Economics Bulletin

Volume 40, Issue 2

Information and Communication Technology and Intra-Regional Trade in the Economic Community of West African States: Ambivalent or Complementary?

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Abstract

This paper analyzes the effect of Information and Communication Technology (ICT) on intra-regional trade in the Economic Community of West African States (ECOWAS) over the period 1994 to 2014. We use an augmented gravity model which controls for bilateral, exporter-year and importer-year fixed effects. To carry out our estimations, data is obtained from the World Bank, the United Nations Conference on Trade and Development as well as the Center for Prospective Studies and International Information (CEPII). The main findings suggest: (i) the presence of both the bilateral and export-year fixed effects; (2) the aggregate ICT index related significantly with intra-regional trade only for importing counties for the Fixed Effect (FE), Random Effect (RE) and Hausman-Taylor (HT) estimates unlike the Poisson pseudo maximum likelihood (PPML) estimates which shows a negative and significant relationship for the exporting country and a positive and significant for the importing country; (3) disaggregated results for the ICT variable-internet mimics those for the aggregate ICT index whereas finding for mobile phone and fix phones rather suggest that the relationship between the ICT and intra-regional trade was positive for both exporting and importing countries. As policy suggestion, we purport that investing in ICT infrastructure that particularly encourage the usage of mobile and fixed phones encourage intra-regional trade for both exporting and importing countries.

Citation: Boniface Ngah Epo and Ronie Bertrand Nguenkwe, (2020) "Information and Communication Technology and Intra-Regional Trade in the Economic Community of West African States: Ambivalent or Complementary?", *Economics Bulletin*, Volume 40, Issue 2, pages 1397-1412
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Submitted: December 20, 2019. **Published:** May 19, 2020.

Introduction

Regional Economic Communities (RECs) in Africa report slow rates of integration, in spite of indicating their willingness to implement custom unions, with additional advancements expected towards common market principles. The Economic Community of West African States (ECOWAS) is one of the eight RECs in Africa with a high intensity for trade creation (Musila 2005). Unfortunately, countries of ECOWAS trade little among themselves despite the acknowledgement that intra-regional trade could help accelerate economic growth and prosperity in Africa (Commission Economique d'Afrique [CEA] 2012) and stimulate productive capacity and competitiveness by enabling domestic industries through intra-regional competition (United Nations Economic Commission for Africa [UNECA], 2010).

Intra-regional trade constitutes a key pillar in promoting regional integration in African (Bankole et al. 2015a; 2015b; United Nations Conference on Trade and Development [UNCTAD] 2009; UNECA 2012). An analysis of intra-regional trade for the different RECs report varying results in spite of an increase in the volume of trading between African countries by about four percent between 1995 and 2015. Over the same period, intra-regional trade decreased by less than a percentage point in the West African Economic and Monetary Union (WAEMU), 0.27% in the Economic Community Central African States (ECCAS) and by a percentage point for the ECOWAS. On the contrary, it witnessed an increase of a percentage point in the East African Community (EAC), five percentage points in the Common Market for Eastern and Southern Africa (COMESA), four percent in the South African Development Community (SADC) (United Nations Conference on Trade and Development 2016).

The evolution of intra-regional trade in Africa has been documented by several authors (Ngepah and Udeagha 2019; 2018; UNECA 2010; 2012; World Trade Organization [WTO] 2008). Concerning the ECOWAS, we find very limited studies evaluating the impact of trade liberalization on intra-regional trade (Shuaibu 2015). Other studies include Arawomo and Badejo (2015) investigating the role of agriculture on intra-ECOWAS trade; (Akpan 2014) studying how regional road infrastructure relates to intra-regional trade; Musila (2005) appraising the intensity of trade creation and diversion within ECOWAS or Ngepah and Udeagha (2019) studying issues on multi-membership and imports. Nonetheless, very few or no studies investigate the effect of ICT on intra-regional trade in the ECOWAS as suggested in this manuscript.

Indeed, the role of infrastructure in general and telecommunication in particular is recognized as one of the three main dimensions of the Trade Competitiveness Index (TCI) within then the New Partnership for Africa's Development and the UNECA framework (Chikhasu 2007; UNECA 2004, 2006). Infrastructures like ICT are expected to stimulate growth and boost regional integration (Bhattacharyay 2009; Bankole et al. 2015a; 2015b) because they improve returns on private factors of production.

Bollou (2010) purports that the use of ICT infrastructure in consolidating development has witnessed an increase over the past few decades. One of the main outcomes has been the growing role of ICT in enabling integration of financial markets among groups of countries (World Trade Organization [WTO], 2008) and intra-regional trade (Christodoulopoulou et al. 2006). In this regard, Africa has reported an increase in the levels of investments in mobile network infrastructure (UNECA 2010). In 2013, about 65% of the total population where telephone (fixed and mobile) subscribers (International Telecommunication Union [ITU] 2009; 2013; World Bank, 2011).

Nonetheless, whereas ICT are growingly recognized as driving factors of economic growth and trade, Africa in general and the ECOWAS post low levels of ICT development. For instance, the

2017 ICT development index (IDI) reports that whereas South Africa (92nd) registered the highest IDI ranking with a value of five, Eritrea (176th) reported the lowest ranking with an IDI value less than one. For countries in the ECOWAS, Ghana (116th) was ranked first and Guinea-Bissau (173rd) ranked last (United Nation 2017).

The role of ICTs on cross-border trade is crucial in improving transparency in trade transactions, ameliorating coordination between the different actors in the trade management process and enhancing information and knowledge about trade processes and markets (Enock et al. 2012). Some studies investigating the role of ICT include the studies by Freund and Weinhold (2002) on the impact of internet on trade, Djankov et al. (2006) on the effect of time on trade as well as Limao and Venables (2001) on the role of efficient infrastructure on bilateral trade. Unfortunately, it appears very few or no studies investigates the role of ICT on intra-regional trade in the ECOWAS which is one of the most diverse and largest RECs in Africa in terms of population and number of countries.
In this regard, we contribute to empirical literature by investigating the effect of ICTs on intra-regional trade in the ECOWAS. This paper seeks to answer the research question: what is the effect of ICTs on intra-regional trade in the ECOWAS. The main objective is therefore to analyze the impact of ICTs on intra-regional trade in the ECOWAS using the gravity model that accounts for endogenous prices and unobserved time-varying exporter and importer multilateral heterogeneity and the country-pair fixed effects or bilateral effects (Bergstrand et al. 2015).

We organize the rest of the paper as follows: section two presents some stylized facts on ICTs and intra-and-inter-regional trade in the ECOWAS. Section three the literature review. Section four outlines the methodology and section five the empirical results. We then conclude the paper in section six.

2. Stylized facts on ICT penetration and intra-regional trade

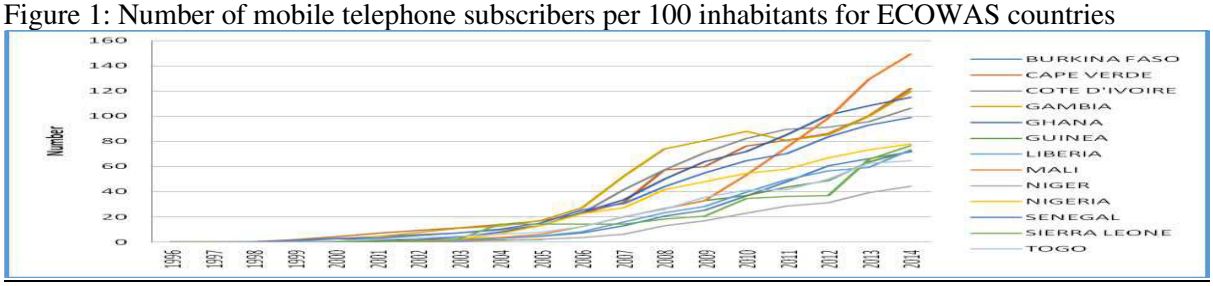
In this section, we present ICT penetration (Section 2.1) and the evolution of intra-regional trade (Section 2.2) in the ECOWAS. Subsequently, we first present the evolution of the number of telephone lines, mobile phone subscribers and internet users in the ECOWAS over the period under review. After this, we present the evolution of intra-and inter-regional trade for the ECOWAS over the same period.

2.1. Evolution of ICT indicators in the ECOWAS

An appraisal of the evolution of some ICT indicators report that whereas mobile telephones and access to internet registered some ameliorations over the period 1996 to 2014, fixed lines in countries of the ECOWAS reported no significant evolution, averaging at about two fixed telephone lines per 100 inhabitants. The only exception to this trend was Cape Verde revealing and increase from six telephone lines per 100 inhabitants in 1996 to eleven telephone lines for 100 inhabitants in 2014 (World Bank 2017).

Concerning the number of mobile telephone subscribers, Figure 1 indicates that over the period 1996-2014, the average for the ECOWAS was 26. For all countries of the ECOWAS, we observe a significant increasing trend since the year 2005. From 2009, all countries of the ECOWAS reported at least 20 mobile telephone subscribers per 100 inhabitants. In 2014, countries like Mali, Cape Verde and Gambia reported more than 100 mobile telephone subscribers per 100 inhabitants.

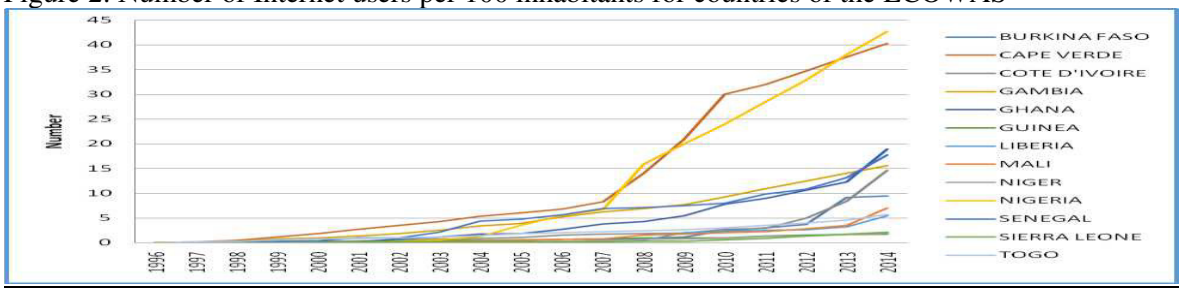
Figure 1: Number of mobile telephone subscribers per 100 inhabitants for ECOWAS countries



Source: Computed by the authors from World Development Indicators (2017).

Figure 2 shows the evolution of the number of internet users per 100 inhabitants over the period 1996 to 2014. On average, the number of internet users was four out of every 100 inhabitants. Despite countries in the ECOWAS experiencing an increase in the number of internet users per 100 inhabitants since 2012, this number is still averaged at less than 20 internet users per 100 inhabitants. The only countries that have reported a stiff and steady rise in number of internet users per 100 inhabitants since 2007 were Cape Verde and Nigeria.

Figure 2: Number of Internet users per 100 inhabitants for countries of the ECOWAS

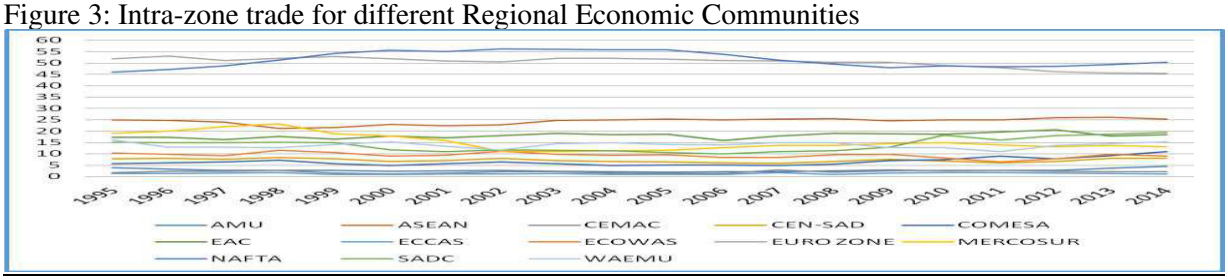


Source: Computed by the authors from World Development Indicators (2017).

2.2. Evolution of intra-and inter-regional trade in the ECOWAS

Over the period 1995 to 2014, between 45 to 50% of total trade for the NAFTA and Euro zones was intra-regional (Figure 3). This value was about five time the value for intra-regional trade in the ECOWAS (8.9%). Looking at other RECs in Africa, the SADC (19%), EAC (18%) and the WAEMU (15.3%) posted the highest percentages of intra-regional trade between 1996 and 2014.

Figure 3: Intra-zone trade for different Regional Economic Communities



Source: Computed by the authors using data from UNCTAD statistics (2016).

Concerning inter-regional trade, Table 1 reports the percentage of total exports to the ECOWAS from other RECs in Africa over the period 1995 to 2014. The South African Development Community and the Economic Community of Central African States (ECCAS) are the main African RECs exporting to the ECOWAS. However, the SADC registered a fall in exports from 27% in 1995 to three percent points in 2014. The ECCAS values averaged around 11% except for the 2010 which recorded significant fall in the percentage of exports to the ECOWAS. For the Arab Maghreb Union, we observe a doubling of exports to the ECOWAS from about three

percent in 1995 to seven percent in 2014. Regarding the East African Community, exports to ECOWAS still remain very marginal and less than a percentage point of her total exports. These findings are similar to Ngepah and Udeagha (2018) who find that regional trade agreements enhance trade in sub-Saharan Africa albeit a small but significant share of the benefits occurred over time in the West African Economic and Monetary Union.

Table 1: Exports from other RECs in Africa to the ECOWAS (% of total exports)

	Economic Community of West African States				
Year	1995	2000	2005	2010	2014
Economic Community of Central African States	11.05	10.87	12.68	3.53	9.33
Arab Maghreb Union	3.67	2.48	3.30	7.08	6.77
East African Community	0.34	0.43	0.91	0.35	0.79
South African Development Community	27.85	13.30	8.06	14.76	2.89

Source: Authors calculation compiled from UNCTAD statistics (2016).

3. Literature review

A review of the empirical literature reveal that several studies find a positive impact of ICTs in promoting multilateral and bilateral trade. Liu and Nath (2013) highlight the positive effect of ICT on trade for 40 emerging economies. Clarke and Wallsten (2006) show that internet access increase exports from developing countries to developed countries using data from 98 countries. Vemuri and Siddiqi (2009) conclude that ICT infrastructures and the availability of the internet for commercial transactions have a positive and significant effect on the volume of international trade using a panel of 64 countries. Rodriguez-Crespo and Martínez-Zarzoso (2019) show that internet use increases trade and also that countries trade more if similar levels of ICT usage are coupled with comparable degrees of product complexity in the trading countries. Other authors construct synthetic indicators to capture the composite effect of ICT using data analysis techniques and find a positive relationship between ICT utilizations and trade (Limao and Venables 2001; Agbodji 2005; Mattes et al. 2012).

Recent empirical findings corroborate the important role of ICT, perceived as a composite indicator, in understanding trade. Nath and Liu (2017) constructed an ICT development index capturing access, use and skill aspects of technology. Their result reveal that ICT usage is more important than access and skills for trade in a number of services in international trade. Juhász and Steinwender (2018), examine how ICT improvements affect trade along the value chain and international technology diffusion. They find that connection to the telegraph disproportionately increased trade in intermediate goods relative to final goods.

In terms of bilateral trade, Freund and Weinhold (2002) show that the development of the Internet in partner countries has had a positive and significant impact on bilateral trade with the US. Fink et al. (2005) also find a significant positive effect of the cost of communication on bilateral trade. On the role of ICTs on trade in services, Nath and Liu (2013) show that the development of ICT has a positive and significant impact on exports and imports of transport services, travel and on other commercial services for 49 developing countries. Choi (2010) highlights the positive effect of ICT use on trade in services on a sample of 151 countries over the period 1990-2006. Xing (2017) examines the impact of internet and E-commerce adoption on bilateral trade flows using a panel of developing and least-developed and OECD countries. Their results reveal that better access to modern ICT and adoption of e-commerce applications stimulate bilateral trade flows at various levels.

Considering the effects of ICT on intra-regional trade, most studies imply a positive relationship. For instance, Yutaka and Akio (2013) find that the level of internet penetration has a positive effect on international trade in Asian developing countries, but has no effect on economic growth.

Mattes et al. (2012) construct an ICT indicator and show that the development of ICT has a positive and significant impact on EU trade. For the Association of Southeast Asian Nations (ASEAN) economic community, Bhattacharyay (2009) shows that infrastructure (transport, energy and ICT) strengthens intra-regional trade. Biryukoval and Matiukhina (2018) argued that the policies aimed at promoting investment and enhancing conditions for trade in ICT services contributed significantly to the expansion of export services in the BRICS countries.

Reviewing literature on current methodologies in international trade highlight the growing use of the gravity model. Current examples include areas such as the role of regional trade agreements on regional trade (Limao 2006: Ethier 1998; Ngepah and Udeagha 2019), institutional weakness and trade performance (Anderson and Marcouiller 2002), trade facilitation and bilateral trade (Djankov et al. 2006) as well as landlocked countries and trade performance (Raballand 2003; Moïse and Sorescu 2013). Nonetheless, only few studies apply the gravity model to investigate the effects of ICTs on intra-regional trade (Lin 2015; Portugal-Perez and Wilson 2010; Martinez-Zarzoso and Márquez-Ramos 2008; Bergstrand et al., 2015).

For Africa, very limited studies investigate the effect of telecommunication infrastructure on intra-regional trade. Bankole et al. (2015a) use a structural equation modeling with partial least squares to investigate the effect of ICT on trade using 28 countries in SSA. They find that telecommunications infrastructure has a major impact on intra-African trade. In another study, they indicate that institutional quality coupled with telecommunication infrastructure enhance efficiencies in intra-African trade flows using the partial least squares analysis, data envelopment analysis and regression splines (Bankole et al. 2015b). It emerges from the review literature that almost no or very few studies have been conducted on the impact of ICTs on intra-regional trade in the ECOWAS using the gravity model as we suggest in this paper. Contributing to empirical literature, this paper therefore seeks to help bridge this gap.

4. Methodology and data

To compute the impact of ICT on intra-regional trade in the ECOWAS region we opt to adopt the gravity model. Simply put, the gravity model argues that export (trade) or the movement of goods and services between two countries (country-i and country-j) depend on their economic masses (or GDP) and negatively relate to both trade cost and the distance between the two trading countries using the functional form of Newtonian gravity. Since the pioneering work of Tinbergen (1962) the gravity model has been largely used in analyzing aspects of international trade and the impact of a variety of policy issues related to regional trading groups. Considering bilateral trade between country-i and country-j, the gravity model of bilateral trade is expressed as:

$$X_{ij} = \alpha_0 Y_i^{\alpha_1} Y_j^{\alpha_2} D_{ij}^{\alpha_3} \mu_{ij} \quad (1)$$

where X_{ij} is the value of bilateral exports from country-i to country-j, Y_i and Y_j the Gross Domestic Product (GDP) for the exporting and importing countries and acts as a proxy for their respective economic masses and D_{ij} the distance between country-i and country-j. $\alpha_i (i = 0,1,2,3)$ are unknown parameters to be estimated and μ_{ij} is the disturbance term.

The theoretical underpinning of the gravity model gained momentum with the initial works of Anderson (1979). He suggests a gravity equation based on a demand function with constant elasticity of substitution and which is consistent with a simple Armington model. Thereon, other studies based on Armingtons' structure of consumer preference include Krugman's (1980) monopolistic framework, Deardorff (1998) model *à la* Heckscher-Ohlin or the model by Eaton and Kortum (2002) that hinges on the Ricardian comparative advantage theory. Recently, the study by Anderson and Van Wincoop (2004) contribute in showing how to deal with differences

in country sizes. Other current theoretical contributions include the study by Bernard et al. (2007) which incorporates questions of firm heterogeneity in modeling international trade. More recently, Bergstrand et al (2015) suggest an econometric specification which addresses the (partial) effects on trade of economic integration agreements, national borders, and bilateral distance. This specification controls for the presence of potential upwards bias owing to inadequate control for time-varying exogenous unobservable country-pair-specific changes in bilateral export costs; (b) endogeneity and unobserved country-pair heterogeneity in initial levels associated with agreements and (c) bias associated with distance.

4.1. The Econometric model

In this paper, the theoretical specification of our empirical model is inspired from studies which adopt the gravity model to investigate the role of ICT on trade (Lin, 2015; Portugal-Perez and Wilson, 2010; Martínez-Zarzoso and Márquez-Ramos, 2008). The econometric estimations use the specification framework by Bergstrand et al (2015) which controls for bilateral, exporter-year and importer-year fixed effects. Gauging for these effects, enable us to account for endogenous prices and unobserved time-varying exporter and importer multilateral heterogeneity and the country-pair fixed effects or bilateral effects. We further justify this consideration because the exporter(importer) effects measure the general openness of a country with respect to its partner countries included in the sample. The bilateral effect accounts for any time invariant geographical, historical, political, cultural and other bilateral influences which lead to deviations from a country pair "normal propensity" to trade. In our empirical model, we include variables associated with geographical, historical, cultural factors of the region as well as others linked with trade openness as outlined in equation two below.
We thereon specify the log-log econometric linear model which investigate the effect of ICT on intra-regional trade by augmenting the standard gravity model as follows:

$$\begin{aligned} LogEXP_{ijt} &= \delta_{it} + \lambda_{jt} + \eta_{ij} + \alpha_1 LogGDP_{it} + \alpha_2 LogGDP_{jt} + \alpha_3 LogDIST_{ij} + \alpha_4 LogPOP_{it} \\ &+ \alpha_5 LogPOP_{jt} + \alpha_6 COL_{ij} + \alpha_7 LANG_{ij} + \alpha_8 BORD_{ij} + \alpha_9 CUR_{ij} + \alpha_{10} LLOCK_{ij} + \\ &\alpha_{11} LogICT_{it} + \alpha_{12} LogICT_{jt} + \varepsilon_{ijt} \end{aligned} \quad (2)$$

where EXP_{ijt} represents bilateral cost of exports between country-i and country-j at time t. GDP_{it} and GDP_{jt} are the gross domestic product of the exporting country (i) and the importing country (j) at time t. $DIST_{ij}$ the distance between the capitals of the exporting country (i) and the importing country (j). POP_{it} and POP_{jt} represent the total populations of the exporting and importing countries at time t. COL_{ij}, $LANG_{ij}$, $BORD_{ij}$, CUR_{ij} are a dummy variables which take the value 1 when the exporting and importing countries were colonized by the same colonial masters (COL_{ij}), speak the same official language ($LANG_{ij}$), share a common border ($BORD_{ij}$) or use a common currency (CUR_{ij}) and 0 when otherwise. $LLOCK_{ij}$ is a dummy variable which takes the value 1 when the exporting country is landlocked and 0 when otherwise. ICT_{it} and ICT_{jt} are the ICT variables for the exporting and importing countries at time t. δ_{it} captures all time-varying multilateral factors of the exporting country (i) ; λ_{jt} show all time-varying multilateral factors of the importing country (j) ; η_{ij} indicates the time-invariant country-pair fixed effects that captures all time-invariant factors that might otherwise be picked up by economic integration agreement (Bergstrand et al., 2015) and ε_{ijt} is an *iid* stochastic error term.

4.2. Estimation methods

Estimation techniques associated with the gravity model requires using complex panel dataset. A number of estimation techniques such as the pooled Ordinary Least Square (OLS), the Fixed

Effects (FE) and the Random Effects (RE) techniques are used to analyze panel datasets. Nonetheless, the assumption that unobserved individual effects are uncorrelated with all the regressors associated with such techniques is convincingly rejected in almost all studies.

The FE estimation technique is the most widely used estimation method to avoid potentially biased estimations, especially when strong structural assumptions on the underlying model are not required and the results yield consistent estimates of the fixed effect components (Head and Mayer 2013; Cheng and Wall 2005). Nonetheless, two main limitations are associated with the FE estimation technique. They are: (1) FE does not work for constant variables across time, as these are ruled out by the averaging within transformation and (2) inferences made by the FE estimator is more sensitive to non-normality and heteroskedasticity and (3) serial correlation in the idiosyncratic errors exist (Wooldridge 2012).

The RE estimation method also appears to be inconsistent due to correlation between some of the explanatory variables with the unobserved individual effects. The multidimensional nature of the datasets suggests we choose an estimation method that take into account the specific effects for the set of unobservable characteristics in order to eliminate the source of bias present in OLS estimations.

The simplest solution to address the correlation between specific effects and explanatory variables is to eliminate the specific effect using for example, the first-difference estimator (Sevestre 2002). Yet, these transformations do not make it possible to estimate the impact of an invariant over time explanatory variable. To eliminate this ambiguity, we use the Hausman and Taylor (1981) estimator which allows us to test the exogeneity hypothesis of the specific individual effects (Serlenga and Shin 2007; Brun et al. 2002; Egger 2002 and Gardner 1998).
Two other potential estimating problem arise when analyzing trade flow. They include: (a) the bias triggered by the logarithmic form of the gravity equation in case of heteroskedasticity in the error term and (b) the presence of zero trade flows between exporting and importing countries. To solution these shortcomings, we use the Poisson pseudo maximum likelihood estimator (PPML) which corrects for both estimation problems (Santos and Tenreyro 2011; 2006; Westurlund and Wilhelmsson 2011). Santos and Tenreyro (2006) show that the PPML performance satisfactory even in the presence of measurement errors. Gourieroux et al. (1984) suggest that PPLM estimation procedure is easy to implement and robust to misspecifications.
In the next section on empirical results, we report results for the Fixed Effect (FE), the Random Effect (RE), the Hausman-Taylor (HT) and the Poisson pseudo maximum likelihood (PPML) estimations.

4.3. Data

To construct our panel data set over the period 1995 to 2014, we exploit three different data sets. Bilateral exports are constructed using data gotten from the United Nations Conference on Trade and Development (UNCTAD, 2016) data base. Data on GDP, population and the different ICT variables (number of internet users per 100 inhabitants, number of mobile telephone subscribers per 100 inhabitants and number fixed telephone lines per 100 inhabitants) are gotten from the 2017 World Development Indicators (World Bank, 2017). We use the Geodist data from the Center for Prospective Studies and International Information (CEPII) to derive data on colonial history, currency, language, country border information, distance and for landlocked countries.

Regarding the composite indicator for ICT, we use the Principal Component Analysis (PCA) technique to construct a composite indicator for ITC which englobes the variables internet users, mobile phone subscribers and fixed line users as suggested by Portugal-Perez and Wilson (2010). The first factorial axis of the PCA technique explains more than 61% of the total information on

the combined effects of the three different ICT variables. Information on the total variance of the composite ICT indicator is reported in Table A1 in the Appendix.

5. Empirical Results

5.1. Descriptive analysis

Table 2 post descriptive statistics for the variables used in this study. Average cost of exports among countries within the ECOWAS was 35,868 dollars US. The mean distance between the capitals of trading countries was 1,355 kilometers. On average, four out of 100 inhabitants reported they have access to internet. Twenty six out of a hundred inhabitants had access to mobile phones and just two inhabitants per one hundred indicated they had access to fixed telephones lines. The aggregate ICT indicator report that thirteen out of 100 inhabitants used simultaneously all three ICT indicators. For the variables associated to language, colonial heritage and currency we comment on proportions to transcribe a more accurate picture. Among the thirteen countries used for this study, 61% have the same colonial master (France), use French as their official language and the XOF Franc as common currency. These eight countries make up the West African Economic and Monetary Union. Forty-six percent of the countries have English as their official language and only one country uses Portugal as her official language (Ginea-Bissau).

Table 2: Descriptive statistics

Variables	Observations	Mean	Standard Deviation	Min.	Max.
Cost of exports from exporting to importing countries (US dollars)	2,964	35867.9	149944.6	0	2644900
Gross Domestic Product (GDP) for each country (US dollars)	2,964	$2.04*10^{10}$	$6.93*10^{10}$	$1.59*10^{8}$	$5.68*10^{11}$
Population	2,964	$1.99*10^{7}$	$3.61*10^{7}$	$3.99*10^{5}$	$1.77*10^{8}$
Distance between capitals of exporting and importing (in km)	2,964	1355.4	713.97	155.9	3395.5
Number of internet users per 100 inhabitants	2,964	3.828	7.410	0	42.68
Number of mobile telephone subscribers per 100 inhabitants	2,964	26.66	33.13	0	149.1
Number fixed telephone lines per 100 inhabitants	2,964	1.910	3.428	0	15.36
Aggregate ICT indicator	2,964	0.132	0.195	0	1
Countries trading speak the same official language	2,964	0.398	0.489	0	1
Exporting country (origin) is landlocked	2,964	0.231	0.421	0	1
Countries trading use a common currency	2,964	0.193	0.394	0	1
Countries trading have the same colonial masters	2,964	0.353	0.478	0	1
Countries trading share the same border	2,964	0.244	0.429	0	1

Source: Authors calculations using data from the WDI statistics (2017), UNCTAD statistics (2016) and the CEPII.

5.2. Empirical results

Table three reports estimations for the composite ICT index constructed using PCA and Table four, the three ICT variables (number of internet users per 100 inhabitants, number of fixed line owners per 100 and number of mobile phone users per 100 inhabitants). For both Tables, we compute estimations for the Fixed Effect (FE), the Random Effect (RE), the Hausman-Taylor (HT) and the Poisson Pseudo Maximum likelihood (PPML) techniques. In addition to the standard test associated with the gravity model, we control for bilateral, exporter-year and importer-year fixed effects.

Table three portrays the effects of the aggregate ICT index on intra-regional in the ECOWAS. The Fischer test with a P-value of 0.000 in Column 1 indicate that the individual fixed effects are significant. However, with the Hausman test reporting a p-value greater than five percent we reject the alternative hypothesis and therefore purport that the Random effects (RE) model

produces more robust results than the FE estimates (Table 3, Col. 2). Furthermore, the Breusch Pagan test being less than five percent indicates that the random effects are significant. The Wald statistics also shows a strong joint significance of the variables associated with the RE estimates (Table 3, Col. 2). From Table three, the goodness of fit measured vary from 0.54 to 0.79 with the RE model registering the highest R-square (Table 3). Table A2 in the appendix report results for the time fixed-effect effects.

Concerning the bilateral, exporter-year and importer-year fixed effects we find the presence of the first two effects (bilateral and export-year) and the absence of the importer-year effect for the FE, RE and PPML estimates. This suggest that the countries trading within the ECOWAS are invariant geographical, historical, political, cultural and other bilateral influences which affect the propensity of any two countries in the sample to trade (Table 3, Columns 1, 2 and 4).

Table 3: Determinants of intra-regional trade in the ECOWAS (Combined effect of ICT). Dependent variable: log of cost of bilateral exports

Variables	Fixed Effect Estimates	Random Effect Estimates	Hausman-Taylor Estimates	Poisson Pseudo Maximum likelihood Estimates
	(1)	(2)	(3)	(4)
Log of GDP for country exporting	0.289*	0.426***	0.338**	0.292***
	(0.166)	(0.160)	(0.138)	(0.029)
Log of GDP for country importing	0.325*	0.309*	1.057***	-0.014
	(0.185)	(0.185)	(0.103)	(0.038)
Log of population of country exporting	1.093	1.239***	1.250***	-0.024
	(1.266)	(0.259)	(0.328)	(0.034)
Log of population of country importing	0.794***	0.814***	-0.102	0.228***
	(0.238)	(0.239)	(0.126)	(0.047)
Log of distance between the capitals of countries exporting and importing	-1.486***	-1.479***	-1.605***	-0.256***
	(0.092)	(0.092)	(0.089)	(0.017)
Countries trading have the same colonial masters (1=yes and 0=otherwise)	0.189	0.233	0.090	0.154**
	(0.241)	(0.241)	(0.237)	(0.066)
Countries trading use a common currency (1=yes and 0=otherwise)	2.347***	2.433***	1.690***	0.690***
	(0.184)	(0.183)	(0.155)	(0.028)
Countries trading speak the same official language (1=yes and 0=otherwise)	-0.102	-0.168	0.253	-0.197***
	(0.223)	(0.224)	(0.214)	(0.065)
Countries trading share the border (1=yes and 0=otherwise)	0.532***	0.536***	0.344***	0.090***
	(0.134)	(0.135)	(0.128)	(0.023)
Log of aggregate ICT of country exporting	-0.820	-0.302	-0.795	-1.148***
	(1.109)	(0.950)	(0.559)	(0.167)
Log of aggregate ICT of country importing	1.823*	1.951*	-1.378***	0.622***
	(1.104)	(1.108)	(0.440)	(0.221)
Exporting country (origin) is landlocked (1=yes and 0=otherwise)		-1.598***	-1.452	-0.268***
		(0.579)	(0.988)	(0.022)
Constant	-28.55	-33.48***	-31.86***	-6.240***
	(19.12)	(3.238)	(3.696)	(0.279)
Fischer test [Prob > F]	73 [0.000]			
Breusch Pagan LM test [Prob > F]		8097.8 [0.000]		
Hausman Test [Prob > F]		213.33 [0.863]		
Wald statistics [Prob > F]		3263 [0.000]		
R-Squared	0.540	0.795		0.629
Bilateral fixed effects	Yes	Yes		Yes
Exporter time effects	Yes	Yes		Yes
Importer time effects	No	No		No
Number of Observations	2,964	2,964	2,964	2,964

*** p<0.01, ** p<0.05, * p<0.1 indicate significance at 1, 5, and 10 percent. Robust standard errors in parentheses.

Regarding our main covariate of interest, the aggregate ICT index related significantly with intra-regional trade in the ECOWAS region only for the importing county for the RE, FE and HT

estimates. In the RE and FE estimates we find a positive relationship (Table 3, Col. 1 and 2) while for the HT estimates we identify a negatively and significant relationship (Table 3, Col. 3). When we control for the possible presence of zero trade flows between countries trading by estimating our empirical model using the PPML estimator, we obtain a negative and significant relationship between the aggregate ICT index and intra-regional trade for the exporting country and a positive and significant for the importing country (Table 3, Col. 4). A potential explanation to this finding is the nature of intra-regional trade in the ECOWAS when the countries overwhelmingly import rather than export. The traders or trading transactions for importing goods and services invest in ICT of their respective countries or region to facilitate their activities unlike exporting transactions. However, there is need to invest in ICT to reverse her mitigating effect on intra-regional export in the ECOWAS. This can be done through investment channeled towards the low ICT endowments of the region or build institutional frameworks around existing ICTs to optimize their effects on intra-regional trade. Nath and Liu (2017) and Bankole et al. (2015a) find similar results.

A review of the other traditional variables included in the empirical model indicates that their relationship with the dependent variable are similar to expected signs in literature. The economic weight or GDP levels and population of both the exporting and importing countries (Matyas et al. 2000), when the countries trading share the same border as well as when both countries use the same currency increase intra-regional trade in the ECOWAS. On the contrary, the variable distance and when the exporting country is landlocked tend to reduce intra-regional trade (Raballand 2003; Moïse and Sorescu 2013).

In order to verify for consistency, Table four reports results for the different types of ICT (internet users, mobile phone users and fixed phone users) used to construct the aggerate ICT index. The goodness for fit for the different ICT variables varies from 0.54 to 0.82 for internet users (Table 4, Col. 1, Col. 2 and Col. 4), 0.54 to 0.79 for mobile phone users (Table 4, Col. 5, Col. 6 and Col. 8) and 0.54 to 0.84 for fixe line users (Table 4, Col. 9, Col. 10 and Col. 12). For all three ICT variables the RE specifications had the highest R-square values.

Appraising the different statistics, the individual fixed effects are significant as reported in Columns two, six and ten of Table 4. Column 10 with a p-value less than five percent indicate that for fixed phones the FE model produced better results than the RE as made evident by the p-values of the Hausman test. For all three ICT variables, Table 4 show the presence of bilateral and exporter-year effects and the absence of the importer-year effect for the FE, RE and PPML estimates.
Considering internet (Table 4, Col. 2) and mobile phone (Table 4, Col. 6) usage, the data fitted to the empirical model fails to meet the asymptotic assumption of the Hausman test. However, a p-value for the Breusch Pagan test shows that random effects are significant. The Wald test shows a strong joint significance of the different variables for internet, mobile phone and fixed line users.

We observe that gauging the effect of the three ICT variables on intra-regional trade in the ECOWAS, we find that the results for the ICT variable internet mimics those for the aggregate ICT index (Table 4, Columns1-4). Nonetheless, finding for mobile phone and fix phones rather suggest that the relationship between the ICT and intra-regional trade was positive for both exporting and importing countries (Table 4, Columns 5-12). For the former, only the values for the importing countries where significant (Table 4, Columns 5-8) while for the latter we have a significant positive relation for both the importing and exporting countries for the RE and PPML estimates (Table 4, Columns 10 and 12). These results suggest the important role of mobile and fixed phones in intra-regional trade and therefor the need for policy enactment to focus on these ICT variables.

Table 4: Determinants of intra-regional trade in the ECOWAS (Individual ICT effects). Dependent variable: log of cost of bilateral exports

	Internet				Mobile Phone				Fixed Phones lines			
	FE	**RE**	**HT**	**PPML**	**FE**	**RE**	**HT**	**PPML**	**FE**	**RE**	**HT**	**PPML**
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Log of GDP for country exporting	0.282*	0.596***	0.306**	0.159***	0.247	0.414***	0.233	0.049**	0.214	0.373***	0.317***	0.021
	(0.169)	(0.150)	(0.152)	(0.023)	(0.155)	(0.147)	(0.146)	(0.023)	(0.155)	(0.144)	(0.116)	(0.023)
Log of GDP for country importing	0.198	0.173	0.670***	-0.0590	0.256*	0.258*	0.617***	0.0342	0.0616	0.0665	0.437***	0.0474
	(0.154)	(0.156)	(0.086)	(0.0387)	(0.137)	(0.137)	(0.075)	(0.032)	(0.162)	(0.163)	(0.101)	(0.029)
Log of population of country exporting	1.200	1.086***	1.138***	0.144***	1.707	1.271***	1.126***	0.263***	1.718	1.526***	1.293***	0.326***
	(1.229)	(0.191)	(0.347)	(0.025)	(1.072)	(0.222)	(0.430)	(0.027)	(1.072)	(0.224)	(0.319)	(0.030)
Log of population of country importing	0.888***	0.911***	0.368***	0.262***	0.807***	0.803***	0.437***	0.157***	1.236***	1.226***	0.749***	0.158***
	(0.180)	(0.182)	(0.090)	(0.043)	(0.158)	(0.159)	(0.081)	(0.038)	(0.222)	(0.223)	(0.135)	(0.038)
Log of distance between the capitals of countries exporting and importing	-1.465***	-1.449***	-1.648***	-0.261***	-1.461***	-1.453***	-1.613***	-0.26***	-1.494***	-1.490***	-1.681***	-0.270***
	(0.092)	(0.092)	(0.088)	(0.016)	(0.091)	(0.092)	(0.088)	(0.016)	(0.091)	(0.092)	(0.088)	(0.015)
Countries trading have the same colonial master (1=yes and 0=otherwise)	0.257	0.352	0.191	0.194***	0.253	0.297	0.178	0.189***	0.182	0.232	0.143	0.161**
	(0.241)	(0.241)	(0.238)	(0.066)	(0.240)	(0.240)	(0.236)	(0.065)	(0.239)	(0.239)	(0.236)	(0.066)
Countries trading use a common currency (1=yes and 0=otherwise)	2.355***	2.548***	1.706***	0.710***	2.247***	2.340***	1.687***	0.675***	2.241***	2.353***	1.577***	0.667***
	(0.182)	(0.182)	(0.156)	(0.027)	(0.182)	(0.182)	(0.155)	(0.028)	(0.182)	(0.181)	(0.158)	(0.028)
Countries trading speak the same official language (1=yes and 0=otherwise)	-0.172	-0.319	0.200	-0.231***	-0.143	-0.214	0.201	-0.22***	-0.0535	-0.130	0.314	-0.177***
	(0.224)	(0.225)	(0.215)	(0.064)	(0.223)	(0.223)	(0.214)	(0.064)	(0.222)	(0.222)	(0.214)	(0.065)
Countries trading share the border (1=yes and 0=otherwise)	0.572***	0.581***	0.364***	0.108***	0.544***	0.547***	0.376***	0.098***	0.545***	0.549***	0.367***	0.108***
	(0.135)	(0.136)	(0.129)	(0.023)	(0.134)	(0.134)	(0.128)	(0.023)	(0.134)	(0.134)	(0.128)	(0.024)
Log of aggregate ICT of country exporting	-0.0627	-0.0309	-0.156*	-0.0413**	(0.128)	(0.128)	(0.128)	(0.128)	0.112	0.773***	0.0925	0.196***
	(0.124)	(0.110)	(0.090)	(0.018)	(0.134)	(0.133)	(0.085)	(0.025)	(0.337)	(0.262)	(0.254)	(0.030)
Log of aggregate ICT of country importing	0.495***	0.532***	0.172**	0.153***	0.766***	0.764***	0.382***	0.0948**	0.984***	0.979***	0.572***	0.072*
	(0.142)	(0.144)	(0.080)	(0.031)	(0.192)	(0.193)	(0.086)	(0.038)	(0.228)	(0.229)	(0.134)	(0.039)
Exporting country (origin) is landlocked (1=yes and 0=otherwise)		-1.565***	-1.394	-0.297***		-1.576***	-1.453	-0.24***		-1.373***	-1.330	-0.270***
		(0.378)	(1.112)	(0.021)		(0.546)	(1.469)	(0.022)		(0.470)	(0.990)	(0.021)
Constant	-28.98	-33.59***	-28.29***	-5.569***	-36.13**	-32.59***	-26.72***	-5.42***	-38.45**	-38.90***	-32.18***	-6.145***
	(18.52)	(2.406)	(4.595)	(0.303)	(16.74)	(3.068)	(6.483)	(0.288)	(16.72)	(2.966)	(3.666)	(0.282)
Fischer test [Prob > F]	76.05 [0.000]				66.03[0.000]				70.06[0.000]			
Breusch Pagan LM test [Prob > F]		9486 [0.000]				8727[0.000]						
Hausman Test [Prob > F]										368 [0.00]		
Wald statistics [Prob > F]		3396.94 [0.000]				3300.59 [0.000]				3353.49 [0.000]		
R-Squared	0.541	0.821		0.621	0.542	0.793		0.623	0.542	0.847		0.622
Bilateral fixed effects	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes
Exporter time effects	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes
Importer time effects	No	No		No	No	No		No	No	No		No
Observations	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964

Source: *** p<0.01, ** p<0.05, * p<0.1 indicate significance at 1, 5, and 10 percent. Robust standard errors in parentheses.

FE: Fixed Effect Estimates; RE: Random Effect Estimates; HT: Hausman-Taylor Estimates and PPML: Poisson Pseudo Maximum likelihood (PPML) Estimates.

An assessment of the other traditional variables indicate that the GDP of both the exporting and importing countries, the populations of the exporting and importing countries, using the same currency by both exporting and importing countries and having a common border between the trading countries (Sadikov 2007) all relate positively with intra-regional trade in the ECOWAS. On the contrary, the variables distance and when the exporting country is landlocked rather reduce intra-regional trade. The expected signs of these results are similar with those observed in the literature (Brun et al. 2002; Disdier and Head 2008; Biryukova1 and Matiukhina, 2018; Rodriguez-Crespo and Martínez-Zarzoso, 2019).

Conclusion

This paper contributes to limited empirically literature studying the effect of ICT on intra-regional trade in the ECOWAS using an augmented gravity model over the period 1994 to 2014. This is motivated by the perceived gap in the limited literature that analysis the impact of ICT infrastructure on intra-regional trade in sub-Saharan Africa.

To gauge this relationship, we adopt an empirical specification suggested by Bergstrand et al (2015) which controls for bilateral, exporter-year and importer-year fixed effects. The value addition of this approach is its capacity to treat issues associated with endogeneity and multilateral heterogeneity. Furthermore, we run these estimates for four different estimation techniques: (a) the Fixed Effect (FE); (b) the Random Effect (RE); (c) the Hausman-Taylor (HT) and (d) the Poisson pseudo maximum likelihood (PPML) estimation techniques. This is guided by the desire to account for different econometric biases associated with non-normality of unobservable, unobserved individual effects, exogeneity of the specific individual effects and heteroskedasticity. To carry out our estimations, data is obtained from the 2017 World Development Indicator, the United Nations Conference on Trade and Development (UNCTDA, 2016) and Center for Prospective Studies and International Information (CEPII).

The main findings of this paper suggest the following: (i) we find the presence of both the bilateral and export-year effects suggesting that in the ECOWAS, there are invariant geographical, historical, political, cultural and other bilateral influences which affect the propensity of any two countries in the sample to trade; (2) the aggregate ICT index related significantly with intra-regional trade in the ECOWAS region only for the importing county for the RE, FE and HT estimates. When we factor-in the possible presence of zero trade flows between countries trading by running the PPML estimator we obtain a negative and significant relationship between the aggregate ICT index and intra-regional trade for the exporting country and a positive and significant for the importing country; (3) disaggregated results for the ICT variable-internet mimics those for the aggregate ICT index whereas finding for mobile and fix phones rather suggest that the relationship between the ICT and intra-regional trade was positive for both exporting and importing countries.
These results purport to policy suggestions that investing in ICT infrastructure that particularly encourage the usage of mobile and fixed lines encourage intra-regional trade for both exporting and importing countries.

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Appendix:

Table A1: Total variance reported from the Principal Component Analysis method

	Initial Eigen values			Extraction Sum of Squares of selected factors		
Component	Total	Variance %	Cumulative Frequency %	Total	Variance %	Cumulative Frequency %
First factorial axis	1,841	61,38	61,38	1,841	61,38	61,38
Second factorial axis	0,847	28,25	89,63	0,847	28,25	89,63
Third factorial axis	0,311	10,37	100,0	0,311	10,37	100,0

Source: Authors calculation compiled from World Development Indicators (2017).

Table A2: Fischer Test for time fixed effects

Year	97	99	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14
Joint test if the dummies for year equal to zero	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fisher (18, 2922) = 0.59 /Prob > F = 0.9065																		

Source: Authors calculation compiled from World Development Indicators (2017).

Table A3 : List of countries

Benin	Guinea	Niger
Burkina Faso	Guinea-Bissau	Nigeria
Cote d'Ivoire	Liberia	Senegal
Ghana	Mali	Sierra Leone
Togo		

Source: Compiled by Authors.