International Journal of Managing Public Sector Information and Communication Technologies (IJMPICT),
Vol. 4, No. 4, December 2013

REGULATION, COMPETITION AND PRODUCTIVITY GROWTH IN THE AFRICAN TELECOMMUNICATIONS INDUSTRY

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ABSTRACT

The telecommunications industry in Africa has exhibited tremendous development since the turn of the century. This study analyzes production efficiency changes in the African telecommunications industry in the period 2000 to 2009. Furthermore, an attempt is made to assess the determinants for such efficiency changes. The results show that the industry has improved its productivity levels. However, most of the productivity growth is resulted from technological advancement and less from technical efficiency. Additionally, market competition and increasing subscriptions have also positively affected the sector's productivity. Hence, this study implies that African countries can further improve productivity in their telecommunications sector by improving on technical efficiencies, increase outputs especially the penetration of mobile telephony, and allow competition in the market with participation from international network operators.

KEY WORDS

Telecommunications industry, Productivity change, Competition, Regulation

1. INTRODUCTION

Prior to the year 2000, the African telecommunication industry was regarded as the least developed and worst performing market in the world. Following a series of telecommunications policy reforms towards the 2000's, the Sub-Saharan Africa for instance, had experienced a surge in annual telecommunications infrastructure investments from only USD 2.7 billion in 2000 to USD 12 billion a decade later, which accounted for 95% of all infrastructure investment with private participation in the region. As a result, the penetration of telecommunication services also surged; notably mobile penetration had reached 45.2% in 2010 from only 2% in 2000. Needless to say, the decade after the turn of the century had been the most vigorous period in the development history of African telecommunication industry thus far.

Such sectoral growth can be attributed to the increase in factors of production, and productivity changes. In case of productivity change, it depends on various determinants which include: deployment of advanced technology, exploitation of economies of scale, changes in organization of the production as well as improvement in labour force [1]. Countries with highly productive

DOI : 10.5121/ijmpict.2013.4402

industries are expected to create greater surplus in terms of higher value added, and they are more efficient in the utilization of labor and capital. The created surplus is further distributed to consumers in terms of lower prices, to employees in terms of higher remuneration and to owners in terms of higher profits, which in turn spurs consumer demand and encourage further investments. Thus, it is the interest of policy makers, producers and consumers to create an environment that allows growth in sector productivity in order to spur the socio-economic development.

Despite the tremendous growth in the African telecommunication industry since 2000, only a handful of evidence is available about the productivity growth pattern in the region during this time. Madden *et al.* [2] examined the productivity growth in global setting, including African countries and found that productivity in the African telecommunication sector had declined at 3.7% annually from 1991 to 1995. In contrast, Lam et al. [3] have recently investigated the productivity growth of 105 countries between 1980 and 2006 and they found that productivity in the Africa telecommunication sector had grown at 6.8%, close to the global sample of 6.7%. According to the author's knowledge, Bollou et al. [4] is the only study that focused on productivity changes in the African telecommunication sector; however, it had covered only six West African countries from 1995 to 2002.

The purpose of this study is two-folds: firstly, it determines the productivity changes in the telecommunications industry among African countries from 2000 to 2009 using the DEA-based Malmquist productivity index. Secondly, it assesses the policy oriented determinants which have led into productivity changes in the African telecommunication sector. This study contributes to the existing literature in various ways. Firstly, it is the first study to exclusively cover productivity changes in the telecommunications sector on the African continent. Secondly, the duration covered in this analysis includes the period when the African telecommunications industry was experiencing tremendous growth in telecommunication infrastructure deployment; as well as the growth in mobile penetration. Finally, considering the role of international network operators in the African telecommunication industry, this study assesses the effect of competition induced by these international network operators on productivity growth in the African telecommunication industry.

The rest of the paper is organized as follows: Section 2 illustrates the overview of the African telecommunication sector followed by the literature review in Section 3. Section 4 provides the methodological details for the measurement of productivity changes by the Malmquist productivity index; data and descriptive analysis are given in Section 5. Empirical results are detailed in Section 6, and finally Section 7 provides the discussion and conclusion.

2. OVERVIEW OF THE TELECOMMUNICATIONS DEVELOPMENT IN THE AFRICAN CONTINENT

Prior to the year 2000, the African telecommunications sector had been concealed as access was predominately provided by state owned incumbents which provided fixed line services concentrated in the urban centers. This situation left the majority of the population in rural areas unconnected. Until then, there was no form of telecommunication services that had achieved more than 3% of penetration across the continent. Various reasons for such under-development have been documented. The first reason is the technological and physical constraints due to the

large landmass of the African continent. Most of the population in this continent live sparsely in rural areas; therefore it was prohibitively expensive to layout fixed line network to reach the masses. The second reason is the weak African economies, which meant low demand for telecommunication services. The third reason is the African governments which were the sole investor in the sector and they were faced with the dilemma to decide where to invest among an array of infrastructure needs such as electricity, water, and transportation. Henceforth, for most African countries, fixed line network which needs high initial investment cost was not their highest priority. Finally, most African economies were characterized by weak institutions, also subsidized and unprofitable state-owned enterprises which were detrimental to the development of the telecommunication sector [5]. Thus, the African telecommunications industry was comparatively inefficient [2], serving only a small part of the population residing in cities.

Between the late 1990s and early 2000s, many African countries began to embrace policy reforms in the telecommunications sector. Many countries had liberalized their markets by enacting new laws that allowed privatization of the incumbent operators and opened their market to competition by licensing new entrants particularly in the area of telecommunications infrastructure and service provision. By the year 2010, 77% of all African countries had established an independent telecommunications regulator to ensure the level playing field for all market players, to protect consumer welfare, and to spur the telecommunication sector advancement. Governments abandoned their position as the sole provider of telecommunications services, and assumed a new role as the industry facilitator by enacting laws, policies and providing regulatory mechanism to encourage the sector's advancement.

The telecommunications policy reforms in Africa coincided with the development of wireless mobile technology, which can be deployed in modular sites and requires relatively lower initial capital and expansion costs compared with fixed line network. Thus, the policy reforms and technological advancements fuelled the private investment in the African telecommunication sector, especially in mobile telecommunications infrastructure and submarine fiber cables. The private investment in telecommunications infrastructure in Sub-Saharan Africa as percentage of total GDP had increased to 1% in 2008 from only 0.3% in 2000 [6] and accounted for 80% of all private infrastructure investment in the region in 2011. Consequently, submarine fiber cables had increased the bandwidth capacity in the continent from only 0.34 Terabits per second (Tbps) in 2008 to 17.16 Tbps in 2011 as major submarine cable projects became operational. Similarly, mobile penetration and Internet usage increased from only 1.5% and 0.5% in 2000 to 45.2% and 10.8% in 2010 respectively. Indeed, the telecommunications policy reforms have revolutionized the African telecommunication sector.

It is imperative to notice the role international network operators – referred to as network operators with operations in two or more countries – have played in the development of African telecommunications markets. In fact, by the year 2009, the seven major international telecommunication operators in terms of the number of subscribers – namely MTN, Vodacom, Airtel, Glomobile, France Telecom, Millicom and Portugal Telecom – had a combined market share of more than 80% of all mobile subscriptions in the continent [6]. Based on the weak foundation of incumbent operators which in many instances could not initiate their own mobile networks, international network operators have been the main providers of mobile

telecommunications infrastructure, mobile value added services such as Vodacom's M-Pesa[1], as well as Internet and broadband services which are mostly accessed through wireless networks. These international network operators have definitely played a significant role in shaping development of the African telecommunications sector.

3. LITERATURE REVIEW

The increasing importance of telecommunications in modern economies, and the sector's pace of development have ignited interest to understand productivity changes in the telecommunication sector [7]. The earlier studies utilized the Divisia TFP (total factor productivity) indexation and conometrics to measure productivity changes, mainly of telecommunication firms as units of analysis, over a period of time [8 - 10]. For example, Nadiri et al. [9] analyzed the technical change and the rate of growth of the total factor productivity for US Bell System using data from 1947 to 1976, their study utilized translog cost function to estimate the adjusted Divisia index for measuring productivity changes. Their results showed that the TFP grew at 4.09% annual rate during the post-war period. However the methodology deployed in these studies is constrained by the use of a single output and strict requirement to specify the functional form.

Majumdar [11] is among the first studies to apply an alternative methodology to measure productivity changes in the telecommunications industry. He applied the Data Envelopment Analysis (DEA)-based model which relies on data; and allows multiple outputs. Following his study on the X-efficiency in emerging competitive telecommunications markets in the United States, many studies have been conducted to analyze productivity changes in telecommunications sector. At firm level, studies have focused production efficiency of telecommunications operators within country boundaries and as well as multinational operators [12 - 14]. At international sectoral level, in which this research is based on, most studies in the current literature are concentrated on OECD and European countries [15 - 17].

As explained in Section 1; both Madden et al. [2] and Lam et al. [3] had included African countries in their analysis at a global level, however, their results on productivity growth of African countries showed opposite developments. While the former showed that productivity in the African telecommunications industry had declined by 3.7% per annum from 1990 to 1995, the later found that productivity had grown at an annual rate of 6.8% from 1980 and 2006. Lam et al. [3] suggested that, the opposite result between the two studies might be due to the difference in length of the data panel. The study by Bullou et al. [4] is the only study that attempted to analyze productivity changes in the telecommunication sector among countries in the African continent. It investigated the productivity changes of six West African countries between 1995 and 2002 using the DEA approach. The results showed that, productivity in the telecommunications sector of the West African countries grew at 2.5%; however, the growth rate was declining quickly.

4. MEASURING PRODUCTIVITY USING THE DEA-BASED MALMQUIST INDEX

Productivity is broadly defined as the ratio of change in output to the change in input of an economic system. When comparing productivity growth of a cross-section of economic systems,

[1] M-Pesa is the mobile money transfer service that enable mobile phone subscribers to transfer funds from their mobile phone account to other parties; it is also used for m-payment services for merchandizes such as gasoline, supermarket shopping and public utilities payment

it is imperative to determine the production frontier, which measures the maximum possible output that can be produced by the most efficient economic agents given a set of inputs at a given technology and time. The most efficient economic agents in the group form the production frontier which is then used to calculate the productivity scores of other economic units in the group relative to the production frontier.

This study follows the nonparametric DEA-based Malmquist productivity index approach to analyze the productivity changes. Unlike the alternative approaches, this method is desirable due to various advantages. Using the DEA-based Malmquist productivity index, productivity changes can be estimated without determining any functional form; price information is not required and no assumptions of economic behavior of a firm such as profit maximization or cost minimization have to be imposed. Furthermore, the method can be applied in cases of multiple inputs and multiple outputs, and besides being easy to compute, the index can also be decomposed into different sources of productivity change, mainly technological efficiency and technical change. In addition, the production frontier estimated by this method is not based on technology hypothetical assumptions; rather, by the actual input and output information of the operating Decision Making Units (DMUs), hence it is considered more practical.

Using the DEA approach, productivity change of the DMUs can be computed between time t and t+1. Caves et al. [18, 19] defined the Malmquist productivity index as a ratio of two output distance function using the same reference technology as technology at time t. DEA allows input- /or output-oriented mechanism to calculate the Malmquist productivity change; however, the choice of orientation does not change the results. Thus, the output-oriented Malmquist Productivity index,

$$M^{t} = \frac{D_0^{t}(x^{t},y^{t})}{D_0^{t}(x^{t+1},y^{t+1})} \quad (1)$$

whereby the numerator is the output distance function at time t based on the technology at t, and the denominator is the output distance function at time t+1 based on the period t technology.
Similarly, the Malmquist productivity index can be expressed in terms of the technology at period t+1 as

$$M^{t+1} = \frac{D_0^{t+1}(x^{t},y^{t})}{D_0^{t+1}(x^{t+1},y^{t+1})} \quad (2)$$

Fare et al. [20] avoided choosing an arbitrary technology by specifying their Malmquist productivity change index as the geometric mean of the Malmquist index in reference to the technology at two different periods, that is period t and t+1. Thus, their Malmquist productivity change index can be defined as:

$$M_0(x^{t+1},y^{t+1},x^{t},y^{t}) = \left[\left(\frac{D_0^{t}(x^{t+1},y^{t+1})}{D_0^{t}(x^{t},y^{t})}\right)\left(\frac{D_0^{t+1}(x^{t+1},y^{t+1})}{D_0^{t+1}(x^{t},y^{t})}\right)\right]^{\frac{1}{2}} \quad (3)$$

Equation (3) above provides the Malmquist productivity index change based on the output distance function, which takes into account the changes in reference technology from period t to t+1. Thus, the value of M_0 in equation (3) can be greater than 1 which indicates productivity

growth from period t to t+1. On the contrary, the value less than 1 indicates that productivity has declined, while the value of 1 indicates that productivity has remained the same from period t to t+1.

The equation (3) can further be written as:

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \times \left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_0^t(x^t, y^t)}{D_0^{t+1}(x^t, y^t)}\right)\right]^{\frac{1}{2}} \quad (4)$$

As interpreted by Fare et al. [20], these two portions of equation (4) can be defined as

$$\text{Efficiency Change (EC)} = \frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)}$$

and

$$\text{Technological Change (TE)} = \left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_0^t(x^t, y^t)}{D_0^{t+1}(x^t, y^t)}\right)\right]^{\frac{1}{2}}$$

Efficiency Change (EC) can be referred to the technical efficiency or catch-up as the managerial efficiency changes depending on their ability to organize the production processes, and increase the output given the level of input and technology from period t to t+1. On the other hand, Technological Change (TC) can be defined as the efficiency change that results from technological advancement that allows better transformation of inputs to outputs between the period t and t+1. Technological Change (TC) stipulates the shift in the production frontier as the innovation increases. Hence, the Malmquist productivity index can simply be defined as the product of Efficiency Change (EC) and Technological Change (TC) under the assumption of constant return-to-scale.

When markets are imposed with restraints – that prevent perfect market assumption – the constant return-to-scale criterion fails. To accommodate the variable return-to-scale criterion, the Efficiency Change (EC) can be further decomposed to include the Pure Efficiency Change (PEC) and the Scale Efficiency Change (SEC). That is, the Malmquist productivity growth index = TC × PEC × SEC. Thus, under the variable return-to-scale assumption, the Malmquist productivity growth index is expressed as the product of the Technical Change, Pure Efficiency Change and Scale Efficiency Change.

Since the telecommunications sector – as any other public utility sector – is subjected to government regulations and there are situations where some services reach saturation levels which distort the constant return-to-scale assumption, this study adopts an input-oriented, variable return-to-scale assumption to compute the Malmquist Productivity index.

5. DATA AND DESCRIPTIVE ANALYSIS

As stipulated in the previous section, the DEA approach requires a set of inputs as well as a set of outputs to compute the Malmquist productivity index. From the literature review, previous studies have used different combinations of input and output variables, mainly based on the relevance and availability of data. In case of input variables, for instance Giokas et al. [16] and Madden et al. [2] used total telecom staffs as a proxy for labor; and access lines and number of Internet hosts

as proxies for capital. Due to the evolution of the telecommunications sector, capital expenditure is not only limited to fixed lines but also to spectrum acquisition, mobile network infrastructure as well as fixed data networks such as fiber optic cables. As more data become available, Madden et al. [2] proposed to use telecommunications capital stock as a more appropriate proxy for the industry-wide measure of capital as an input variable. Following this wisdom, this study employs the number of full-time telecom staff and telecommunications investment stock as input variables.

In terms of output variables, there are two major views that have governed the choice of output variables in studies measuring productivity changes in the telecommunications sector: the operators' view and the policy makers' view. The operators' view focuses on the increase in sector's revenue which implies that increasing firms' profit is important to keep operators in ongoing profitable business operation; thus, a sufficient measure of output. Most studies [2, 21, 22] have used the operator's view – telecommunications revenue as the only measure of the industry's output. On the other hand, although policy makers may monitor telecommunications providers' profitability and revenue, they are more likely to focus on the increasing penetration of various telecommunication services. Symeou [23] used the policy makers' view: penetration of fixed lines, penetration of mobile phones and the percentage of Internet users as output variables. Bollou et al. [4] and Giokas et al. [16] combined both views by incorporating industry revenue and penetration levels of telecommunications services as indicators of output. Additionally, Madden et al. [2] included in their model the quality aspect as an output variable measured by the ratio of waiting list to total fixed lines. This study uses the combined approach by using three variables as a set of output: number of telephone (fixed and mobile) subscriptions, number of Internet users as well as total telecommunications revenues.

For measuring productivity in the telecommunications sector, our data consist of 30 African countries for the period 2000 to 2009. The main sources of data are the International Telecommunications Union (ITU's) World Telecommunications/ICT Indicators database 2010. In order to cross check the data and to fill the missing data, the World Bank's Private Public Investment (PPI) database is also used. Despite all efforts, a number of African countries has missing data in the period covered, hence they are excluded from the analysis. The values for telecommunication investment stock and revenues are in US dollars at constant 2000 prices.

6. EMPIRICAL RESULTS

To determine changes in productivity in the telecommunications industry, the Malmquist productivity index and its components were computed following the DEA approach over 30 African countries for the period 2000 to 2009. Using equation 5 developed in section 5, the productivity change scores were calculated under the assumption of variable return-to-scale (VRS) for the telecommunications industry in all 30 African countries in the sample. The value of 1 indicates the same level of efficiency in the current period compared to the previous period, while greater than 1 exhibits improvement and less than 1 implies declining productivity.

6.1 Results of Data Envelopment Analysis on the productivity changes in the African telecommunications sector

6.1.1 General results of the productivity changes

To reveal the overall dynamics of productivity changes in the telecommunications sector in African countries across the period under study, the yearly scores for the entire sample are first presented. As depicted by table 7.1, the efficiency changes in the African telecommunication industry have remained to be positive throughout the period of the study. The first two years have recorded the weakest growth in productivity, both below 10% annual growth, with the period 2001/2002 recording the lowest productivity growth of only 2.9 percentage increase. The weak productivity growth in the African telecommunications industry in these two early years can further be seen in other indicators, namely the lowest productivity growth recorded by individual countries, and the number of countries that underperformed – with less than 1 productivity change score. More precisely, in the initial year 2001, the least performing country has recorded only 0.356, which means that this country has lost 64.1% of its 2000 productivity score. Furthermore, the number of countries whose productivity has declined is the largest in the initial two years, which has reached 11 and 13 in 2001 and 2002 respectively. Perhaps the initial weakness in productivity growth is due to the newness of the sector's reforms and mobile technology, yet to be adopted by many countries in the continent.

Table 6.1 Annual Mean Efficiency score for the telecommunications sector in African countries based on DEA (2001 – 2009)

Year	Average efficiency	lower score	Upper score	No. of underperforming countries
2001	1.092467	0.359	1.622	11
2002	1.0289	0.53	1.896	13
2003	1.209867	0.665	1.715	4
2004	1.227867	0.938	1.689	4
2005	1.226833	0.772	1.737	3
2006	1.377167	0.904	3.039	3
2007	1.255067	0.824	1.842	4
2008	1.2943	0.656	2.246	4
2009	1.358067	0.866	4.292	5

Following the initial two years which have recorded weak productivity gains, the countries have gained remarkable pace in the rest of the period under study. They have achieved more than 20% productivity growth in each year. The peak year is in 2006 where the average efficiency gain in the telecommunication industry has reached 37.7% more than the levels recorded in 2005. Furthermore, in the period 2003 to 2008, the number of countries that have recorded negative efficiency growth has been reduced to only three or four countries per year. This trend is perhaps the result of the acceptance of mobile technology and industry reforms that have started to become a norm in many African countries.

6.1.2. Decomposition of the Malmquist Productivity index to Technical efficiency change (EC) and Technological efficiency change (TC)

Figure 6.1 shows the general trend of the Malmquist productivity index and its components for the sample African countries across the period of the study. As it can be clearly seen, productivity

has improved in all years as the TFPC is above 1 in all years except in 2002 where productivity has grew only slightly. More specifically, the Malmquist productivity index has grown by an average of 18.7% per annum throughout the period of the study indicating substantial and consistent increase in efficiency.

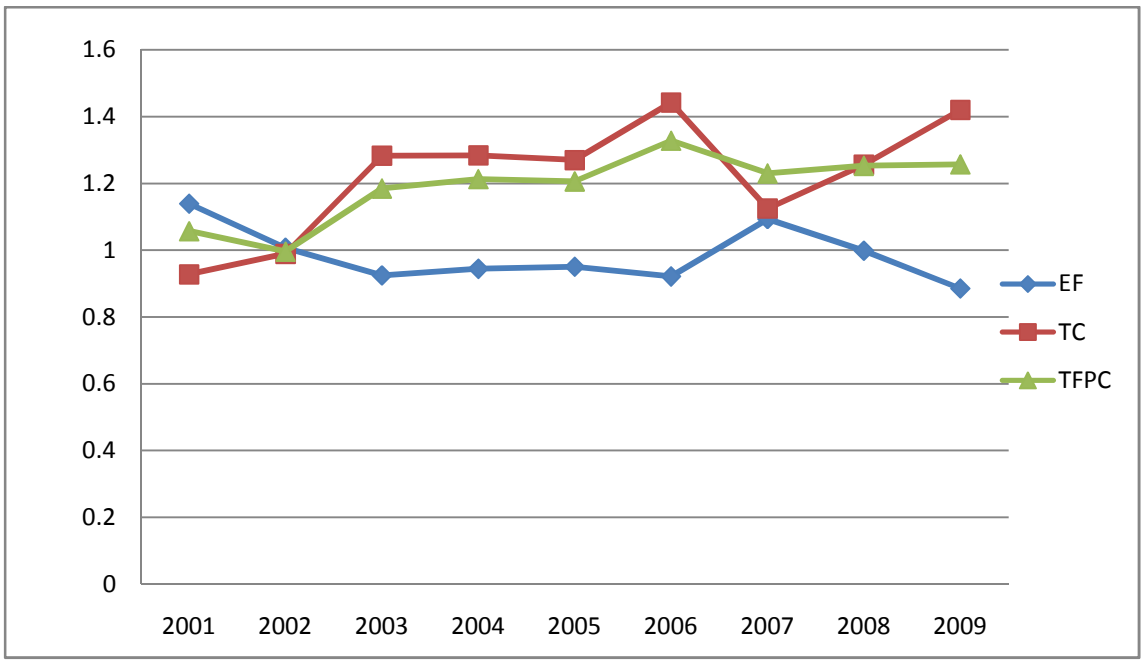

Figure 6.1 The Malmquist productivity index and its components for the African telecommunication industry from 2001 to 2009

When looking into the components of the Malmquist productivity change, the African telecommunication sector has benefited from the increase in technological change. As seen from figure 6.1, technological change or innovation has improved by an average of 21% per annum throughout the period of the study. With the exception of first year (2001) and second year (2002) where technological change has underperformed and remained unchanged respectively, it has improved in the rest of the years in the study. Indeed, African countries have benefited from the technological improvements in the communication technologies that induced efficiency gains in the telecommunications industry.

On the other hand, efficiency change has underperformed through the study. Figure 6.1 shows that with exception of 2001 and 2007 when the efficiency change has improved, and in 2000 where it has remained stagnant, it has declined in all other years. When the entire period is considered, efficiency change has declined at an average of 2% per annum across the period

under study. In other words, the ability of the management to improve their organization has deteriorated.

6.1.3. Cumulated efficiency scores of the African telecommunication industry

Although the yearly productivity change score has been a standard representation of efficiency result, Fare et al. [20] offered an additional perspective by including the cumulative results of the productivity indices. Showing the cumulative results of the productivity indices provide a clear picture on the continuous trend of the Malmquist productivity index, and the contribution mix of its components. Figure 6.2 provides the cumulative scores of the Malmquist Productivity index and its core components: the technical efficiency change (EC) and technological efficiency change (TC).

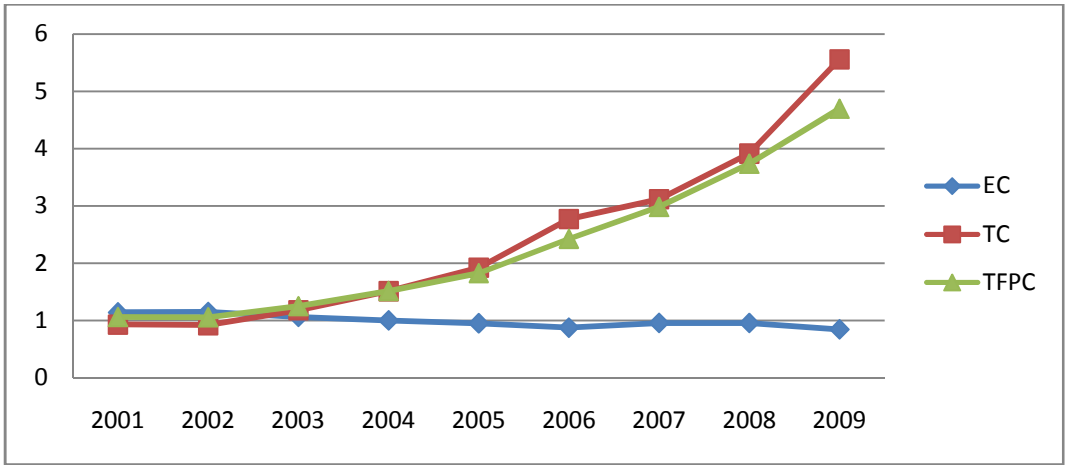

Figure 6.2 The Malmquist productivity index and its components for the African telecommunication industry from 2001 to 2009

As it can be clearly seen in figure 6.2, the productivity of the telecommunication industry has grown tremendously between 2001 and 2009. Furthermore, since the technical efficiency has remained almost the same in cumulative terms throughout the study period, it has neither contributed nor substantially dragged down the Malmquist productivity index. However, gains in the technical efficiency have grown more than five times during the period. Needless to say, most of the gains in the sector's productivity are the results of the substantial improvement in technological advancements.

6.1.4 Economic development and productivity growth

Due to the wide difference in the level of economic activities between the African countries, which affects their telecommunication demand and investment, a more detailed picture can be grasped by studying productivity in the telecommunication sector according to their economic situation. Table 6.1 shows the results of the analysis for each country in terms of the Malmquist productivity index and its components with respect to the World Bank's income classification of economies.

Table 6.1 Malmquist index and its components for countries 2000 – 2009

Category	Countries	EC	TC	PEC	SEC	TFPC
Low income	Benin	0.991	1.287	1.042	0.951	1.276
	Burkina Faso	0.956	1.258	1.004	0.952	1.203
	Eritrea	1.047	1.093	1.021	1.025	1.145
	Ethiopia	0.984	1.054	1.01	0.974	1.036
	Ghana	0.983	1.231	1.043	0.943	1.211
	Kenya	1.094	1.192	1.098	0.997	1.304
	Madagascar	0.994	1.201	1.04	0.956	1.194
	Mali	1.025	1.188	1.055	0.972	1.219
	Mauritania	0.922	1.226	0.944	0.977	1.131
	Mozambique	0.99	1.291	1.052	0.941	1.279
	Niger	1.209	1.36	1.238	0.977	1.644
	Rwanda	0.976	1.271	0.977	0.999	1.241
	Senegal	0.994	1.248	1	0.994	1.241
	Togo	0.904	1.251	0.925	0.977	1.13
	Uganda	1.029	1.177	1.027	1.003	1.211
Low-middle Income	Cameroon	0.963	1.259	1.006	0.958	1.213
	Cape Verde	0.949	1.172	0.952	0.997	1.112
	Cote d'Ivoire	0.995	1.286	1.027	0.969	1.28
	Egypt	0.908	1.226	0.948	0.958	1.113
	Morocco	0.956	1.28	0.959	0.997	1.223
	Nigeria	1.113	1.224	1.091	1.019	1.362
	Sao Tome and Principe	1	1.214	1	1	1.214
	Sudan	1.065	1.224	1.061	1.003	1.303
	Tunisia	0.908	1.231	0.898	1.011	1.117
Upper-middle Income	Algeria	0.898	1.034	1	0.898	0.929
	Botswana	1	1.186	1	1	1.186
	Gabon	0.83	1.187	0.837	0.992	0.986
	Mauritius	0.857	1.226	0.861	0.995	1.051
	Namibia	0.98	1.089	0.981	0.999	1.067
	South Africa	1	1.193	1	1	1.193
Low Income countries		1.007	1.222	1.032	0.976	1.231
Low-middle Income		0.984	1.235	0.994	0.99	1.215
Upper-middle Income		0.928	1.153	0.947	0.981	1.069
Sample		0.981	1.21	1.001	0.981	1.187

Notes: EC – Efficiency Change, TC – Technological Change, PEC – Pure Efficiency Change, SEC – Scale Efficiency Change, TFPC – Total Factor Productivity Change (Malmquist Productivity Change)

As it can be seen, in regard to productivity changes in the African telecommunications sector, major differences exist between countries of diverse economic status. The results show that productivity has increased the most in low income countries at an average of 23% per annum, while in upper-middle income countries (the wealthiest countries in the sample) productivity has grown the slowest at only 6.9%. Focusing on the components of the Malmquist productivity index, technological change has grown in all country categories led by the low-middle income countries which have grown at an average of 23.5%, while the low income and upper-middle income countries have improved at 22% and 15% respectively. Furthermore, with the exception of the low income countries which have remained almost constant (0.7% improvement per annum), the efficiency change in other country groups have declined throughout the period; the most decline is 8% in upper middle income countries.

Thus, these results suggest two points about productivity growth in the African telecommunication industry during the period studied. First, productivity has grown across the region; however, similar to Madden et al. [2] and Lam et al. [24] studies, most of the productivity growth is due to technological progress (innovation) and there is a decline in technical efficiency. Second, low income countries have exhibited higher productivity improvement and the only group with positive technical efficiency growth compared to their peers. Hence, although productivity in the telecommunications industry has grown across the continent, most of it is due to technological progress and productivity in low income countries since they are the late adopters of the telecommunications reforms and technologies starting from a relatively weak base.

6.2. Second Stage Regression: Environmental determinants of productivity change

In order to examine the environmental factors affecting productivity change in the African telecommunications industry, a second stage regression analysis was conducted. Following the wave of liberalization and widespread of international network operators, this section empirically tests how productivity growth responds to the increase of output, liberalization coined by presence and experience of the national telecommunication regulatory authority and changes in market structure as competition is induced by international telecommunication operators.

First, to measure output growth, three variables were used in terms of their annual growth rate: revenues in USD at constant 2000 prices (Q_REV), mobile subscriptions (Q_MOB) and Internet users (Q_NET) [2]. Second, to indicate the level of competition induced by international operators, the number of international telecommunications operators (INTERFIRMS) operating in each country in a particular year was used. International telecommunications firms refer to telecommunications services providers which operate in two or more countries. They are expected to boost productivity in the countries they operate in due to transfer of technology and technical know-how across countries through infrastructure investments and allocation of human personnel. Third, NRA_AGE was used as the measure of liberalization based on the assumption that countries which have liberalized their market earlier have gained regulatory experience and organizational setup when compared to countries with newly liberalized market. NRA_AGE has a value of 0 for a country without national regulatory authority, which changes to 1 when the regulator is established, and the value increases by 1 each year afterwards. Fourth, WEALTHY is included to capture the effect of countries wealthy on the telecommunications sector productivity. Since most wealthy countries have a saturated mobile market, similarly, this variable indicates the

level of mobile market saturation. Fifth, log of POPULATION measures the market size within national boundaries; and sixth, as telecommunications technology tends to advance rapidly over time, the TIMETREND variable is used to capture this effect.

Therefore, the determinants of productivity change are estimated by the following econometric model:

Malmquist productivity $index_{it} = \beta_0 + \beta_1 Q\_REV_{it} + \beta_2 Q\_MOB_{it} + \beta_3 Q\_NET_{it} + \beta_4 INTERFIRMS_{it} + \beta_5 NRA\_AGE_{it} + \beta_6 WEALTHY_{it} + \beta_7 POPULATION_{it} + \beta_8 TIMETREND_{it} + \varepsilon_{it}$

The model is estimated using the General Least Square regression technique to account for possible "within group autocorrelation" and "group-wise heteroscedasticity" in the panel. Table 6.2 shows results of the analysis

Table 6.2 Econometric results

Independent variables		Coefficient
Output (revenue)	Q_REV	0.00194***
Output (mobile subscriptions)	Q_MOB	0.00025**
Output (internet users)	Q_NET	0.00077***
International Network Operator	INTERFIRMS	0.03999**
Regulation presence and experience	NRA_AGE	-0.00620
Wealthy (GDP per capita)	WEALTHY	-0.00004***
Population	POPULATION	-0.02521
Time trend	TIMETREND	0.04781***
Constant		-94.30477
Number of Observations	NT	270
R^2*:between countries*		0.49

*** statistic significance at the 1% level,
** Statistics significant at the 5% level
* Statistics significant at the 10%

The econometric results show that all three outputs – revenues, mobile subscriptions and Internet users – are positively and significantly related to productivity growth in the telecommunications sector. Furthermore, the number of international network operators which indicates the level of competition and the effect of international network operators also shows a positive and significant (β_4 = 0.034 and $p<0.05$) influence on productivity growth. The presence and experience of regulatory agency shows negative and it is statistically significant in productivity changes of a country. As countries become wealthier, productivity in the telecommunications industry shrinks [3]. The results on regulatory agency experience and country's wealth are likely due to the weak starting base of the telecommunications services for the low income countries which are in the growing phase, compared to the saturated mobile markets in the wealthy countries. In addition, population shows a negative effect to productivity growth, however, statistically insignificant; and time trend is positive and significant (β_8 = 0.04781and $p<0.01$), which shows advancement of technology over time.

7. DISCUSSION AND CONCLUSION

This study have shown that productivity in the African telecommunications sector grew across the continent, and most of the productivity improvement is due to technological progress (innovation) resulting from shifting of the technology frontier in the sector. Technological advancement such as digital switching and 3G technologies are usually industry-wide developments which benefit the broader telecommunication industry; the African telecommunication industry seems to have benefited from such developments. As suggested by Madden et al. [3], African countries could achieve more productivity gain by improving their technical and managerial efficiency.

From the second stage regression, the results have depicted show that the increase in output, especially telephone subscriptions was crucial in boosting productivity growth in the African telecommunications sector. This result implies that the African countries can further increase their productivity by increasing the number of telephone subscribers, especially mobile telephony by utilizing the available infrastructure. By 2009, 60% of the African population was covered by mobile telecommunications signals [25], while mobile phone penetration was only 45.2%. Henceforth, the African countries, especially low income countries – most of them with low penetration levels of telecommunications services – can further gain productivity growth by increasing the penetration of telecommunication services on the mobile signals-covered population.

Perhaps the most interesting result of this study is the role competition, induced by the number of international network operators in each country, to spur productivity gains. As the number of international telecommunication operators increases, at first, it intensifies competition in individual markets which leads to better and more affordable services. Secondly, international operators have economies of scale and hence lower investment costs; and finally, international network operators can easily apply the managerial know-how, strategies and experience they have learned from other markets into new markets. When more capable and strategic operators are operating in a particular market, the competition is likely to intensify, which will lead to increase in penetration of telecommunications services and improvement of the overall sector productivity. Thus, the study suggests that competition policy accompanied with proper market players can improve productivity and create a greater value for the telecommunication industry.
Additionally, the results have shown that the low income countries exhibited higher productivity improvement compared to the wealthier ones. This may be due to the fact that the low income countries are late adopters of technologies; hence, they can enjoy the well established technologies (such as GSM for mobile communications) and avoid the cost of trial and error when deploying alternative technologies during their initial development stages [26]. Similarly, the telecommunications markets in wealthier countries have achieved or are approaching market saturation in mobile services [5] and are struggling to encourage penetration of advanced services particularly broadband. For example, in Botswana, Gabon and South Africa, their mobile penetration has reached beyond 93% in 2009; hence, the saturation of mobile telephony, and the infancy of newer technologies particularly broadband in which most of the wealthier countries have already committed resources on but the consumers are yet to experience the mass adoption, might explain the low productivity growth in the telecommunication industry experienced by the wealthier African countries.

In conclusion, the African telecommunications industry has improved its productivity levels between 2000 and 2009; however, most of the productivity is resulted more from technological advancement than from technical efficiency. Additionally, competition and increase in telecommunication services subscriptions have also boosted the sector's productivity. Hence, the study implies that African countries can further increase productivity in their telecommunications sector by improving on technical / managerial efficiencies, increase output especially penetration of telecommunication services, and encourage competition in the market with participation from strategic international network operators.

Acknowledgement

This paper was presented at the Africa-Asia-Australasia Regional Conference of the International Telecommunications Society (ITS) in Perth on 4th to 7th August 2013. The authors would like to give gratitude to all participants for their Invaluable comments which lead to the improved analysis of the paper.

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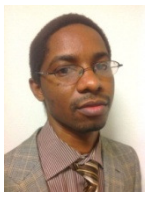

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