ICT Infrastructure Utilization in Africa: Data Envelopment Analysis Based Exploration

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ABSTRACT

The last few years have witnessed a rapid growth in information and communication technologies (ICT) infrastructure in both developed and developing countries. This has resulted in an increase in ICT capabilities whereby its application is found in every sector of economies and societies. The speedy spread in ICT systems is creating an avenue for African countries to harness technology for developmental purposes. At the same time, many African countries are increasing their national information infrastructure investments so that they can partake in knowledge-based development as well as socio-economic payback. This study complements an earlier study that used Data Envelopment Analysis (DEA) to analyze ICT expansion in West African countries

The paper investigates efficiency in ICT utilization across four regions in Africa. The DEA analysis shows that ICT utilization in Africa varies across the regions and is determined by level of infrastructure accessibility and cost of ICT services.

Keywords: Africa, ICT infrastructure, DEA, SADC, ECOWAS, NA, EA.

1.0 INTRODUCTION

The last few years have witnessed a rapid growth in ICT infrastructure in both developed and developing countries. This has resulted in an increase in ICT capabilities whereby its applications are found in every sector of economies and societies (Colecchia and Schreyer, 2002; Qiang and Pitt, 2003; Mhalaga, 2006). Globally, ICT are gradually affecting individuals,

communities, industries, societies and governments. This has influenced the decrease in the overall cost of ICT worldwide. The speedy spread in ICT systems is creating avenues for developing countries to harness the technology for developmental purposes (Mhalaga, 2006).

Several initiatives have been put forward by governments, industries, ICT stakeholders, and business managers to promote the formation of a global information infrastructure. International organizations [e.g. International Telecommunication Union (ITU)] have been in the vanguard of advising developing nations, especially in Africa, to invest in ICT (Bollou, 2006), and many African countries have responded by increasing their national information infrastructure investments so they can partake in knowledge-based development and its socio-economic payback.

In this paper, we investigate ICT utilization in Africa. Our objective is to determine which of the regions is efficient in their ICT utilization and what are the factors affecting ICT utilization. The paper uses a 10-year panel data set of 28 African countries (1998-2007). The countries were grouped into four regions based on standard geographic and economic classification in Africa. This study uses DEA to analyze ICT utilization and evaluate efficiency improvements in each region. The use of DEA in the study of IT and productivity is not new. It has been used increasingly to measure the relative efficiency of ICT sectors in both developed and developing economies (Bollou, 2006; Bollou and Ngwenyama, 2008, Samoilenko, 2008; Samoilenko and Osei-Bryson, 2008; Samoilenko and Osei-Bryson, 2010).

Ngwenyama and Morawcyzski, (2009) interrogated factors affecting ICT infrastructure in five Latin America countries and Bollou, (2006) explored ICT expansion in six West African countries using DEA analysis. Neither of these projects compared ICT utilization across varying regions, particularly in the context of African countries. This study addresses this gap by investigating ICT utilization in four regions of African countries. The analysis shows that efficiency in ICT utilization in Africa varies across the region and is determined by the level of infrastructure accessibility and the cost of ICT services. The rest of this paper is organized as follows:

- The second section discusses an overview of ICT infrastructure in Africa.
- The third section presents the background of African countries.
- The fourth section outlines the methodology used in the study

- The fifth section presents the data collection and analysis procedure.
- The sixth section is a discussion of the results.
- Finally, the last section presents the conclusions of this study.

2.0 OVERVIEW OF ICT INFRASTRUCTURE IN AFRICA

In acknowledgment of the importance of ICT for socio-economic development, several African countries established the African Information Society Initiative (AISI), a framework for building ICT infrastructures in Africa (Okello, 2010). The AISI adopted regional e-strategies to provide a support for the development of ICT infrastructure, capacity building, trade and regional integration.

Presently, Africa still faces a challenging gap in the ICT sector when compared to the rest of the world in terms of access to technology such as main telephone lines and fixed broadband. Although, there has been a rapid increase in mobile phone and public Internet access due to private sector participation, yet, the percentage share of ICT access still remain low in Africa (ITU, 2007a). Existing undersea cables such as South Atlantic (SAT-3) and West African Submarine Cable (WASC) are providing broadband services to East Africa through South Africa (Calandro et al., 2010; Jensen, 2010). The SEA-ME- WE submarine cable connected the North African countries to the global network in Djibouti. About 85 percent of international bandwidth traffic in Africa is routed through Europe to its required destinations. (ITU, 2007b; UNCTAD, 2010). The New Partnership for Africa's Development (NEPAD) commission proposes 52,040km backbone infrastructure connectivity in Africa as follows: 19,330 km in the Western region, 15,950km in the Central region, 2,200 km in the Northern region and 145,060 km in both Eastern and Southern Africa. (ITU, 2008). The ITU also estimates investment of about US$1billion for international fibre optic networks and US$1.6 billion for regional links. Such investment will expand about 92,000km of fibre optic networks where 25,000km of international submarine cable will be provided to bridge regional and international broadband gap (Okello, 2010; ITU, 2008). In response to this demand, several initiatives have been established, such as the construction of the East African Submarine Cable System (EASSy) to link the east coast of Africa, SEACOM undersea cable projects for the African eastern coast, Main One and GLO-1(GLOBACOM) linking Nigeria and the United Kingdom. The terrestrial and satellite networks

like COMTEL, EAC Broadband Network, SATA Backhaul, and RASCOM, among others are provided to complement submarine cables that connect non-coastal areas (Okello, 2010).

3.0 BACKGROUND OF AFRICAN COUNTRIES

The Africa continent consists of 56 countries, where 50 of these countries are in the Sub-Saharan region and the remaining six are in North Africa. There have been initiatives that gave rise to regional groupings based on geographic and economic structure. We started this study with the intention of exploring ICT infrastructure utilization in all African countries; but, we were able to collect data for only 28 countries. The 28 countries were grouped into four regions according to standard geographic and economic groupings: Southern African Development Community (SADC), Economic Community of West African States (ECOWAS), Eastern Africa (EA) and Northern Africa (NA).

3.1 Southern African Development Community (SADC)

SADC consist of 15 member states within a regional community. One of the aims of SADC is to support human development in Southern Africa (SADC, 2010). The vision is to reinvigorate the positive values, principles, culture, and history that existed among the people of the region prior to colonization.

The SADC region was formed as a result of the Lusaka declaration of 1980 where each member state committed to the development of ICT, human resources and economic integration (SADC, 2010). The SADC countries have a combined population of over 200 million with 80 percent of people living in rural areas (SADC, 2010). During the 1990s the region experienced growth in its ICT sector (Bollou, 2006). The SADC countries selected for this study are Mauritius, South Africa, Botswana, Namibia, Swaziland, Madagascar, Lesotho and Mozambique.

Mauritius is the only that country placed highly on the UN Human Development Index (HDI) rankings in 2007. Mauritius has a population of 1.2 million, with 45% of people living in urban areas and literacy rates of 87%. South Africa, Botswana, Namibia, Swaziland, Madagascar and Lesotho are ranked as medium in terms of human development. These countries have populations varying from 1.1million (Swaziland) to 49.1million (South Africa), with average of

37 % of people living in urban areas and average literacy rates of 81.9%. Mozambique has a population of 21.8million, with 35.2 % living in urban areas and literacy rates of 44.4 %. Mozambique was grouped as low on human development according to the HDI rankings.

The SADC countries have increased their ICT infrastructure investments and usage since 1994 due in part to the liberalization of telecommunication policies in the states (The Africa Initiative, 2004). Table 1 below shows a summary of demographic data for the countries.

3.2 Economic Community of West African States (ECOWAS)

ECOWAS is a region of fifteen countries founded in 1975 to promote economic integration in '*all fields of economic activity, particularly industry, transport, telecommunications, energy, agriculture, natural resources, commerce, monetary and financial questions, social and cultural matters…*'.(ECOWAS, 2011; New African, 2011). It consists of 15 member states with the main objective of establishing a regional customs union and common market that will facilitate trade within West Africa (EIU, 2007). ECOWAS has also been active on regional security issues thereby initiating the ECOWAS ceasefire Monitoring Group (ECOMOG), used for peace enforcement operations in Liberia, Sierra- Leone, Guinea- Bissau, the Guinea-Liberia border and Cote d'Ivoire (EIU, 2007; Kessides, Noll and Benjamin, 2009). The region has instituted a borderless community where residents have one ECOWAS passport and are united by one ECOWAS citizenship for regional integration (New African, 2011). The ECOWAS countries in this study are Benin, Burkina Faso, Cape Verde, Cote D'Ivoire, Gambia, Ghana, Mali, Nigeria, Senegal and Togo.

Cape Verde, Ghana and Nigeria were ranked as medium in the UN Human Development Index (HDI) rankings in 2007. Cape Verde has a population of 0.04 million, with 63.4 % living in urban areas and a literacy rate of 83.8 %. Ghana has a population of 22.8 million, with 50.6 % people living in urban areas and a literacy rate of 72.3%. Nigeria has a population of 147 million, with 49.9 % living in urban areas and a literacy rate of 72 % (See Table 1). Benin, Burkina Faso, Gambia, Mali, Senegal, Togo and Cote d'Ivoire are ranked as low in the HDI ranking. The seven countries have populations varying from 6.3 million (Togo) to 20.1 million (Cote d'Ivoire), with average of 40.6 **%** people living in urban areas and an average literacy rate of 39.5 %. They are close to the bottom of the UN HDI rankings and are classified as least developed countries.

Group	Countries	Population (Million)	% Living in urban Area	Infant Mortality Rates (per 1000)	GDP per Capita Constant 2000 US$	Literacy Rate %	HDI 2007	HDI Ranking 2007
SADC	Mauritius	1271.15	42.14	15.10	4709.23	87.4	0.80	81
SADC	Botswana	1892.43	58.61	39.70	4541.05	82.9	0.61	125
SADC	Namibia	2088.67	35.99	67.60	2665.28	88	0.59	128
SADC	South Africa	49173.16	59.52	59.00	3715.81	88	0.60	129
SADC	Swaziland	1151.40	24.38	90.90	1542.22	79.6	0.48	142
SADC	Madagascar	18604.37	28.87	111.80	260.24	70.7	0.43	145
SADC	Lesotho	2031.68	18.97	83.50	508.05	82.2	0.41	156
SADC	Mozambique	21869.36	35.28	168.47	349.07	44.4	0.27	172
ECOWAS	Benin	8393.13	43.97	123.40	352.79	40.5	0.42	161
ECOWAS	Burkina Faso	14721.43	19.14	190.70	259.27	28.7	0.29	177
ECOWAS	Cape Verde	491.72	63.46	32.20	1561.78	83.8	0.53	121
ECOWAS	Cote d'Ivoire	20122.80	43.88	126.50	530.13	48.7	0.39	163
ECOWAS	Gambia	1615.51	58.88	108.60	363.24	37.8	0.37	168
ECOWAS	Ghana	22870.97	50.64	115.20	314.13	72.3	0.46	152
ECOWAS	Mali	12408.82	31.40	195.60	289.10	26.2	0.30	178
ECOWAS	Nigeria	147721.84	49.92	188.80	472.90	72	0.41	158
ECOWAS	Senegal	11893.34	43.74	113.60	530.95	41.9	0.40	166
ECOWAS	Togo	6300.50	43.40	100.30	248.53	53.2	0.42	159
NA	Algeria	33858.17	64.63	37.00	2158.92	75.4	0.66	104
NA	Egypt	80060.54	17.42	36.20	1697.05	66.4	0.60	123
NA	Morocco	31224.14	60.01	34.40	1692.91	55.6	0.55	130
NA	Sudan	40432.30	40.61	108.60	502.27	60.9	0.37	150
NA	Tunisia	10068.57	67.73	21.20	2651.99	77.7	0.66	98
EA	Kenya	37754.70	21.14	121.20	459.58	73.6	0.46	147
EA	Uganda	30637.54	12.95	130.40	328.36	73.6	0.40	157
EA	Eritrea	4781.17	20.50	70.40	149.18	64.2	0.47	165
EA	Ethiopia	78646.13	17.42	118.60	174.98	35.9	0.31	171
EA	Djibouti	834.29	86.85	127.40	831.51	65.5	0.39	155

Table 1: Demographic Background of the Regions (Source: African Development Indicators) (http://data.worldbank.org/data-catalog/africa-development-indicators)

3.3 Northern Africa (NA)

Northern Africa is a region in the northernmost part of Africa spanning about 7.2 million square Kilometers from the Atlantic Ocean to the Red Sea (Danowitz, Nassef and Goodman, 1995). It covers the Saharan Desert and the Nile River Valley. There have been popular imaginative views that have tended to leave out the northern region when speaking of the African continent. Sub-Saharan Africa countries are often referred to as Africa, yet evidence of connections between the people on both sides is visible through the formation of trans-Saharan commerce and trade routes on the Mediterranean coast, which date back to the ninth century BCE (Bentahar, 2011). This has facilitated cultural exchanges and trade relations among the other regions. The Northern Africa countries in this study are: Algeria, Egypt, Morocco, Sudan and Tunisia. The five countries are grouped as medium in the HDI rankings. They have populations varying from 10 million (Tunisia) to 80 million (Egypt). These countries have 50% of urban populations, with average literacy rates of 67.2% (See Table 1).

3.4 Eastern Africa (EA)

East Africa (EA) is a region in the eastern part of Africa. EA consist of 19 member states bonded by geography. The countries selected in this study are Kenya, Uganda, Eritrea, Ethiopia and Djibouti. The five countries are members of the Common Market for Eastern and Southern Africa (COMESA). COMESA's aim is to promote regional economic integration through trade and ICT infrastructure investments (COMESA, 2010). Kenya and Uganda are also members of the East Africa Community (EAC), a regional group that promotes the establishment of financial institutions and infrastructure in member states (UNCTAD, 2005). Kenya, Uganda and Djibouti are ranked medium in the HDI rankings. They have populations varying from 0.8 million (Djibouti) to 37.7 million (Kenya), with 40.3 % of populations living in urban areas. They have average literacy rates of 70.9%. Eritrea and Ethiopia are grouped as low medium in the HDI rankings. Eritrea has a population of 4.7 million, with 20.5% living in urban areas and 62% literacy rates. Ethiopia has a population of 78.6 million with 17 % of urban population and 65.5% literacy rate.

4.0 METHODOLOGY

4.1 Data Envelopment Analysis (DEA)

The methodology used in this study is DEA, which is a well-known non parametric linear programming method for measuring the relative efficiency (Thanassoulis, Kortelainen, Johnes and Johnes, 2011). This technique is known for its effectiveness in measuring the relative efficiency of organizations and countries (Bollou, 2006; Cooper et al., 2004). DEA is a frontier analysis originated from the work of Farrel (1957) and was later amended by Banker, Charnes and Copper (1984) and Charnes, Copper, and Rhodes (1978) to form two DEA models known as variable return to scale (VRS) and constant return to scale (CRS) respectively (Samoilenko and Osei-Bryson, 2008; Samoilenko and Osei-Bryson, 2010).

DEA is a data oriented method for evaluating the performance (efficiency) of entities known as Decision Making Units (DMUs). DMU (e.g. Bank, university or country) is distinct unit that converts multiple inputs to multiple outputs (Thanassoulis et al., 2011; Ngwenyama and Morawczynski, 2009; Bollou, 2006). It uses input-output data to compute an efficient production frontier produced by the most efficient units (Bollou, 2006). The efficient production frontier is the set of all technologically feasible production plans (development policies) with the highest efficiency (Bollou, 2006; Ngwenyama and Morawczynski, 2009). Figure 1 shows the efficiency frontier.

The DEA model generates efficiency score for each DMU, where the value of each DMU varying from 0 to 1.00 (or 100%). The efficiency score of 1.00 signifies maximum efficiency compared to all other DMUs in the study. This represents the best practice or benchmark unit and the inefficient units are compared to efficient ones for possible performance improvement (Ngwenyama and Morawczynski, 2009).

The advantage of DEA is its flexibility for several models and orientations thereby offering multiple vantage points (Samoilenko and Osei-Bryson, 2010). There are two commonly used types of DEA orientation models: input oriented and output oriented (Charnes, Copper, Lewin & Seiford, 1994). An input oriented model deals with efficient utilization of inputs to achieve a certain level of output. An output oriented model is concerned with efficient utilization of outputs for a certain level of inputs. Under the input orientation, a relatively efficient DMU orientation cannot reduce its levels of inputs any further and so has a relative efficiency score of

1.00, while relatively inefficient DMUs could reduce its level of inputs and so has a non-negative relative efficiency score that is less than 1.00. On the other hand, an output-oriented DEA model, is concerned with the maximization of the level of the outputs per given level of inputs. DEA can also be applied under different underlying economic assumptions about the returns to scale (Seiford and Zhu, 1999). For example, an assumption of the *constant return-to-scale* (CRS) model reflects a situation where the changes in output are in the same proportion as the changes in inputs, while assumptions of the *variable returns-to-scale* (VRS) model reflect increasing returns to scale. The basic DEA model is defined as follows:

Maximise:

$$h_o = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}}$$

Subject to:

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leqslant 1 ; \qquad j = 1, \ldots, n,$$

$$u_r, v_i \geqslant 0 ; \qquad r = 1, \ldots, s ; \qquad i = 1, \ldots, m.$$

Where y_{rj} , X_{ij} are the known inputs and outputs of the *jth* DMU and U_r , $V_i \geq 0$ are the variable weights to be determined by the solution of the problem (Charnes et al., 1978).

4.2 Technical Efficiency

In DEA method, there are different concepts of efficiency. The most common efficiency concept is technical efficiency (Deliktas and Kok, 2003; Bhagavath, 2009). Technical efficiency is the conversion of inputs into outputs relative to best practice (Bhagavath, 2009). It can be expressed by the ratio of sum of the weighted outputs to sum of weighted inputs (Komleh, Omid and Keyhani, 2011). Technical efficiency is the ability of a DMU to produce maximum outputs from a given set of inputs for a stipulated period. A technically efficient DMU operates on the efficient production frontier (see DMU 2 and DMU 3 in Figure 1) and technically inefficient operates below the efficient production frontier. The continuous upward movement of a

technically efficient DMU along efficient production frontier results to higher level of productivity that might be caused by improvements in technical efficiency, scale efficiencies or change in production technology. Scale efficiency is the ratio of the distance function satisfying constant returns to scale to the distance function restricted to satisfy variable returns to scale (Fare, Grosskopf, Norris and Zhang, 1994).

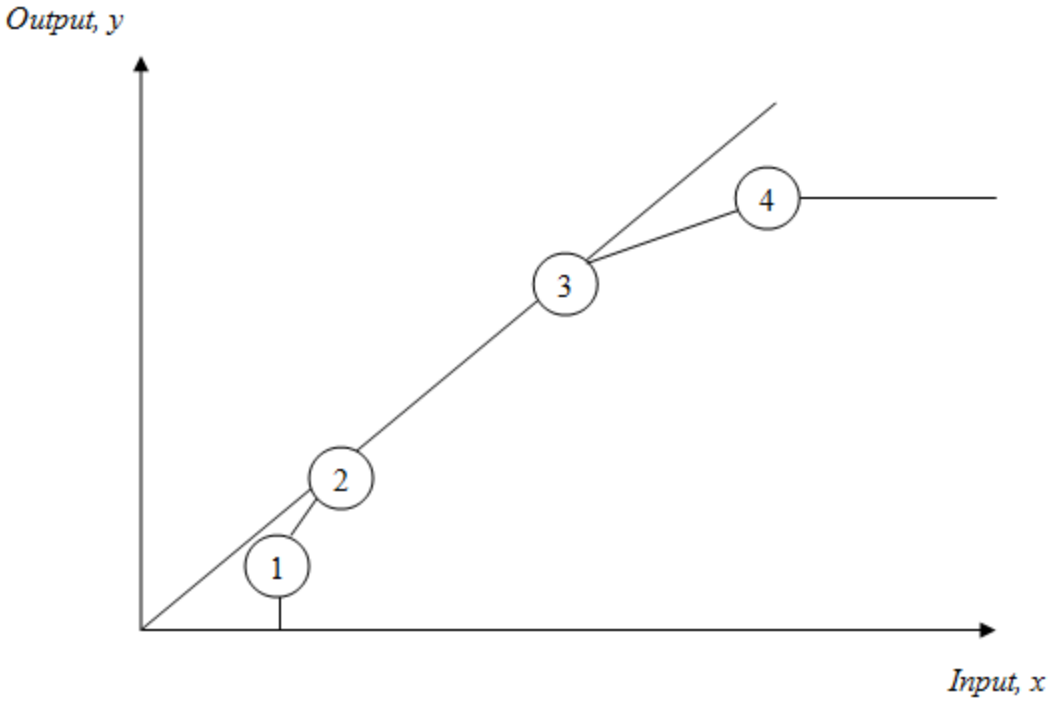

Figure 1: The Efficient Production Frontier

The assumption for assessing scale efficiency of DMUs under CRS model and VRS model are stated as follows: (Deliktas and Kok, 2003; Ngwenyama and Morawcuski, 2009)

- The CRS model evaluate whether a DMU is operating on the production frontier. It assumes that 1 unit of input will result in 1 unit of output. Technically efficient DMU = CRS (TE_{CRS}) of 1 (100%) and not technically efficient DMU = TE_{CRS} < 1 (This fall below production frontier).
- The VRS model estimate the improvement outputs required to reach the efficiency frontier based on the slacks of input variables. It assumes that 1 unit of input can result in output ranging from less than 1 unit to more than 1 unit. A DMU operating at VRS

technical efficiency (TE_{VRS}) = 1 (100%). [i.e. no changes in inputs will improve its outputs]. When technically efficient VRS DMU = TE_{VRS} < 1 (100%) [i.e. DMU can achieve higher levels of outputs when the inputs are rearranged].

For the analysis, we use the VRS input oriented DEA model to examine the DMUs on the efficient production frontier to determine the improvements or reduction that can be made to their inputs (optional) while maintaining same (higher) level of outputs.

5.0 DATA COLLECTION AND ANALYSIS

We gathered data for this analysis from the International Telecommunication Union (ITU) and the African Development Indicators (World Bank) databases. The study employs a country level dataset drawn from the years 1998-2007. This period follows the years of major ICT investments in the continent (Bollou, 2006, Ngwenyama et al., 2006; Bollou and Ngwenyama, 2008).

In this study, we developed input oriented VRS as used to generate the efficiency score of the 28 Africa countries using MaxDEA (Version 5.0) software. Our data set spans a 10-year period, we performed DEA analysis one for each year for the period (1998-2007). The efficiencies of each country in a region in a year were averaged to obtain 10 scores of the relative efficiency, one for every year, for each of the region in our sample (see Table 3). These scores are referred to the relative efficiency of transforming ICT infrastructure into ICT utilization.

5.1 The DEA Model

The choice of appropriate input and output variables is a fundamental step in DEA analysis. The variables that were used in the model was developed based on literature review; outlining the widely used variables in this context (e.g. see Bollou, 2006; Samoilenko, 2008; Ngwenyama and Morawczyski, 2009; Bollou and Ngwenyama, 2008). However, our goal is to find out how efficient the regions are in terms of ICT infrastructure utilization. Therefore, we identified the input and output variables that are related to ICT infrastructure, capabilities and utilization in the specification of the DEA model. It also important to mention that there is no objective consensus on which variables best describe a DEA model. The decision is based on the selection of the

researcher (Samoilenko, 2008; Santo, Amado and Rosado, 2011). The variables outlined are presented in Table 2.

Input Variable	Output Variable
Annual telecoms investment (% of GDP in current US$)	Annual outgoing call traffic (minutes per subscribers)
Line capacity of exchanges	Annual incoming call traffic (minutes per subscribers)
International Internet bandwidth (mbps)	Main telephone line subscribers (per 100 inhabitants
Full time telecoms Staff (% of total labour force)	Internet users (per 100 inhabitants)
	Mobile cellular subscribers (per 100 inhabitants)
	Main telephone lines in operations
	Percentage of households with telephone
	Percentage of digital main line
	Percentage population coverage of mobile phone
	Percentage of residential main line

Table 2: DEA Model Variables

Region	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Score Average
SADC	0.826	0.860	0.868	0.861	0.872	0.918	0.915	0.915	0.944	0.945	0.892
ECOWAS	0.818	0.862	0.910	0.915	0.901	0.915	0.925	0.921	0.953	0.966	0.908
NA	0.953	0.945	0.956	0.935	0.937	0.971	0.978	0.962	0.987	1.000	0.962
EA	0.844	0.843	0.816	0.825	0.819	0.779	0.789	0.782	0.791	0.790	0.808

Table 3: Average Relative Efficiency Scores

6.0 DISCUSSION OF THE RESULTS

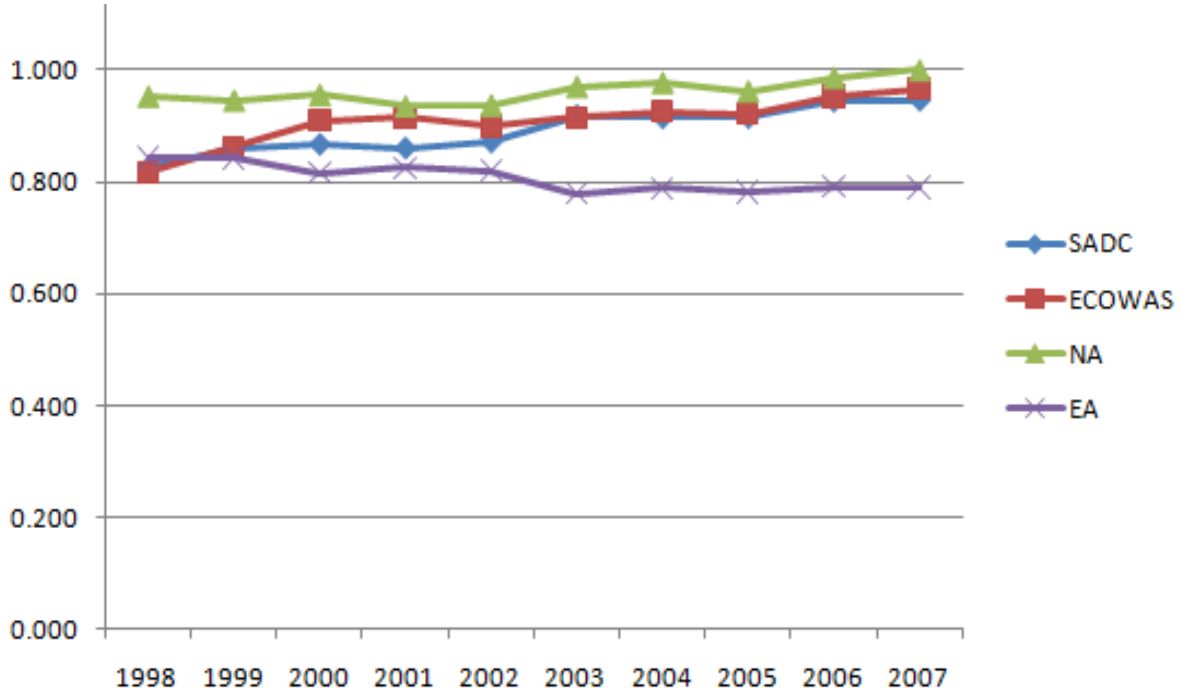

Figure 2: Trend of Average Relative Efficiency in Africa regions

6.1 Trend Analysis

To answer our first research question: Which of the regions is efficient in their ICT utilization? We performed VRS input oriented analysis and the relative efficiency scores were computed for the NA, ECOWAS, SADC and EA regions over a 10 year period (see Table 3). Recall that the highest placed (ranking) DMU are considered to be 100 % efficient and assigned a score of 1 while the rest of the DMUs in the sample would be considered to be inefficient and are assigned a score of less than 1. The observation from Figure 2 shows that North Africa is the most efficient region in the group. It has an average relative efficiency score of 0.962 for the entire period of the study (Table 2). The empirical analysis suggests that North Africa is the best managed region in term of ICT utilization. The North Africa region uses most efficient combination of inputs to produce current levels of outputs relative to other regions under study.

The trend analysis in Figure 2 shows that North Africa placed (ranked) first in the 10 years of the study. It is the only region that attained 100% score in 2007 in the model. Hence, it serves as a benchmark for best performance practices among the regions.

The ECOWAS placed next best in performance with an average relative efficiency score of 0.908 for the period of the study. It is followed by the SADC region with an average relative efficiency score of 0.892 and the East Africa region, with average relative efficiency score of 0.808. East Africa was the least efficient region. The relative efficiency score was 0.844 in 1998 and dropped slightly to 0.834 in 1999. This was further decreased in 2000 from 0.816 to 0.790 in 2007. Although, the reasons for this decrease required further investigation, analysis shows that there is a persistent monopoly in national fixed line telecommunication provision in the region (Ochara, Van Belle and Brown, 2008). A typical case is Kenya, where less than 10 percent of the population accessed the Internet as a result of a skewed provision of broadband infrastructure in favour of urban cities (Ochara et al., 2008). The observations that stand out from the trend analysis are:

- The North Africa region shows the highest efficiency scores (with slight improvements) when compared with other regions over the period of this study.

- The ECOWAS and SADC regions shows general increase in efficiency scores, though ECOWAS efficiency scores improve faster than SADC from 2000 to 2007, yet both regions progress rapidly in overall performance and tends to close the gap towards the Northern region.

- The East Africa region efficiency scores appeared to be higher than the ECOWAS and SADC regions in 1998. This later decreased slowly till 2007 thereby creating a wide gap when compared with the other regions.

6.2 Factors Affecting ICT Infrastructure Utilization

As a general observation, all the regions except East Africa show improvements in the ICT infrastructure utilization over the period of time of this study (1998-2007). In the Northern

region, this was to be expected as the region has a well developed ICT platform when compared with other regions. For instance, the majority of Africa's telephone lines over the period of 2001 to 2006 are concentrated in Algeria, Egypt, Morocco and Tunisia, while Tunisia accounted for almost 80 percent of the subscriptions (Okello, 2010). Similarly, there were about 44 million Internet users in Africa in 2006, with over half of them located in North Africa (ITU, 2007b). ICT expansion in most of the countries in other regions has been a challenge, as they do not have direct terrestrial access to a global network and must rely on satellite networks. This led to a high cost of Internet subscriptions. The total fixed broadband available in 25 African countries was 28,177 Mbps in 2006, while 75.5% subscribers are in the Northern African countries (ITU, 2007b; Okello, 2010). The lack of broadband access is hindering the chance to benefit in global ICT development.

Although, most of the countries in ECOWAS (e.g. Burkina Faso, Benin, Burkina Faso, Mali, e.t.c) are listed as poorest in the world economy, with human development close to the bottom of UN human development ranking, the liberalization of the telecommunication sectors in the region has enabled growth of their ICT infrastructure. For example, the ECOWAS region has the highest number of mobile cellular subscribers and the fastest growing in the continent (ITU, 2010). There has been evidence of growth in socio-economic development in the region due to the increase in mobile communication usage (UNCTAD, 2009). The correlation conducted in this study between human development scores and efficiency scores in ECOWAS region shows a positive relationship (Table 4). This suggests why growth in ICT infrastructure utilization is associated with the level of human development in the region.

Despite the high level of sophisticated ICT infrastructures in the SADC region, the region was placed (ranked) third in term of efficiency among the regions. This might be due to the low level of ICT access and high cost of ICT services in the region. For example, the diffusion of Internet connectivity in South Africa shows that ICT use declined in 2000 to 2004 as a result of monopolization in the telecommunications industry, restrictive regulations, delayed implementation of policies, and the socio-economic divide (Makhaya and Simon, 2003; Brown et al., 2007). The recent study on telecommunications price and access shows that SADC has the highest telecommunications tariff in the continent (ITU, 2009a; UNCTAD, 2009; OECD, 2011), thereby making ICT services expensive in the region. East Africa was the least in the region due

to limited access to ICT infrastructure. Examination of the relative efficiency scores across the regions shows that the relevant output variables were impacted by the relevant input variables. For instance, provision of international Internet bandwidth and adequate line capacity of exchanges in North Africa serves as important underlying factors to determine ICT utilization efficiency in the region.

In general, the ICT infrastructure in Africa, especially the mobile market, has experienced tremendous growth but at a sub-optimal rate, except in countries like Ghana, Nigeria and Kenya. Africa still lags behind other parts of the world in terms of the percentage of people with access to ICT services and manner of usage due to high cost of services. The cost of telecommunication services remains high, thereby escalating the cost of business in most countries. The contribution of ICT utilization to GDP (except North Africa) is less than global averages (Calandro, Gillward, Moyo and Stork, 2010). This would have improved if ICTs were used widely as a lever for socio-economic growth on the continent.

Region	Coefficient	N	t-stat	CV	P-Value	Correlation?
SADC	-0.034	80	-0.300	-1.990	0.760	None
ECOWAS	0.265	100	2.730	1.980	0.010	Positive
NA	-0.177	50	-1.260	-2.010	0.210	None
EA	-0.488	50	-3.910	-2.010	0.000	Negative

Table 4: Correlations between Average Relative Efficiency Score and Human Development Index, 1998-2007.

7.0 CONCLUSION

In conclusion, we performed VRS analysis to determine the relative efficiency of ICT utilization for all the countries in Africa according to their regional groupings (SADC, ECOWAS, North Africa and East Africa). The DEA results suggest that the North Africa region is the best managed of the groups. This is followed by the ECOWAS region, SADC and the East Africa region. The use of DEA in the study of IT and productivity is not new. It has been used increasingly to measure the relative efficiency of ICT sectors in both developed and developing

economies However, none of this research compares ICT utilization across varying regions, particularly in the context of African countries. This study addresses this gap by investigating ICT utilization in four regions of African countries.

This study analyzed the state of ICT infrastructure, the efficiency in ICT utilization across four regions in Africa. The analysis reveals that ICT utilization in Africa varies across the regions and is determined by level of infrastructure accessibility and cost of ICT services.

REFERENCES

Bentahar, Z. (2011). Continental Drift: The Disjunction of North and Sub-Saharan Africa. *Research in African Literature, 42(1), 1-13.*

Bhagavath, V. (2009). Technical Efficiency Measurement by Data Envelopment Analysis: An Application in Transport. *Alliance Journal of Business Research,(1), 60-72.*

Bollou, F. (2006). ICT Infrastructure Expansion in Sub-Saharan Africa: An analysis Of Six West African Countries from 1995-2002. *Electronic Journal of IS in Developing Countries, 26 (5), 1-16.*

Bollou, F., & Ngwenyama, O. (2008). Are ICT Investments Paying Off in Africa? An Analysis of Total Factor Productivity in Six West African Countries from 1995 to 2002. *Information Technology for Development, 20(9), 1-14.*

Brown, I., Collins, T., Maleka, B., Morrison, D., Muganda, N., & Speig, H. (2007). Global Diffusion of the Internet x: Internet Diffusion and Its Determinants in South Africa: The First Decade of Democrazy (1994-2004) and Beyond. *Communications of the Association Information Systems, 19 (170), 142-182.*

Calandro, E., Gilward, A., Moyo, M., & Stork, C. (2010). Comparative ICT Sector Performance Review: *Towards Evidence-based ICT Policy and Regulation, 2(5), 1-50.*

Charnes, A., Cooper, W., & Rhodes, E. (1978). Measuring the Efficiency of Decision Making Units. *European Journal of Operational Research, 2(6),429-444.*

Charnes, A., Cooper, W.W., Lewin, A.Y., & Seiford, L.M. (Eds.). (1994). Data envelopment analysis: Theory, methodology, and applications. Boston: Kluwer.

Colecchia, A., & Schreyer, P. (2002). ICT Investment and Economic Growth in the1990s: Is the United States a Unique Case? A Comparative Study of Nine OECD Countries. *Review of Economic Dynamics, 5(2), 408-442.*

COMESA: Common Market for Eastern and Southern Africa (2010). Promoting regional economic integration through trade and investment Retrieved at 15 http://www.comesa.int/

Cooper, W.W., Seiford, L.M., & Zhu, Joe. (2004). Data envelopment analysis: History, models and interpretations. In W.W. Cooper, L.M. Seiford, & J.Zhu. (Eds.), Handbook on data envelopment analysis (pp. 1-39). Boston: Kluwer Academic Publishers.

Danowitz, A.K., Nassef, Y., & Goodman, S.E (1995). Cyberspace across the Sahara. Computing in North Africa. *Communications of ACM, 38(12), 23-28.*

Deliktas, E., & Kok, R. (2003). Efficiency convergence in transition economies: 1991-2002. A non parametric frontier approach. Ege University: Department of Economics. Retrieved June 10, 2011 from *http://www.deu.edu.tr/userweb/recep.kok/efficiency.pdf*

ECOWAS: Economic Community of West African States (2011). Discover Ecowas. Retrieved September 3, 2010, from *http://www.ecowas.int/*

EIU: The Economist Intelligence Unit (2007). Regional Overview: Membership of organizations. Retrieved June 20, 2011 from *www.eiu.com.*

Fare, R., Grosskopf, S., Norris, M., & Zhang, Z. (1994). Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries. *The American Economic Review,1 (84),66-83.*

Garbacz, C., & Thompson, H. G. (2007). Demand for telecommunication services in developing countries. *Telecommunication Policy, 31(2007), 276-289.*

ITU: International Telecommunication Union (2007b).Telecommunication/ICT Markets and Trends in Africa Report.

ITU: International Telecommunication Union (2007a). World Information Society Report.

ITU: International Telecommunication Union (2009a). ITU News Magazine.*pp2*

ITU: International Telecommunication Union (2009b). World Information Society Report.

ITU: International Telecommunication Union (2010).Measuring the Information Society. The ICT Development Index. Retrieved April 12, 2010, from *www.itu.int/ITU-D/ict/.../idi/2010/.../MIS_2010_without%20annex%204-e.pdf*

ITU: International Telecommunication Union (2008). *Global Information Society Watch,* Measuring *Progress. Pp77-95.*

Jensen, M. (2010). ICT in Africa: A Status Report. World Economic Forum. Retrieved June 16, 2011, from *https://members.weforum.org/pdf/Global_Competitiveness_Reports/Reports/GITR_2002_2003/ICT*

Kessides, I.N., Noll, R.G., & Benjamin, N.C. (2009). Regionalizing Telecommunications Reform in West Africa. The World Bank Development Research Group Environment and Energy Team. *Policy Research Working Paper 5126* Retrieved April 15, 2011, from *http://econ.worldbank.org*

Komleh, P.S.H., Omid, M., & Keyhani, A. (2011). Study on Energy use Pattern and Efficiency of Corn Silage in Iran by using Data Envelopment Analysis (DEA) Technique. *International Journal of Environmental Sciences, 1(6), 1094-1106.*

Makhaya, G., & Simon, R. (2003). Telecommunications in developing countries: reflections from the South African experience. *Telecommunications Policy 27(3), 41-59.*

Mhlanga, F.S (2006). A Developing Country's Information and Communication Technology Infrastructure in Perspective: A Vision for 21st Century. *Transaction of Society for Design and Process Science, 10, (1), 71-79.*

Morawczynski, O., & Ngwenyama, O. (2007). Unraveling the impacts of investments in ICTs, education and health on development. An analysis of archival data of five West African countries using regression splines. *Electronic Journal of IS in Developing Countries, 29(5), 1-15.*

New African (2011). Moving towards an Ecowas of people. Retrieved June 17, 2011, from at *http://content.yudu.com/A1sbf2/NA0611/resources/55.htm*

Ngwenyama, O., & Morawczynski, O. (2009). Factors Affecting ICT Expansion in Emerging Economies: An Analysis of ICT Infrastructure Expansion in Five Latin American Countries. *Information Technology for Development, 15(4), 237-258.*

Ngwenyama, O., Andoh-Baidoo, F.K., Bolou, F., & Morawczynski, O. (2006). Is There A Relationship Between ICT, Health, Education and Development? An Empirical Analysis of five West African countries from 1997-2003. *Electronic Journal of IS in of Developing Countries, 23 (5), 1-11.*

Ochara, N., Van Belle, J.P. & Brown, I (2008). Global Diffusion of the Internet XIII: Internet Diffusion in Kenya and Its Determinants. A Longitudinal Analysis. *Communications of the Association for Information Systems, 23(7), 123-150.*

OECD: Organization for Economic Cooperation and Development (2011). Telecommunications Price Basket. Retrieved June 17, 2011, from *http://www.oecd.org/document/5.*

Okello, R.M (2010). Infrastructure and Intra- African trade. Retrieved April 10, 2011 from http://www.lyciar.com/uploads/resources/Infrastructure%20and%20Intra-African%20Trade.pdf.

Qiang, C. Z., & Pitt, A. (2003). Contribution of Information and Communication Technologies to Growth. *The World Bank Working Paper, Vol: 24.*

SADC: Southern African Development Community (2010). Retrieved June 17, 2011, from http://www.sadc.int/sadc2010.

Samoilenko, S. (2008). Contributing factors to IT investment in Transition Economies, *Information Technology for Development, 14(1), 52-75.*

Samoilenko, S., & Osei-Bryon, K.M. (2008). Increasing the discriminatory power of DEA in the presence of the sample heterogeneity with cluster analysis and decision trees. *Expert Systems with Applications. 34(08), 1568-1581.*

Samoilenko, S., & Osei-Bryson, K.M. (2010). Determining source of relative inefficiency in heterogeneous samples: Methodology using Cluster Analysis, DEA and Neural Networks. *European Journal of Operation Research, 206(10), 479-487.*

Santos, S.P., Amado, C.A.F., & Rosado, J.R. (2011). Formative evaluation of electricity distribution utilities using data envelopment analysis. *Journal of the Operational Research Society, 62 (1), 1298-1319.*

Seiford, L., & Zhu, J. (1999). An investigation of returns to scale in data envelopment analysis. *Omega, 27(1), 1-11.*

UNCTAD: United Nations Conference on Trade and Development (2009). Economic Development in Africa: Strengthening Regional Economic Integration for Africa's Development. United Nation, New York.

World Bank (2010). World Bank Indicators, World Bank. Retrieved September 15, 2008, from http://data.worldbank.org/data-catalog/africa-development-indicators