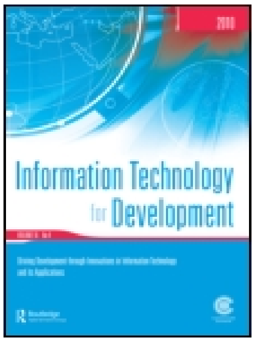

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The Impacts of Telecommunications Infrastructure and Institutional Quality on Trade Efficiency in Africa

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One of the dominant issues for Information Systems (IS) researchers in developing countries is to determine the impact of Information Communication Technology (ICT) infrastructure expansion on socio-economic development. Generating sustained socio-economic development in Africa depends largely on the ability of nations to make profitable investments and accumulate capital, which could be achieved through efficient ICT-enabled trade flows. Trade supports employment creation and improves national income levels, revenue generation, consumer price reductions and government spending. It is a key driver of African poverty alleviation, growth, economic maturity and human development. Previous research, in particular Bankole et al. [(2013a). The impact of information and communications technology infrastructure and complementary factors on intra-African trade. *Information Technology for Development*] identified the significant and positive effect of telecommunication infrastructure and institutional quality (IQ) on intra-African trade flows. As part of the ongoing research discourse on ICT for Development, the current article explores the impacts of telecommunications infrastructure and IQ on *trade efficiency* in Africa, using archival data from 28 African countries. We employed partial least squares analysis, data envelopment analysis and regression splines to analyze data. Our results suggest that IQ coupled with telecommunication infrastructure enhance efficiencies in intra-African trade flows.

Keywords: SEM; MARS; DEA; trade efficiency; telecommunications; institutional quality

1. Introduction

Generating sustained growth (socio-economic development) in Africa depends largely on the ability to make profitable investments and accumulate capital. This could be achieved through efficient trade flows, such as having access to foreign capital, investments, enlarging regional economies and promoting intra-regional trade (Busse & Hefeker, 2005; UNECA, 2010). Trade is one of the cornerstones of socio-economic development. The 2001 World Trade Organization (WTO) Doha Ministerial Declaration emphasized trade-related assistance and capacity building as core elements for development (WTO, 2001).

Trade-related capacity building is a coherent set of activities designed to improve trade performance through provision of institutional quality (IQ), human capital and infrastructural development (e.g. telecommunications infrastructure) (Mugadza, 2010). Ngwenyama and Morawczynski (2009) argue that provision of high level Information Communication Technology (ICT) investment (telecommunication infrastructure) is essential for developing countries to achieve trade integration within the global economy. The positive impact of telecommunications on economic performance in both developed and developing countries has been widely researched, but with sometimes mixed

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Marlene Holmner is the accepting Editor for this article.

results (Colecchia & Schreyer, 2002; Kuppusanmy & Santhapparay, 2005; Wang, 1999). There has been consensus among research and development communities that lack of, or inadequate levels of complementary investments in ICT and other related domains is a major reason why ICT investments do not always show impact at the macro level (Bankole, Shiraz, & Brown; 2011; Gera & Wulong, 2004; Jalava & Pohjla, 2002; Samoilenko & Osei-Bryson, 2008). None of these studies have investigated the issue of complementary impacts on intra-African trade flow efficiency. Examining efficiency is important in developing countries of Africa, where there often has to be trade-offs between investing in ICT infrastructure, versus investing in other needs such as clean water sources or basic transport infrastructure. Understanding how to improve efficiencies will help in optimizing the use of scarce resources.

The research question, therefore, posed is:

> Under what conditions and complementarities do Institutional Quality and Telecommunications Infrastructure impact on Trade Efficiency in Africa?

This paper reports on this issue in the context of ongoing research on the impact of ICT on intra-African trade. Bankole, Osei-Bryson, and Brown (2013a) demonstrated the impact of IQ and telecommunications infrastructure on intra-African trade flows. The paper builds on Bankole et al. (2013a) by offering insight into the *complementary* impacts of these capacity-building factors on trade *efficiency* in Africa. By employing the same intra-Africa trade data set of 28 African countries as with Bankole et al. (2013a), this study goes further by making use of multiple data analysis techniques, namely partial least squares (PLS) (to obtain factor scores), data envelopment analysis (DEA) (for trade efficiency) and regression splines (RS; for ascertaining the complementary impacts of telecommunication and IQ on trade efficiency). This multi-analytic approach yields superior approximations compared to previous studies that have looked into the impact of telecommunications or IQ on trade separately.

The paper is organized as follows: we discuss briefly telecommunication infrastructure in Africa in Section 2. We then discuss the concept of IQ in Section 3. In Section 4, trade and regional integration are discussed. Section 5 presents the methodology. The data used in this study are described in Section 6, and we present the conceptual framework (structural estimation) in Section 7. Data analysis and results follow in Sections 8 and 9. Some discussion and concluding remarks are offered at the end in Sections 10 and 11.

2. Telecommunication infrastructure in Africa

National telecommunications infrastructure is typically reflected by three main indicators – mobile cellular subscription rates, fixed line telephone penetration and Internet users per capita (ITU, 2013; UNECA, 2004), as well as broadband penetration. Each of these will be discussed in turn in the African context.

Mobile penetration rates in Africa increased from 0.6% to 32% between 1998 and 2008 (World Bank, 2011). The 2013 estimates show a doubling over the past 5 years to about 64% (International Telecommunication Union (ITU), 2013). Nigeria overtook South Africa as the biggest mobile market in Africa in 2008 (World Bank, 2011). In 2009, Egypt also bypassed South Africa. These three countries accounted for 39% of mobile subscriptions in Africa in 2012 (ITU, 2013).

The fixed line penetration rate in Africa was 1.3 subscribers per 100 people in 1998. This rose to 1.5 in 2007, and later fell to 1.4 in 2008 (ITU, 2009; World Bank, 2011), with an estimate of 1.3 in 2011 (ITU, 2013). The drop has been due to the greater accessibility and affordability of mobile telephony.

Internet user penetration rates averaged less than 1% across African countries in 2000, with this average jumping to 14% in 2012 (ITU, 2013). Countries which had achieved more than 30%

penetration rates by 2012 included small island states such as Seychelles, Mauritius and Cape Verde; the North African states of Morocco, Egypt and Tunisia, and regional powerhouses South Africa, Kenya and Nigeria.

Broadband Internet penetration on the continent increased from zero at the beginning of 2000 to 19 million in 2010 (World Bank, 2011). Even though, this is only about 2% relative to the population of the region, the rate of growth averaged 200% per year between 2005 and 2009. South Africa and Nigeria accounted for 80% of broadband Internet subscribers in sub-Saharan Africa (World Bank, 2011).

3. IQ in Africa

IQ is the term used to describe the quality of social structures (e.g. rule of law, corruption perception, property rights, investor protection and political systems) affecting the economic outcomes of a nation (Levchenko, 2007). For example, economies with weak institutions such as corrupt administrations will not attract capital required for economic performance (UNECA, 2010). The IQ variable has its theoretical foundations in North (1990), Shleifer and Vishny (1993), Mauro (1995), Knack and Keefer (1995). These studies have concluded that IQ is essential for socio-economic development. The new growth theory has recognized that the presence of less corruption, property rights, rule of law, and government and political stability encourages investment and ultimately improves economic growth (Rodrik, Subramanian, & Trebbi, 2004). There have been several studies that have suggested the integration of IQ into explanations of economic growth (Batuo & Fabro, 2009; Easterly & Levine, 1997). These studies have found a positive and significant impact of IQ on economic performance.

Furthermore, international organizations, research centers as well as multilateral agencies such as the International Monetary Fund (IMF), the World Bank and the United Nations (UNs) have been in the forefront of developing institutional indicators and have demonstrated causal relations between IQ and economic development (Batuo & Fabro, 2009).

In Africa, IQ is a significant determinant of disparities in economic growth especially trade performances across countries (Batuo & Fabro, 2009). Recent studies that have focused on the impact of IQ on growth in Africa have arrived at various findings as follows:

- Fosu (2001, 2006) discovered that political instability affects the economic growth of some certain African countries through the negative impact that it has on the marginal production of capital. They also find that democracy exhibits a relationship with gross domestic product (GDP) growth in Africa.
- Easterly and Levine (2003) concluded that institutional development has a positive impact on the level of per capita income in a number of former colonies in Africa.
- A study by Faruk et al. (2006) about North Africa concludes that IQ encourages positive and significant private investment in the region.

Consequently, institutional development is now acknowledged as an integral part of successful developmental strategies for trade, economic and regional integration (Batuo & Fabro, 2009).

4. Intra-African trade

In Africa, there has been a long history of trade flow and regional integration since the wave of independence in the 1960s; yet, the proportion of intra-African trade remains low when compared with developed and developing regions of the world (UNCTAD, 2009; UNECA, 2010). Trade links in Africa are oriented towards Europe (UNCTAD, 2009; UNECA, 2010, 2012). These links were inherited at independence by different countries at different times

(UNCTAD, 2009). Several African countries still produce commodities for the industries of their previous colonial powers (UNCTAD, 2009; UNECA, 2010). The continent had the lowest proportion of intra-regional trade in 2006 (UNCTAD, 2008). Both intra-African exports and intra-African imports were below 10%, far below those found in other regions of the world (UNCTAD, 2008).

South Africa is a dominant force both in terms of exports to and imports from Africa. UNECA (2010) data shows that the value of goods exported from South Africa represented 29.6% of total intra-African export trade for the period 2000–2007 (US $5.9 billion), followed by Nigeria with 15.5% of intra-African exports (US $3 billion). Other key exporters to African markets were Cote d'Ivoire and Kenya with 9.3% and 4.7%, respectively. With regard to imports, South Africa ranked as the major importer of goods from Africa accounting for 10.4% of imports, followed by Ghana (5.9%), Cote d'Ivoire (5.8%) and Nigeria (5.1%), respectively.

5. IQ, telecommunications and trade efficiency

Institutional quality and telecommunications infrastructure have been demonstrated as key influences on trade. For example, it has been shown that a thriving trade-based economy requires appropriate regulations of financial markets, a defensive rule of law, the protection of property rights and institutions that fight against corruption (Barro, 1997; Rodrik, 2000). Any country with unstable institutions, such as corruption in administration, and weak legal systems does not attract the required capital for production and export (Gyimah-Brempong, 2002; Gyimah-Brempong & Camacho, 2006; Gyimah-Brempong, Padisson, & Mituku, 2006; Gyimah-Brempong & Racine, 2010; UNECA, 2004). Shirazi, Gholami, and Higón (2010) showed a positive relationship between institutional quality and economic freedom, an indicator of trade.

Similarly, with regard to telecommunications, Demirkan et al. (2009) found that higher Internet usage was associated with greater bilateral trade flows between countries. Kurihara and Fukushima (2013) found Internet prevalence to be associated with international trade in Asia. In the context of developing countries access to the Internet was shown to improve export performance (Clarke & Wallsten, 2006). Telecommunications creates an avenue to maintain quick and effective communication with trade partners to sustain trade competitiveness.

Bankole et al. (2013a) demonstrated the impact of both IQ and telecommunications infrastructure on intra-African trade flows. In this paper, the intent is to go further by investigating the nature, condition and complementarities of the impacts of these two predictor variables on the target variable of *trade efficiency*, rather than trade per se. Trade efficiency can be defined as performance assessment used to describe the process whereby the production output is maximized in a given country, for a given set of inputs.

6. Methodology

To explore the impacts of telecommunication and IQ on the efficiency of trade flows in Africa, multiple data analytical techniques were employed. First, structural equation modelling (SEM) with PLS was conducted to establish the factors scores with respect to the impacts of IQ and telecommunications infrastructure on intra-African trade. Using these factor scores, DEA was used to establish the efficiency of intra-African trade. Finally, RS were employed to examine the conditional impacts and interaction effect of telecommunication and IQ on the efficiency of trade flows in Africa. The process is illustrated in Figures 1–3, and each of the techniques discussed in turn thereafter.

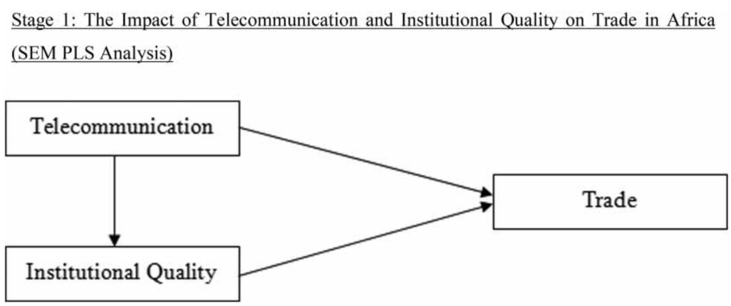

Figure 1. SEM PLS analysis.

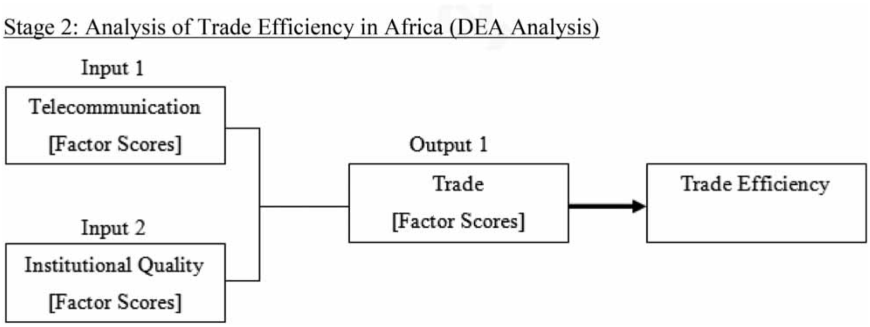

Figure 2. DEA analysis.

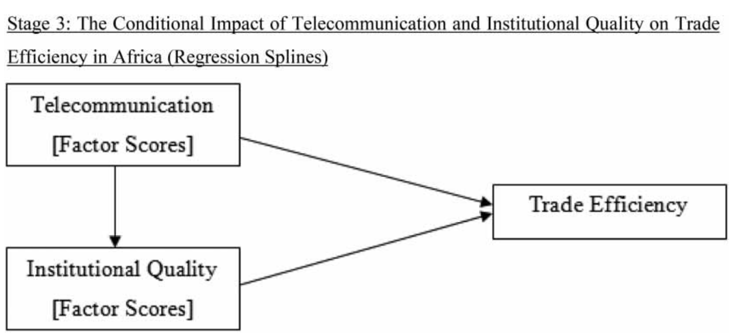

Figure 3. Regression splines analysis.

6.1. *SEM PLS*

SEM is a multi-equation regression model that extends beyond general linear modeling such as analysis of variance (ANOVA) or multiple regression analysis (Fox, 2002).

SEM has the capability to model relationships among multiple independent and dependent variables, as well as theoretical latent constructs that the observed variables might represent (Hoe, 2008). This means variables in an SEM may influence one-another reciprocally, directly or indirectly or through other variables as intermediaries (Fox, 2002). For example, the dependent variable in a regression equation in an SEM may appear as independent in another equation. This exploratory approach in SEM analysis allows for theory development and involves the repeated application of data to explore potential relationships between observed or latent variables (Urbach & Ahlemann, 2010).

The PLS-based structural equation model is a component (variance)-based SEM that is used to estimate the coefficients of structural equations with the PLS method (Morales, 2011). The SEM PLS approach consists of two iterative procedures: the use of least squares estimation for single models and multi-component models (Urbach & Ahlemann, 2010). These iterative procedures enable the minimization of the variance of the dependent variables where the cause and effect directions between the variables are defined (Chin, 1998). The advantages of SEM PLS analysis is that it allows for theory confirmation and development in the initial stages while at a later stage, it facilitates the development of propositions by exploring the relationships between variables (Chin, 1998).

6.2. *Data envelopment analysis*

DEA is a well-known non-parametric method for measuring the relative efficiencies of decision making units (DMUs) (Charnes, Cooper, & Rhodes, 1978; Farrell, 1957). A DMU refers to any entity that receives inputs and produces outputs (e.g. a bank, a university or a country). DEA is a data analysis technique that has been widely applied to the efficiency measurement of many organizations and economies (Thanassoulis, Kortelainenen, Johnes, and Johnes 2011; Sueyoshi, 1995). The main characteristics of DEA lies in its model specification, which requires that the functional similarities of the DMUs are ensured by identifying all the particular sets of inputs and outputs for all DMUs in a given sample (Samoilenko & Osei-Bryson, 2010).

DEA entails a principle of extracting information about a population of observations to evaluate efficiency with reference to an imposed efficient frontier. This process occurs when DEA calculates a discrete piecewise frontier determined by a set of referent (efficient) DMUs which are identified by the ability to utilize the same level of inputs and produce same or higher outputs (Coelli, 1996; Cooper, Seiford, & Zhu, 2011). It involves the use of linear programing to calculate a performance measure (efficiency) for each DMU relative to all the other DMUs with regard to the sole requirement that all observations lie on or below the extreme frontier (Cooper et al., 2011).

DEA was initiated by Charnes et al. (1978), following on the earlier work of Farrell (1957). Charnes et al. (1978) proposed a DEA model which assumed constant returns to scale (CRS) and subsequently Banker, Charnes, and Cooper (1984) proposed alternative assumptions known as the variable returns to scale (VRS) model.

In the CRS, an increase in input requires a proportional increase in output. This means the CRS assumption is appropriate when all the DMU's are operating at an optimal scale. While in the VRS, the relative increase may not be proportional. Regarding the assumptions (envelopment surfaces) considered, one relevant virtue of the DEA model lies in its flexibility, in that it is straightforward to estimate input/output in two common orientations: *input-oriented and output-oriented*. An input orientation involves the minimization of inputs to achieve a given level of output while an output orientation is the maximization of outputs for a given level of inputs (Cooper et al., 2011).

6.3. *Multivariate adaptive regression splines*

Multivariate adaptive regression splines (MARS) is a technique for flexible modeling of high dimensional data and for fitting both linear and nonlinear multivariate functions (Friedman, 1990). It is a non-parametric method that possesses the capabilities to characterize the existence of relationships between independent and dependent variables that are impossible for other regression methods (Balshi et al., 2009). The procedure of MARS modeling involves the separation of the parameter of independent variables into different regions where a linear relationship is used to characterize the impact of independent variables on the dependent variables within each of these regions (Balshi et al., 2009). Each point at which the slope changes between the different regions is referred to as a Knot. The set of knots in the MARS algorithm is used to generate the Basis Functions (BFs; Splines) that signify single variable transformations or multivariable interactions (Balshi et al., 2009). Hence, the MARS model obtains the form of an expansion in a spline BF so that the number of BFs and the parameters restricted to each of the knots are determined by the data (Friedman, 1990). This MARS capability entails the selection of suitable independent variables, and the elimination of the least useful variables, from the selected set, thereby building a model in a two-phase process: first forward and the second backward stepwise algorithms. The first forward algorithm preserves the knot and variable pairs that provide the best model fit, and adjusts the response by employing linear functions that are non-zero on one side of the knot (Balshi et al., 2009).

In the backward stepwise algorithm, the set of independent variables is reduced according to a residual sum of squares criterion in a reverse stepwise approach, while the optimal model is achieved based on a generalized cross-validation (GCV) measure of the mean square error (MSE) (Balshi et al., 2009; Ko & Osei-Bryson, 2006; Osei-Bryson & Ko, 2004).

A predictive model such as RS can provide better explanation (causal links, order of importance and interaction effect) for our analysis (Ko & Osei-Bryson, 2006). The use of MARS analysis in Information Systems (IS) research is not new. It has been successfully applied to explore the impacts of information technology on firm performance (see Ko & Osei-Bryson, 2006; Kositanurit, Ngwenyama, & Osei-Bryson, 2006; Osei-Bryson & Ko, 2004) and recently to investigate the impact of ICT on country-level development (Bankole, Osei-Bryson, & Brown, 2013b).

7. Description of the data

7.1. *Data sources*

The data for this study were obtained for the period 1998–2007 from several archival sources: e.g., the ITU (for telecommunications data), the World Bank (African Development Indicators and World Development Indicators) (for IQ data). The data were collected for 28 African countries available from March 2010–October 2011. The data set was validated by comparing with other credible sources such as the IMF data base and Trading Economics for consistency.

As mentioned above, the data set was compiled from the ITU, the World Bank and the UNCTAD. The data from these sources have often been used in ICT research. The ITU is one of the UN groups which have the most reliable source of data for the ICT sector. The World Bank group compiles statistical profiles for all countries in the world in a well-organized database. The World Bank data are presented in several dimensions such as the human development indices, ICT and other basic infrastructures. The UNCTAD is one of the principal organs of the UN that deals with trade, investment and other developmental issues. It was established to provide a forum for developing countries to discuss problems (formulating policies) relating to trade and economic development. The UNCTAD provides a series of data and indicators presented in multidimensional tables that illustrate new and emerging trends in the world economy covering areas such as trade, international finance, ICT, commodities and demography.

7.2. *Data explanation*

Trade: Data for import and exports were collected for all commodities (except oil and gas) for each home country and their trade partners. The exclusion of non-productive natural resources or minerals is made in an effort to avoid distortion in the data. This is intended to avoid the bias that would give resource rich countries such as Nigeria or Botswana very high competitive values in the data. South Africa is regarded as the home country in this study, while other African countries are trading partners. South Africa is chosen based on its high level of telecommunication infrastructure and trade flows on the continent. Five hundred and sixty bilateral trade flows were collected. The main effect variables reflect telecommunication infrastructure and IQ. These are as follows:

Telecommunications: The variables that represent telecommunications are: main telephone line subscribers per 100 inhabitants, Internet users per 100 inhabitants and mobile cellular subscribers per 100 inhabitants (ITU, 2013).

Institutional quality: For IQ, the following variables apply (UNECA, 2004):

- *Rule of law:* This indicates the extent to which citizens or agents have confidence in and abide by the rules of society, especially the quality of contract enforcement, the police, the courts as well as the likelihood of crime and violence. This ranks from 0–100.
- *Corruption perception:* This relates to the degree of corruption as determined by expert assessment, opinion surveys, business people and country analysts. This ranges from 0–10.
- *Democratic accountability:* This indicates the level of institutionalized democracy of a country (Soper, Dermirkan, Goul, & Louis, 2012). It is seen as being made up of three essential interdependent elements of democracy namely:

(a) The presence of institutions and procedures through which citizens can express effective preferences about alternative policies and leaders.
(b) The existence of institutionalized constraints on the exercise of power by the executive.
(c) The guarantee of civil liberties to all citizens in their daily lives in acts of political participation.

- *Bureaucratic quality:* This is a measure of government effectiveness in terms of quality of the civil service, its protection from political pressure, the quality of policy formulation and implementation and the credibility of the government's commitment to such policies.
- *Government stability*: This indicates the political stability of a country. It measures the degree of absence of violence or the perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent ways (domestic or terrorism).

8. Data analysis

In this section, we discuss the procedures observed in the process of data analysis as follows:

8.1. *First step: SEM PLS*

We developed a conceptual model through SEM-based PLS. Satisfactory model fit was achieved (the conditions for a model fit assessment require that the p-values for both average path coefficient (APC) and average R-squared (ARS) be lower than 0.05, while the average variance inflation factor (AVIF) must be lower than 5 (Kock, 2010)). The model is presented in Figure 4.

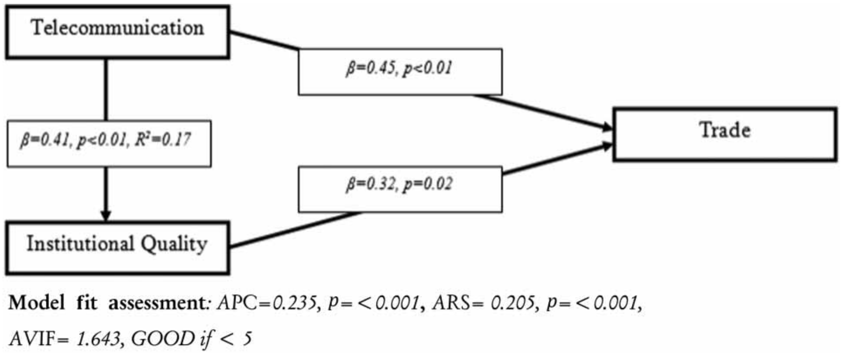

Figure 4. Structural model (PLS path analysis).

The model shows that that both telecommunications and institutional quality have positive statistically significant impacts on trade in Africa.

8.2. *Second step: DEA*

The second step in our approach is the use of DEA. We employed DEA to compute the impact of both telecommunication and IQ on trade efficiency in Africa. Trade efficiency is the ratio of the actual to the potential trade flow for each observation (Drysdale, Huang, & Kalirajan, 2000). We, therefore, followed the popular notion of technical efficiency (TE; the effectiveness with which a given set of inputs is used to produce an output) in production economics using the DEA approach (Farrell, 1957). Our focus in this article is on the basic DEA model for measuring the efficiency of a DMU relative to similar DMUs in order to estimate a best practice frontier.

We employ an input-oriented DEA model under the envelopment surface (assumption) of VRS. Since the African countries in our analysis are not operating at the optimal scale, the use of the VRS assumption will allow the calculation of TE devoid of scale efficiency (SE) effects. SE is the ratio of the distance function satisfying CRS to the distance function restricted to satisfy VRS (Fare et al., 1994).

We utilize transformed factor scores (latent variable score) (see Brockett, Charnes, Cooper, Huang, & Sun, 1997) generated from PLS analysis to compute efficiency scores using MAXDEA 5.2 software. These factors scores were calculated from PLS based on a least squares minimization sub-algorithm where path coefficients were being estimated in a robust path analysis algorithm (Kock, 2010). Our choice of using this approach is grounded on the guidelines for using variable selection techniques in DEA that is based on regression-tests developed by Ruggiero (2005). This regression-based test suggests that a variable selection procedure in which an initial measure of efficiency is attained from known production variables. Such efficiency could, therefore, be regressed against a set of candidate variables provided their coefficients in the regression are statistically significant (e.g. the coefficients values should be positively significant for inputs or negatively significant for outputs). This means these variables are relevant to the production process and the analysis is then repeated while identifying one variable at a time until there are no further variables with significant and correctly signed coefficients (Nataraja & Johnson, 2011). The regression-based test approach also allows for a three or two input and one output production process and performs effectively under low correlation (e.g. <0.2) and larger data sets (e.g. >200) (Nataraja & Johnson, 2011). The factor scores of telecommunication and IQ are the input variables while the factor scores of trade are the output variables. These are presented in Table 1.

Table 1. DEA variables.

Input variable	Output variable
Telecommunications, institutional quality	Trade

8.3. *Third step: RS*

With regard to the theory by Ruggiero (2005) and Nataraja and Johnson (2011) described in the first procedure, we performed a regression splines analysis utilizing Salford System's MARS Software 6.6. to generate a MARS model where the transformed factor scores of telecommunications and IQ are the predictors, while the efficiency of trade flows (generated from DEA analysis) is the target variable. The MARS analysis involves two phases: forward and backward. In the *forward phase,* BFs were added to allow the model to become flexible and complex, and terminating when the specified number of BFs was achieved, in the *backward phase* BFs are deleted in order of least contribution to the model until an Optimal model is found based on a GCV. For this reason, the forward phase model was set to 16 maximum BFS and 50 observations between knots and allowed for two-way interaction. This provided more opportunities for the MARS algorithm to learn during the iteration process. The results of this final step are reported in the next section.

9. Results

In this section, we explain the results of the regression splines analysis. The R^2 for the regression splines model is 0.731 (Adj $R^2 = 0.737$) (as in Table 4). This suggests that the MARS model can explain 73% of the variation of the target variable (i.e. TE). It is a much stronger model that allows for more explanation of the predictors of TE. The data in Table 2 are obtained using the BFs that include the relevant variables. The reader will notice that both telecommunications (as measured by *TELECOMS)* and institutional quality (as measured by *IQ)* impact efficiency of trade flows in two and three different regions, respectively, in the model.

The Table 3 provides the order of importance of the predictive variables in the generated regression splines model. IQ is the most important predictor with a relative score of 100%, followed by TELECOMS with relative score of 76.5%. To demonstrate the nature, condition and complementarities of the impacts of the predictor variables (*IQ and TELECOMS*) on the target variable (*efficiency of trade flows*), the detailed analysis of the direction of the impacts are presented in Table 4. The results in Table 4 suggests that for IQ to have a positive statistically significant impact on trade efficiency, depending on the value of IQ, there could be a *lower bound* on the level of TELECOM investments (e.g. Positive if TELECOMS > 2.70298) or an *upper bound* on the level of TELECOM investments (e.g. Positive if TELECOMS < 0.418161). This shows that IQ will not impact trade efficiency without some level of TELECOMS infrastructure investments.

Table 2. Basis functions (BFs) of MARS model (trade efficiency).

BF	Coefficient	Variable	Expression
1	1.59259	IQ	Max(0, IQ-0.789552)
2	1.15696	IQ	Max(0, 0.789552-IQ)
4	0.63227	TELECOMS	Max(0, 0.418161-TELECOMS)
5	−1.62354	IQ	Max(0, IQ-0.725677)*Max(0, TELECOMS-0.418161)
7	−0.89277	TELECOMS	Max(0, TELECOMS-2.70298)*Max(0,0.789552-IQ)

Table 3. Relative importance of variables (trade efficiency).

Variable	Importance
IQ	100.000
TELECOMS	76.472

Table 4. Regression splines (trade efficiency).

Variable	Interval	BFs	Impact expression	Direction of impact
TELECOMS	≤0.418161	BF4	0.63227*(0.418161-TELECOMS)	*Negative*
	(0.418161,2.70298)	BF5	−1.62354*Max(0,IQ-0.725677)*Max(0, TELECOMS-0.418161)	*Negative* if IQ > 0.725677 None otherwise
	>2.70298	BF7	−0.89277*Max(0,0.789552-IQ)*Max(0, TELECOMS-2.70298)	*Negative* if IQ > 0.725677 or IQ < 0.789552
		BF5	−1.62354*Max(0, IQ-0.725677)*Max(0, TELECOMS-0.418161)	
IQ	≤0.789552	BF2	1.15696*Max(0.789552-IQ)	*Positive if* TELECOMS > 2.70298 + (1.15696/0.89277) *Negative* otherwise
		BF7	−0.89277*Max(0,0.789552-IQ)*Max(0,TELECOMS-2.70298)	
	(0.725677,0.789552)	BF2	1.15696*Max (0,0.789552-IQ)	*Negative* since (−1.15696 + 0.89277)*Max(0, TELECOMS-2.70298) −1.62354*Max(0, TELECOMS-0.418161)<0
		BF7	−0.89277*Max(0,0.789552-IQ)*Max(0,TELECOMS-2.70298)	
		BF5	−1.62354*Max(0, IQ-0.725677)*Max(0,TELECOMS-0.418161)	
	>0.789552	BF1	1.59259*Max(0, IQ-0.789552)	*Positive if* TELECOMS < 0.418161
		BF7	−0.89277*Max(0,0.789552-IQ)*Max(0, TELECOMS-2.70298)	
		BF5	−1.62354*Max(0, IQ-0.725677)*Max(0, TELECOMS-0.418161)	
$R^2 = 0.737$ Adj $R^2 = 0.731$				

10. Discussion and implications

IQ is of prime importance to enhancing trade efficiencies in Africa. Strong commitment to the rule of law, the elimination of corruption, democratic accountability, bureaucratic sophistication and political stability are necessary to improve efficiencies in intra-African trade. Telecommunications infrastructure is also important to this endeavor – such infrastructure can enhance transparency, efficiency and effectiveness in institutional and trade activities, resulting in further improvements in trade efficiency.

The multiple data analytical techniques employed here offer insight into the conditionality and directionality of the impacts of IQ and telecommunications infrastructure on trade efficiency. It is shown that there needs to be careful consideration by governments about how much investment in telecommunications infrastructure is needed to yield positive effects on trade efficiencies, under certain conditions of IQ. For instance insufficient telecommunications infrastructure can have a negative effect on trade efficiency. Similarly there is a negative effect where, for example, the available telecommunication infrastructure is above a certain threshold, but IQ is low. For there to be a positive effect on trade efficiency requires the right balance and complementarities between IQ and telecommunications infrastructure.

11. Conclusion

This paper is part of the rapidly growing theoretical and empirical literature on the impacts of ICT on development in Africa. It focuses specifically on the interaction of telecommunications and IQ on trade efficiency within African countries. It hence goes further than Bankole et al. (2013a) who identified simply the impact of telecommunications and IQ on trade flows. This study is a first attempt to directly investigate how telecommunication and IQ *in complement* impact trade *efficiency* in Africa. We moved away from traditional trade theory, to employ a new theoretical framework that could be used to explore the impact of telecommunications on trade efficiency flows in Africa. Our analysis suggests that the conditions for successful translation of IQ to produce efficiency of trade flows require some degree of telecommunication infrastructure investments. These conclusions provide important implications for the agenda of institutional reform to promote the effective use of telecommunication for trade facilitation, growth and development. The provision of telecommunication infrastructure and other development assistance is more effective in countries with good IQ. Finally, this research provides insight into telecommunication investments that can complement good governance to support socio-economic development of African countries.

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