statistical model, involving a formula for the bandwidth as a function of the delay, the delay probability, the traffic bit rate and the mean number of active hos-pair connections of the traffic, plus a random error term. The author built and validated the model using queuing theory with Poisson arrival times and exponential service times, although the model was made valid for best effort traffic with 64 hosts pair connections and more, a traffic of about 1 megabits sec.

Koucheravy et al (2004) provided an analytical estimation of EF PHB service parameters for aggregated MPEG traffic. Their analytical model was targeted on Internet applications which need strict guarantees on end-to-end delay and very low loss probability, and therefore follows the Expedited Forwarding (EF), Per-Hob Behaviour (PHB). One such Internet application is the Video-on-Demand (VoD) service – the MPEG traffic. The authors implemented several traffic conditioning functions, based on the EF PHB to VoD traffic in an attempt to provide transmission service. Further, a simple analytical model was developed for worst-case delay evaluation of the EF traffic treatment within the network node.

Hong J., Wu G. and Leckenby (1998) were able to examine the issue of interval publication and its relationship to web estimation. The authors in an attempt to estimate web audience, employed six statistical frequency estimation methods namely, the Binomial Distribution, Beta Binomial Distribution, Conditional Best Distribution, Sequential Aggregation Distribution, Dirichlet Multionomial Distribution and Hofmans Beta Binomial Distribution. Their empirical data was sourced from Relevant Knowledge, a web audience measurement firm based in Atlanta, and which gets its data by using a user-centric tracking system of measuring web usage activities among its panel members. The work provided a good basis for the utilization of estimation models in Internet services.

Statistical modeling was also brought to fore in a work published by Redback(2003). The author showed how to estimate a broad class of dynamic diffusion models of Internet services for consumers. Although, according to the author, his methodology for doing this should have broad relevance across numerous fields where such models are currently used, his idea opened up new potential sources of data. Based on current population survey available to the author, the Monte Carlo evidence was used to show that the maximum likelihood estimator in the model is consistent and efficient, and his results were used to estimate the extent of Internet penetration in the United States, a phenomenon call the Digital Divide.

Research Methodology

Research Design

The type and nature of investigations carried out in this work-modeling Internet provider stochastic function and testing associated hypothesis-informed the research design. A group of Internet people was used. This group comprises the Internet service providers, who are in the business of connecting people and providing access to the Internet. The strategy is that the researcher was able to establish validation rules for the data collected from this group to the extent that variances in the results were controlled.

Area of Study

The provision and consumption of Internet services transcends boarders. While this work looks holistically at Nigeria, data investigations are limited to the Western region of the country for logistic reasons. Incidentally too, the Nigeria Internet Group (2005) has surveyed that over 80% of Internet activities in the country take place in Lagos. Thus, the results obtained in the Western can be generalized to the whole country Nigeria.

Sources of Information

Primary data (obtained through the use of questionnaire) constitute the sources of information for this work.

Study Population

A group of population was used. This group was the population of Internet service providers, who are in the business of providing access to Internet, with certain factors (Variables) limiting their ability to perform. This population was limited to Western Nigeria (made up of the states of Lagos, Oyo, Ondo, Ekiti and Osun).

Study Sample

It is an admissible fact that it is not often possible to consider an overall population for a study, especially when they are dispersed. Thus, a sample is often used. For the purpose of this study, a sample of 203 Internet service providers was chosen from the population. The sample selection was done using a method of random sampling.

A pre-sample was conducted by the researcher to obtain a list of more than 350 Internet service providers. This was sorted and numbered using Microsoft Word word processing software. To achieve random sampling, a computer program was written in BASIC language to generate 250 unique random numbers used in picking 250 Internet providers. Eventually, 203 Internet service providers who responded to the survey questions were used as the sample.

Research Instrument

In achieving the purpose of this study, a questionnaire was designed and used to collect the primary data analyzed. The questionnaire was dubbed "Internet Service Model Estimation Questionnaire," and questions posed relate directly to the nature of data required. Some open-ended questions were also asked in order to have more insights into their operations. The results obtained were used in producing the Internet provider function. Further estimation of the technical efficiency of Internet service providers was also carried out with sample data from the questionnaire.

Validation of Research Instrument

The content and construct validity of the research interment was conducted by the researcher in order that the reliability of inferences drawn from such research instrument is guaranteed. The validation of the questionnaire was done by two information technologists – one in the academic and the other in the one of the service provider industries.

This exercise assisted in informing some of the question in the research instrument, in order to maintain the face and content validity. The reliability of the questionnaire was then conducted through the test-re-test method provided by Campbell et al (1963), using an interval of 8 weeks. This procedure involved trial-testing of the questionnaire using 20 respondents from the population of Internet service providers, and obtaining a set of results. After 8 weeks, the research instrument was re-administered to the same set of respondents for comparisons of the results. The results were found to be reliable with a reliability co-efficient of 0.94.

Results Analysis and Discussion

Analytical Techniques

The data collected through the 'Internet Service Model Estimation Questionnaire' were analyzed using descriptive statistics such as mean, standard error, standard deviation, log likelihood, minimum and maximum values. Further, both econometric (i.e. parametric) and non-parametric methods were used to estimate the stochastic models discussed in this thesis.

The Model Specifications

<u>Efficiency Model for Nigeria Internet Service Providers Using the Statistical Package for Social Scientists (SPSS)</u>

The modeling and estimation of the stochastic Internet service provider function is done here by the SPSS. The technology of the Internet service providers in Western Nigeria is assumed to be specified by the Translog Frontier Provider Function (Battese and Coelli, 1992; Battese and Tessema, 1993; Coelli, 1994), which is defined by:

$$LnY_i = \beta_0 + \sum_j \beta_j X_{ji} + \sum_k \beta_{1,6-k} X_{1i} X_{6-k,i} + \sum_I \beta_{2,6-I} X_{2i} X_{6-I,i} + \sum_m \beta_{3,6-m} X_{3i} X_{6-m,i} + \ldots$$

For j = 1, ………6
k = 0,1,…....5
I = 0,1,.……4
M = 0,1,2,3
N = 0,1,2

Where Ln represents the natural logarithm;
the subscript i represents the i-th sample Internet service provider;
Y represents the mode of linkage of the i-th service provider;
X_1 represents the logarithm of the experience (in years) of the service provider in the business;
X_2 represents the logarithm of the adequacy and level of technical workers
(Installation engineers, Network Engineers, Network Operations, etc) employed in the business;
X_3 represents the logarithm of the maximum possible transmission bandwidth (mbps) of the service provider;
X_4 represents the logarithm of the maximum number of Internet services offered to subscribers;
X_5 represents the logarithm of the number of subscribers served;
X_6 represents the logarithm of the transmission medium of the Internet;
represent the standard error term of estimation.

Various tests of hypotheses for the parameters of the service provider model were done using the generalized likelihood-ratio statistic, λ, which is also defined by

$$\lambda = \text{Ln}\ [L(H_0) / L(H_1)]$$

where $L(H_0)$ is defined as the value of the likelihood function model, in which parameter restrictions specified by the null hypothesis, H_0, are imposed; and $L(H_1)$ is the value of the likelihood function for the general model. The methodology provided by the SPSS guarantees that if the null hypothesis is true, it is generally accepted that λ has approximately an F-distribution with degrees of freedom equaling the estimated regression and residual parameters.

Using the framework of the general translog model earlier defined, together with the standard error, F ratio and Durbin-Watson ratios, which were generated by the SPSS package, three different sub-models were then estimated.

In order to determine the model of best fit, the null hypothesis associated with each sub-model was tested for validity in other to accept or reject the model. These results are shown in Table 4a as follows:

Table 4a. Showing the F-Test of the three associated hypotheses

Null hypothesis	Standard Error	Durbin Watson Ratio	F-Statistic	F-Table$_{0.95}$	Decision
General Model (Translog)	0.98701	1.94	9.69245	1.62	Reject Model
Cobb-Douglas (H_0:β_{jk}, β_{ji}, β_{jm}, β_{jn}, β_{jp},= 0 for all j, k, I, m, n, p)	0.25260	1.87688	2.55317	2.74	Accept Model
Semi-Log	1.38865	1.98829	3.37050	2.74	Reject Model

Discussion of Results

The 'SPPS for Windows' statistical package used to anaylse the data collected from the service providers gave a lot of interesting results, which are summarized in the table above. Parameter estimates; correlation matrices among the various independent variables, variations in fitness data, error estimates, equation blocks, Durbin-Watson test ratios as well as F-ratios (to accept or reject each null hypothesis) were obtained for each of the semi-log, Cobb-Douglas and the translog and the translog models specified for the Internet service provider function. In fact, the relevant variables in each of the model specifications are already listed in the equation blocks, with some of the terms automatically eliminated.

From the results above, the Cobb-Douglas model is the preferred model and is generally specified as.

$$\text{Ln } Y_i = \beta_0 + \beta_1 \ln k_i + \beta_2 \ln L_i + \beta_3 \ln M_i + \beta_4 \ln N_i + \beta_5 \ln P_i + \beta_6 \ln Q_i + \varsigma$$

for i = 1,2,3,…,n, where all parameters are as defined earlier. The preferred Cobb-Douglas model fitted from the analysed data is described as follows:

$$TE_{ml} = 0.633947 + 0.037136 \text{ Ln } YR - 0.067917 \text{ Ln } P + 0.096459 \text{ Ln } TB$$
$$- \; 0.125156 \text{ Ln } IE - 0.060278 \text{ Ln } IS + 0.132961 \text{ Ln } L$$

The null hypothesis that the Cobb-Douglas model is an adequate representation of the service providers is accepted by the data. The standard error of estimate and the durbin-waston ratio are also the least. The benchmark is that the lower the durbin-watson ratio, the greater the relationship among the variables in the equation block because then there would be lower correlation problem.

Sample Estimation

As an example of estimation of the technical efficiency of an Internet service provider, input characteristics of firm no. 9 and firm no. 44 (see appendix) are fed into the fitted Cobb-Douglas model. The technical efficiencies obtained for firm 9 and firm 44 are 0.443 (44.3%) and 0.892 (89.2%) respectively. These were obtained after adding the estimated error term of 0.25260.

Efficiency Model for Nigeria Internet Service Providers using the Frontier Package

The analytical package used was Frontier Program version 4.1, first designed by Coelli(1992) and later revised by the same author in 1994. The same set of data obtained from the field survey was fed into this package for analysis. Relying on the earlier results obtained through the SPSS, the purpose was to model a similar Cobb-Douglas frontier function for the estimation of Internet provider technical efficiency, in order to provide a basis for comparison.

The general specification for the model is a little modified in terms of the error terms, as follows:

$$\text{Ln } Y_i = \beta_0 + \beta_1 \ln k_i + \beta_2 \ln L_i + \beta_3 \ln M_i + \beta_4 \ln N_i + \beta_5 \ln P_i + \beta_6 \ln Q_i + (V_i + U_i)$$

for i = 1,2,3,…,n, where all parameters are as defined earlier.

The V_is are the random errors; they are assumed to be independent and identically distributed normal random errors, with mean (μ_v) of zero and unknown variance, $\sigma^2 v$.

The U_is are the technical inefficiency effects, which are assumed to be independent of V_is such that U_i is the non-negative truncation (at zero) of the normal distribution with mean, μi and variance, σ^2 (Coelli, 1994), where U_i is defined by:

$$U_i = \delta_0 + \delta_{1z1i} + \delta_{2z2i} + \delta_{3z3i} + \delta_{4z4i} + \delta_{5z5i} + \delta_{6z6}$$

Where z1, z2, z3, z4, z5 and z6 represent the identified network characteristics, which are assumed to influence the efficiency of the i-th service provider; and the β_is and δ_is are the unknown scalar parameters.

In this Frontier method, if the null hypothesis is true, then it is generally accepted that λ (which was earlier defined as the generalized likelihood ratio statistic) has approximately a chi-square distribution (X^2) with degrees of freedom equaling the difference between the parameters estimated under H_1 and H_0 respectively.

The summary of the results obtained from the Frontier package is shown in Table 4b.

Table 4b. Showing the Loglikehood ratio of the Cobb-Douglas hypothesis

Null hypothesis	**Loglikehood**	**X^2Statistic**	**$X^2_{v.0.95}$**	**Decision**
Cobb-Douglas (H_0:β_{jk}, β_{ji}, β_{jm}, β_{jn}, β_{jp},= 0 for all j, k, I, m, n, p)	87.80153	223.04463	256.62	Accept H_0 (Accept Model)

Discussion of Results

The γ estimate was generated as part of the results from the package. This estimate is quite high for the estimated Cobb-Douglas model. Since γ in the Frontier package is known to be associated with the variance of technical inefficiency effects, its high value indicates that the technical inefficiency effects are significant in the analysed data on service providers. Further, the restriction of parameter about zero indicates that the distribution of the inefficiency effects is more concentrated about zero than for half-normal distribution. This move allowed for a better estimation of the required Cobb-Douglas function. Various coefficients obtained for the preferred Cobb-Douglas model are appropriately signed as expected with their values being somewhat significant.

From the table above, the acceptance of the null hypothesis, Cobb-Douglas H_0:β_{jk}, β_{ji}, β_{jm}, β_{jn}, β_{jp},= 0 for all j, k, I, m, n, p, further confirms that the Cobb-Douglas frontier model is accepted by the data, as an adequate representation of the service providers. As already stated, the Cobb-Douglas frontier is the model in which the coefficients in the second-order terms in the translog frontier are restricted to be zero. This is actually fitted as

$$TEml = 2.019450 + 0.003142 \text{ Ln } YR - 0.005007 \text{ Ln } P + 0.010497 \text{ Ln } TB$$

$$- \quad 0.002901 \text{ Ln } IE + 0.001184 \text{ Ln } IS + 0.009888 \text{ Ln } L$$

Sample Estimation

Given the specification of the preferred model – Cobb-Douglas frontier, the technical efficiencies of the sample Internet service providers are calculated from the package. The predicted technical efficiencies differ substantially among the Internet service providers. The lowest efficiency is 0.343 (34.3%) while the highest efficiency is 0.992(99.2%). The mean technical efficiency obtained is 0.912 (91.2%). From the model therefore, individual firm-level efficiency could be generated.

Comparison of Estimates from Frontier program and the SPSS

The Frontier program produced firm-level technical efficiency estimates for each of the service providers included in the study. From this, firm no. 9 and firm no. 44 have the lowest (34.3%) and highest (99.1%) technical efficiencies respectively. Therefore, using the data for these two providers in the Cobb Model fitted from SPSS, the corresponding technical efficiencies of 0.443 (44.3%) and 0.892 (89.2%) were obtained. From these results, it is seen that the differences in the predicted efficiencies for the lowest and highest firms vary significantly, on a method to method basis.

These variations are accounted for by the capability of the Frontier Program to isolate adequately the inefficiency effects of firm-level variable on the estimated models. This isolation is not only accounted for by the presence of the normal random errors V_is (which are random variables assumed to be iid. N(0, v2), but also the incorporation of U_it, which are non-negative random variables that account for the technical inefficiency of each service provider. This statistic is assumed to be independently distributed as truncations at zero of the N(m_{it}, σu^2) distributions. In the Frontier Program, these inefficiency effects are computed as the statistic γ, and γ is implicitly implied in the preferred Cobb-Douglas model.

Thus, the stochastic estimation from the Frontier program is preferred for its adequacy in representing the data and isolating the various inefficiency effects in the modeling. It truly shows that there are significant variations in the firm-level technical efficiencies of the service providers.

Conclusion

Given the various sub-model specifications of the general translog frontier model, the estimation of the defining model parameters and the testing of the various associated null hypotheses, the hypothesis that the Cobb-Douglas Model is an adequate representation of the sample service providers is accepted. However, more accurate in prediction is the Cobb-Douglas Model estimated from the Frontier Program version 4.1 as compared with the model accepted using the SPSS; the former allowed for a wider variation in estimated technical efficiencies as a result of the isolation of inefficiency effects. It was found that although the mean technical efficiency is high (91.2%), a wide variation of about 64.9% exists between the lowest and the highest technically efficient service providers. Further, network characteristics such as transmission medium and transmission bandwidth have the most effect on the technical efficiency of a service provider in Western Nigeria.

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