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Does ICTs diffusion increase bilateral trade in Africa? Empirical evidence using an augmented gravity model

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Abstract

The use of Information and Communication Technologies (ICTs) in Africa has increased considerably over the past two decades, and has been the subject of an extremely fruitful literature. In this article, we examine their effect on bilateral trade of goods and services observed in 32 African countries. To achieve this, we specify and estimate an augmented gravity model by the Poisson Pseudo Maximum Likelihood (PPML), Negative Binomial (NEGBIN) and Zero Inflated Poisson (ZIP) estimators over the period 1995-2019. The theory of trade openness is highlighted to assess the determinants of the bilateral trade in Africa. Our results show that the use of ICTs, measured by the penetration of mobile phones, fixed phones, broadband and the Internet, significantly increases the bilateral trade in Africa. We suggest investing more in telecommunication infrastructures and strengthening the public-private partnership, in order to reduce the costs of accessing and using new ICTs.

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1. Introduction

Information and Communication Technologies (ICTs), essentially driven by the forces of international evolution, play a crucial role in the growth and economic development (Ogunsola, 2005; Xing, 2017; Ozcan, 2017; Nath and Liu, 2017; Ali et al., 2020; Tay, 2020). In this line, Baldwin (2016) argues that ICTs and increasing trade flows are becoming the two fundamental drivers of the new globalization around the world. However, the evolution of international trade shows strong disparities between regions whit Africa appearing as the region with the lowest level of intra-regional trade. According to the UNCTAD's Report (2019) on African Development, the average total value of exports from Africa to the rest of the world stood at 760 billion US dollars in current prices between 2015 and 2017, compared to 481 billion for Oceania, 4109 billion for Europe, 5140 billion for the United States and 6801 billion for Asia. In 2017, intra-African exports accounted for only 16.6% of total exports, compared to 68.1% for intra-European exports, 59.4% for intra-Asian exports, 55.0% for intra-American exports and 7.0% for intra-Oceanic exports. Intra-African trade, which is the average of intra-African exports and imports, amounted to about 15.2% of Africa's total exports during 2015-2017, while America, Asia, Europe and Oceania had intra-continental trade of 47%, 61%, 67% and 7% of total trade, respectively. This low level of intra-African trade represents a significant loss of earnings for these economies, which are still struggling to sustain their economic development process.

Among the factors that can help Africa to boost its trade and enhance its development process, the literature highlights the diversification of exported products, the transformation of the industrial processes, financial inclusion and, above all, the improvement of the institutional framework favorable to business (De Brauw et al., 2014; Lin and Ge, 2021; Ongo and Song, 2018). Furthermore, there is a large consensus in the literature concerning the beneficial effects of ICTs on the socioeconomic and environmental dimensions of development in Africa (Asongu and Le Roux, 2017; Ejemeyovwi and Osabuohien, 2018; Eyike, 2019; Avom and Melingui, 2020; Avom et al., 2020; Djoumessi and Eyike, 2021; Djoumessi, 2021). However, this abundant literature pays less attention to the opportunity that ICTs represent for the development of trade in African countries. Indeed, the Covid-19 pandemic and its economic consequences have shown that ICTs represent a source of resilience for trade as well as for other economic sectors.

Therefore, ICTs[1] have proliferated over the last decades, emerging in African countries as a great opportunity for marginalized groups, to reduce gender inequalities as laid out in the fifth United Nation's sustainable development goal (International Telecommunication Union, 2019). Indeed, not only do ICTs have an increasingly important role in countries and financial inclusion, but they also increase the transparency of labor market information (Roztocki et al., 2019).

However, little is known about the effects of ICTs on bilateral trade in Africa. Yet, there are several transmission channels through which the diffusion of ICTs can accelerate bilateral trade, notably the improvement of productivity, the reduction of costs and Foreign Direct Investments attractiveness. Firstly, Wadhwani (2000) argued that the internet is likely to significantly impact productivity and inflation during the next few years after 2000. In addition, ICTs diffusion can improve productivity indirectly by reducing corruption practices

[1] Information and Communication Technologies (ICTs) is a broader term for Information Technology (IT), which refers to all communication technologies enabling users to access, retrieve, store, transmit, and manipulate information in a digital form.

as traders can interact directly through internet or mobile communications without intermediaries (Vinod, 1999). In addition, Choi (2003) argues that ICTs in general and internet in particular can lower prices by reducing the costs in Business-to-costumer (B2C), Business-to-Business (B2B) and Business-to-Government (B2G) nexus. The author also states that productivity can be improved by market competition intensification as ICTs reduce search costs and entry barriers in some markets. According to DePrince and Ford (1999), the acceleration of internet use can cut the cost of holding inventories by allowing a large panel of suppliers to bypass retailers and connect directly sellers and customers from one country to another. In this line, Venables (2001) argue that there are three main channels through which ICTs can lead to a decline in trading costs and improve bilateral trade. Firstly, digital technologies reduce the costs of communication and search of information as well as the costs of a match, leading to more transparency in the market. Secondly, the diffusion of ICTs also induces the reduction in costs for the monitoring and management of the firm with a beneficial impact on trade. Thirdly, the use of ICTs can reduce time in transit and all other associated costs. In addition, ICTs can accelerate bilateral trade through their impact on FDI attractiveness (Avom and Melingui, 2020). Indeed, financial capital owners look for the level of commercial flow of a country before engaging in investments.

According to this argument, Freund and Weinhold (2000) performed cross-country regressions based on the gravity model and find that internet positively and significantly impacts bilateral trade. The use of mobile phones and the internet also offer the possibility of selling and buying on line, with low physical movement of persons but with an important gain of time and efficiency. ICTs can also improve trade through electronic payment. In this line, internet online selling and mobile money, mobile banking and payment offer opportunities to accelerate trade and finally attract more foreign investors (Avom and Melingui, 2020)

The contribution of this research is twofold. First, it reveals whether ICTs influence bilateral trade. Second, this paper adds to the literature on ICTs externalities in African countries. To the best of our knowledge, this study is the first attempt to appreciate the effects of ICTs diffusion on bilateral trade using a panel dataset of African countries through a gravity model methodology.

The rest of the article proceeds as follows. The second section presents a synthesis of the literature. The third section outlines the distinct steps of the empirical strategy adopted. Results and robustness checks are discussed in section 4. A conclusion in section 5 suggests some policy recommendations.

2. Literature review

2.1. ICT and trade: a theoretical deduction

Following Smith (1776) who based explanations of international trade on absolute benefits, the literature highlights three main theories: *(i)* Traditional theories that incorporate Ricardo's theory of comparative advantage (1817), and the Heckscher-Ohlin-Samuelson (HOS) model. Thus, in 1821, Ricardo introduced the theory of comparative advantage, which explained why it is beneficial for two countries to trade, even though one of them may be able to produce both goods and services more cheaply than the other. According to his theory, a country can reap welfare gains by specializing in the production of a good or service in which it has the lowest opportunity cost relative to the other; *(ii)* Modern theories that incorporate the new theory of international trade developed by Krugman (1979) and the financial theories initiated by Levine (2005); *(iii)* institutional theory with Davis and North (1971) who highlighted the

importance of institutional arrangement. In the early literature, growth theory was the theoretical vantage point to observe and examine the contribution of exogenous technological progress to growth, development and trade process (Solow 1956; Swan, 1956; Grossman and Helpman, 1995; Grossman and Helpman, 1990; Helpman 1988). For high-income countries, it has seen the technological advancement and technical efficiency gained through research and development (R&D), while the technical efficiency gains of the middle- and low-income countries are found in the adoption of technologies already developed in technologically advanced countries (Caselli et al. 1996; Hall and Jones 1999). Therefore, the growth of internet access was widely acknowledged, it imposes numerous integration challenges for developing countries and less developed Countries to participate in this e-trade mode.

2.2. ICT and trade: an empirical synthesis

The empirical evidence evaluating the theoretical positions is non-consensual because of the measures of trade and ICTs, samples of countries, and the estimation techniques. The effects of ICTs diffusion on bilateral trade have been assessed in both multi-country and bilateral-country investigations. However, the literature examines two strands of debate on trade.

The first strand examines the impact of ICTs on trade in goods and services. Daly and Miller (1998), Freund and Weinhold (2004), Tang (2006), Vemuri and Siddiqi (2009), Choi (2010) found that adoptions of fixed-line telephones, mobile phones, and internet connection promotes trade flows in developing and developed countries. Liu and Nath (2013) found that internet subscriptions and internet hosts are positively and significantly related to trade performance in 40 emerging markets between 1995-2010. Yushkova (2014) in the sample of 40 countries finds that the internet usage by business communities in both exporting and importing countries has a positive link with the export flows between these countries. In the same vein Tay (2015) using data from 189 countries from 2000 to 2012, finds that internet facilitates education trade. Similarly, Nath and Liu (2017) using panel data for 49 countries from 2000-2013, argue that the access, use, and skills aspects of the technology contribute to the growth of international trade. Other authors found that ICTs indicators such as fixed broadband and fixed telephone have significant impacts on service trade, service export and service import (Wang and Li, 2017; Tay, 2018). Fernandes et al. (2019), Osnago and Tan (2016), Clarke and Wallsten (2006) also find a positive correlation between Internet and exports, even before the rise of e-commerce platforms.

The second strand of the literature appreciates the impact of ICTs on bilateral trade. Porojon (2001) revisiting the popular gravity model of trade, find that the distance variable and GDP per capita of the exporting/importing country significantly contribute to accelerating bilateral trade. Linders and Groot (2006) also using the gravity model to describe and explain variation in bilateral trade patterns, found that trade increases with GDP, common language, common border, and trade agreement. In addition, Nordas and Piermartini (2004) and Ahmad et al. (2011) found that ICTs infrastructures have significant effects on bilateral trade in Asian countries. Using a gravity model, Abeliansky and Hilbert (2017) and Xing (2018) found that better access to the modern ICTs and adoption of e-commerce applications stimulate bilateral trade flows. Rodriguez-Crespo et al. (2018), Lin (2015), Meijers (2014) analyze the effect of three different technologies on exports: internet, mobile phones, and broadband, finding a positive effect of ICTs on trade. Visser (2019) found that internet affects the extensive and intensive margins positively of differentiated exports. Besides, Rodríguez-Crespo and Martínez-Zarzoso (2019) find that the relationship between internet users and trade differs by income level and the degree of product sophistication. Rodríguez-Crespo and Zarzoso (2019) on their part, apply a gravity model using up-to-date Poisson Pseudo-Maximum Likelihood

(PPML) estimation techniques to a sample of 120 countries over the period 2000-2014, showing that internet use increases bilateral exports. Tay (2020) using data from the US to 34 partner countries from 2000-2016, find that ICTs perform better on bilateral trade in service than bilateral trade in goods. Recently, Abeliansky et al. (2021) used an augmented gravity model to analyse the effect of ICT on trade. Based on a sample of 150 countries from 1995 to 2014, the results show that ICT diffusion of ICTs increases extensive trade margins.

3. Empirical strategy

3.1. Empirical model

The gravity model used in this study is inspired by Head and Mayer (2014) who presented a comprehensive review of theories and applications of this model whose initial specification is as follows:

$$X_{ij} = C\frac{M_i M_j}{D_{ij}^2} \tag{1}$$

This equation implies that a mass of goods or services *(M_i)* at origin *i* is attracted to a mass of demand for goods or services *(M_j)* at destination *j*, and the potential trade flow decreases by the physical distance *(D_{ij})* between *i* and *j*. *C* is the gravitational constant term, and X_{ij} is the predicted movement of goods or services from *i* to *j*. Based on equation (1), the gravity model of bilateral trade takes the following form:

$$X_{ij} = a_0 (\mathrm{Y_i})^{a_1} (\mathrm{Y_j})^{a_2} (\mathrm{D_{ij}})^{a_3} \mu_{\mathrm{ij}} \tag{2}$$

Where X_{ij} is the value of bilateral exports from *i* to *j*; Y_i and Y_j represent the gross domestic product per capita as a proxy for the exporters and importers economic masses. D_{ij} denotes the distance between trading countries, and μ_{ij} the disturbance term. Therefore, a_0, a_1, a_2, a_3 are the unknown parameters. Given the bi-directional features of the predicted movement of goods and services, the panel data technique of fixed-effects estimation is applied to examine the contribution of ICTs infrastructures to bilateral trade in Africa. Drawn from the literature on bilateral trade, explanatory variables such as GDP per capita, geographical distance between trade partners, population, colonial origin and common border are included in the empirical investigations. In the nexus between ICTs and bilateral trade, our study follows the estimation strategies in Freund and Weinhold (2004). The underlying augmented gravity model is expressed by equation (3) below:

$$\begin{aligned}\ln(EXP_{ijt}) = a_0 + a_1 \ln(GDP_{it}) + a_2 \ln(GDP_{jt}) + a_3 \ln(Pop_{it}) + a_4 \ln(Pop_{jt}) + a_5 \ln(Dist_{ij}) + a_6 Com\_border_{ij} \\ + a_7 Com\_Lang_{ij} + a_8 Com\_colony_{ij} + a_9 ICT_{it} + a_{10} ICT_{jt} + \mu_{ijt}\end{aligned} \tag{3}$$

ICTs indicators are introduced since they are considered as a trade facilitator (Abeliansky and Hilbert, 2017). The ICT_{it} and ICT_{jt} variables will change (ICT = Internet, Broadband, Fixed phone, Mobile phone) according to different specifications. The distance and other control variables are standard in the gravity model literature. Distance has been included in gravity models since the early contributions of Tinbergen (1962) who argues that countries trade more with those closest to them. In this line, the greater the distance between two countries, the less the volume of trade, *ceteris paribus.* Table A3 of the appendices describes different variables used in estimates. Estimation of equation (3) leads to an omitted variable bias because the error term is not orthogonal to the vector of explanatory variables. Santos and Tenreyro (2006) suggest solving this bias by using the Poisson Pseudo-Maximum Likelihood

(PPML). The specification of the following equation (4) addresses more than one problem, namely: (1) zero flows can be included in the regression since the dependent variable (EXPijt) is not log-expanded. (2) Heteroscedasticity in the level error term is taken into account (Zakaria Sorgho, 2013).

$$EXP_{ijt} = a_0 + a_1 \ln(GDP_{it}) + a_2 \ln(GDP_{jt}) + a_3 \ln(Pop_{it}) + a_4 \ln(Pop_{jt}) + a_5 \ln(Dist_{ij}) + a_6 Com\_border_{ij} + a_7 Com\_Lang_{ij} + a_8 Com\_colony_{ij} + a_9 ICT_{it} + a_{10} ICT_{jt} + \mu_{ijt} \quad (4)$$

Existing literature suggests controlling the gravity model by including multilateral resistances (MRs). The easiest way to control these effects and obtain an unbiased coefficient is to use country-specific or country-pair-specific fixed effects (Eaton and Kortum, 2002; Feenstra, 2004; Baier and Bergstrand, 2009). In this paper, we adopt an approach proposed by Baier and Bergstrand (2009) as follow[2]:

$$MR\_B_{ij} = \sum k \left(\frac{Y_k}{Y_w} * \ln(B_{ik}) \right) + \sum m \left(\frac{Y_m}{Y_w} * \ln(B_{mj}) \right) - \sum k \sum m \left(\frac{Y_k}{Y_w} * \frac{Y_m}{Y_w} * \ln(B_{km}) \right) \quad (5)$$

Thus, the specification estimated will be that of equation 6 with the incorporation of MRs.

$$EXP_{ijt} = a_0 + a_1 \ln(GDP_{it}) + a_2 \ln(GDP_{jt}) + a_3 \ln(Pop_{it}) + a_4 \ln(Pop_{jt}) + a_5 \ln(Dist_{ij}) + a_6 Com\_border_{ij} + a_7 Com\_Lang_{ij} + a_8 Com\_colony_{ij} + a_9 Internet_{it} + a_{10} Mobile\_phone_{it} + a_{11} Fixed\_phone_{it} + a_{12} Broadband_{it} + a_{13} Internet_{jt} + a_{14} Mobile\_phone_{jt} + a_{15} Fixed\_phone_{jt} + a_{16} Broadband_{jt} + a_{17} MR_{ij} + \mu_{ijt} \quad (6)$$

3.2. Estimation technique

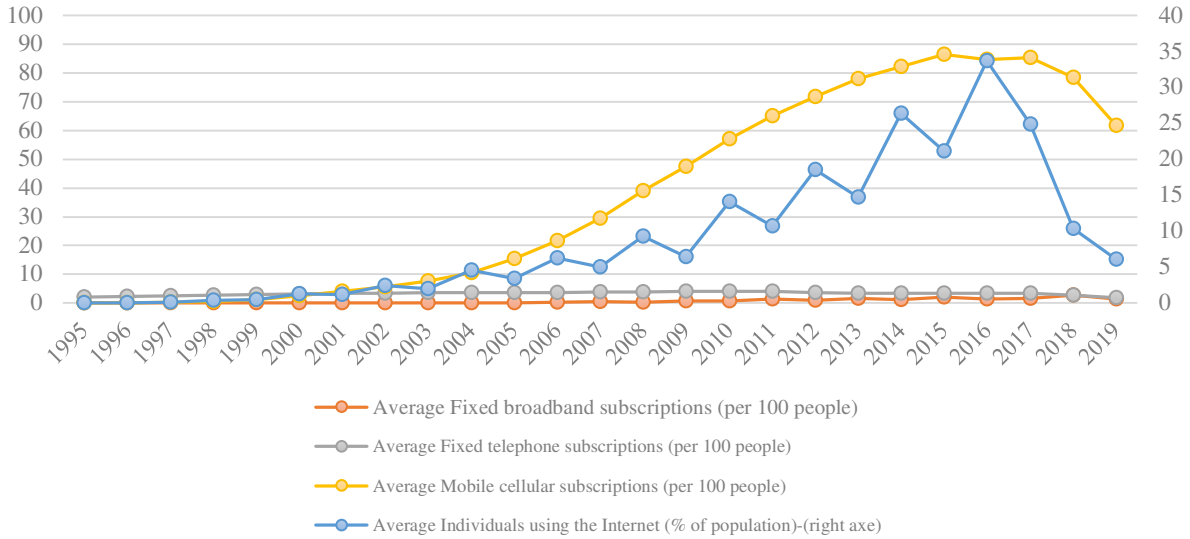
The specification in equation (1) can be estimated using Ordinary Least Square, Fixed Effects or Random Effects tolls. According to Shepherd et al. (2019), the Poisson estimator naturally includes observations for which the observed trade value is zero. Such observations are dropped from the OLS method because the logarithm of zero is undefined and lead to inconsistent results. To solve these problems and obtain unbiased results, the literature recommends proceeding by the Poisson Pseudo-Maximum Likelihood (Silva and Tenreyro, 2006, 2010 and 2011). Most importantly, this estimation technique solves the problem of loss or absence of data on the dependent variable (Westurlund and Wilhelmsson, 2011). To validate our results, after having retained the PPML estimator as the main estimation technique, we perform sensitivity tests through Negative Binomial (NEGBIN) and Zero inflated Poisson (ZIP) estimators. The first is for a possible bias related to the "overdispersion" of the dependent variable (De Benedictis and Taglioni, 2011) and the second is indicated in case of high dispersion and a large proportion of zeros in the dependent variable (De Benedictis and Taglioni, 2011).

3.3. Data

The data come from World Development Indicators (2020) and concern a sample of 32 countries during the period 1995 to 2019. Four different ICTs indicators are considered in this article because they have different impacts derived from their diffusion trajectories. Figure 1 shows the evolution of the digitalization in Africa over the studied period.

[2] See appendices for more details on MRs calculation and justification.

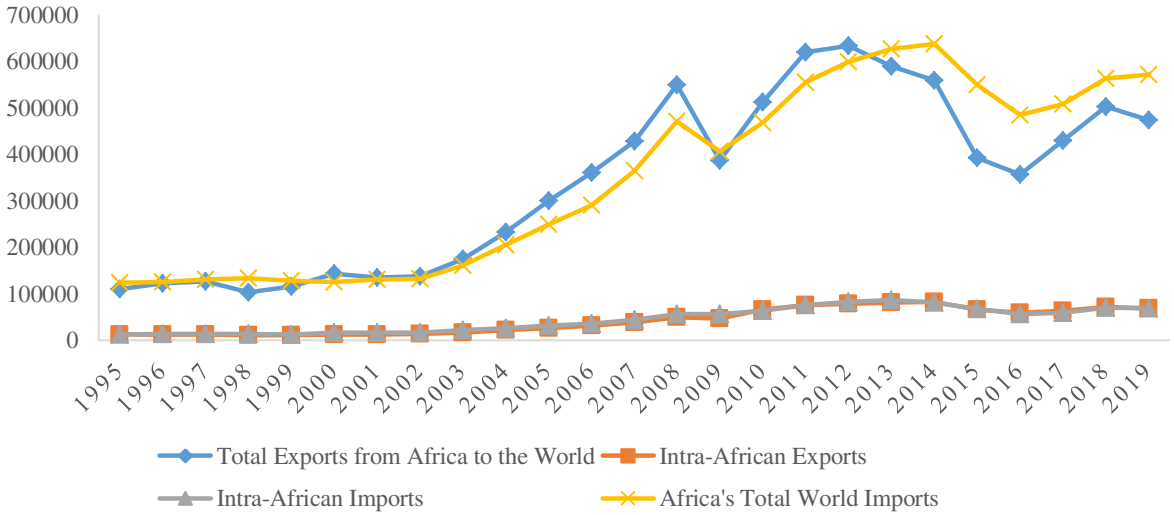
Figure 1: Evolution of ICT variables in Africa



Source: Authors, from World Development Indicators (2020).

Average mobile phone, fixed phone and broadband subscriptions per 100 people jumped from 0.144; 2.000 and 0.090 in 1995 to 61.76; 1.894 and 6.063 in 2019 respectively. In the same period, average internet penetration increased from 1.16 to 26.86%. Figure 2 shows the evolution of intra-African trade and African international trade[3].

Figure 2: Evolution of trade in Africa (in millions of US Dollars at current prices)



Source: Authors, from World Development Indicators (2020).

Therefore, African countries do not trade enough with each other compared to the global trade of African countries. While intra-African trade remains low, it has shown a slight upward trend from 1995 to 2019. Another finding is that Africa's total exports are above imports between 1995-2013. However, there has been an upward trend in African imports.

[3] Total group trade: this is the trade of all group members with the world, including their intra-group trade.

4. Results and discussion

4.1. Baseline results

Table 1 presents the results obtained after estimating Equation (6) using PPML method. Our results show that ICT indicators globally have a positive and significant effect on bilateral trade in Africa. The results also confirm the basic theory of gravity, according to which GDP and distance have respectively positive and negative affect on bilateral trade[4].

Our results suggest that having better access to high-speed broadband and secured servers enhance trade performance between economic partners (Rodriguez-Crespo and Martínez-Zarzoso, 2019). As can be seen in Table 1 all ICT indicators have a positive and significant effect on trade flows between country *i* and country *j* in Africa. A possible explanation is that an increase in access to ICTs contributes to digital activities as e-trading, mobile banking and payment and, as a result, exports and total trade increase. These results also suggest that the diffusion of ICTs improves the accessibility to foreign markets and reduces transaction costs for bilateral trade in goods and services. These findings are consistent with the results reported by Nath and Liu (2013), who conclude that the use of significantly boosts bilateral.

Table 1: The linear impact of ICTs on bilateral exportation using PPML estimator

	Dependent variable: Bilateral Exportation			
	(1)	*(2)*	*(3)*	*(4)*
VARIABLES	*Internet*	*Broadband*	*Fixed phone*	*Mobile phone*
Ln (GDP for exporting country) $_{it}$	*1.591****	*1.632****	*1.483****	*1.591****
	(0.0001)	*(0.0001)*	*(0.0001)*	*(0.0001)*
Ln (GDP for importing country) $_{jt}$	*1.121****	*1.195****	*0.963****	*1.028****
	(0.0001)	*(0.0001)*	*(0.0001)*	*(0.0001)*
Ln (Population) $_{it}$	*0.321****	*0.294****	*0.479****	*0.357****
	(0.0001)	*(0.0001)*	*(0.0001)*	*(0.0001)*
Ln (Population) $_{jt}$	*0.0978****	*0.0385****	*0.302****	*0.246****
	(0.0001)	*(0.0001)*	*(0.0001)*	*(0.0001)*
Ln of Distance (in km) $_{ij}$	*-2.995****	*-3.074****	*-3.244****	*-2.854****
	(0.0001)	*(0.0001)*	*(0.0001)*	*(0.0001)*
$Border_{ij}$	*0.795****	*0.742****	*0.664****	*0.788****
	(0.0001)	*(0.0001)*	*(0.0001)*	*(0.0001)*
$Language_{ij}$	*0.149****	*0.125****	*-0.0651****	*0.235****
	(0.0001)	*(0.0001)*	*(0.0001)*	*(0.0001)*
$Colonial\ ties_{ij}$	*0.632****	*0.676****	*0.850****	*0.558****
	(0.0001)	*(0.0001)*	*(0.0001)*	*(0.0001)*
Internet (% of population)$_{it}$	*0.0079****			
	(2.65e-06)			
Broadband (per 100 people) $_{it}$		*0.0506****		
		(2.48e-05)		
Fixed phone (per 100 people)$_{it}$			*0.0380****	
			(1.21e-05)	
Mobile phone (per 100 people)$_{it}$				*0.0035****
				(1.10e-06)
Internet (% of population)$_{jt}$	*0.0098****			

[4] These empirical results are robust to multi-colinearity tests. See Table A4 of appendices.

	(2.72e-06)			
Broadband (per 100 people) $_{jt}$		*0.0582****		
		(2.49e-05)		
Fixed phone (per 100 people)$_{jt}$			*0.0510****	
			(1.14e-05)	
Mobile phone (per 100 people)$_{jt}$				*0.0061****
				(1.11e-06)
Multilateral resistance	*Yes*	*Yes*	*Yes*	*Yes*
Constant	*-12.31****	*-12.51****	*-11.40****	*-13.47****
	(0.0017)	*(0.0017)*	*(0.0017)*	*(0.0017)*
Observations	*24748*	*24748*	*24748*	*24748*
Countries	*32*	*32*	*32*	*32*
Log likelihood	*-6.581e+08*	*-6.670e+08*	*-6.568e+08*	*-6.355e+08*
Wald chi2(14)	*1.32e+09*	*1.31e+09*	*1.31e+09*	*1.32e+09*
Prob > chi2	*0.0000*	*0.0000*	*0.0000*	*0.0000*

Source: Authors

***Notes**: *, **, and *** significance at 10%, 5%, and 1% respectively. Standard deviations robust to heteroscedasticity are in brackets.*

Despite the various degrees of ICTs diffusion across the sample countries, having a reliable landline is crucial for Africa traders to engage in the international trade. Also, having better access to the high-speed broadband and secured servers enhances trade performance between the trading partners. In other words, the ICTs based technologies encourage individuals and enterprises to search for the best service providers or producers regardless of physical distance (Egger and Lassman, 2012). For these countries, the cost of dealing with tacit knowledge is understandably lower and ICTs usage constitutes a real comparative advantage that can boost bilateral trade flows (Freund and Weinhold, 2002).

4.2. Robustness analysis

To test the robustness of our baseline results, we use two alternative estimation techniques: NEGBIN (Table 2) and ZIP (Table 3). Overall, findings in Table 2 confirm the beneficial effect of ICTs diffusion in boosting export growth by encouraging firms/producers/exporters, especially those in developing countries to increase trade in response to the proliferation of global e-commerce value chains. This suggests that ICTs diffusion is the most important factor that positively contributes to the bilateral trade of goods and services in Africa. Compared with the baseline results, all the coefficients conserve their sign and significance. The plausible explanation of our results is that to unlock Africa export potential and improve its participation in global trade, development efforts have been made through the Backhaul System providing African countries with access to submarine cables. Also, the recent development in ICTs such as broadband cables has encircled Africa's coastlines. Innovative solutions are emerging, allowing the delivery of small pieces of the Internet to basic handsets. At the same time, digital payment services are becoming more important and various online marketplaces are spreading. The findings are consistent with the consensus that ICTs diffusion promotes international trade and reduces communication and transaction costs (Wallsten, 2006).

Table 2: The linear impact of ICTs on bilateral exportation using NEGBIN estimator

	Dependent variable: Bilateral Exportation			
	(1)	*(2)*	*(3)*	*(4)*
VARIABLES	*Internet*	*Broadband*	*Fixed phone*	*Mobile phone*

Ln (GDP for exporting country) $_{it}$	*1.610****	*0.0744****	*0.114****	*0.0368****
	(0.0001)	*(0.0087)*	*(0.0094)*	*(0.0087)*
Ln (GDP for importing country) $_{jt}$	*1.127****	*0.0753****	*0.111****	*0.0419****
	(0.0001)	*(0.0102)*	*(0.0103)*	*(0.0103)*
Ln (Population) $_{it}$	*0.202****	*0.674****	*0.692****	*0.825****
	(0.0001)	*(0.0306)*	*(0.0303)*	*(0.0301)*
Ln (Population) $_{jt}$	*0.0209****	*0.515****	*0.522****	*0.597****
	(0.000140)	*(0.0320)*	*(0.0322)*	*(0.0314)*
Ln of Distance (in km) $_{ij}$	*-2.864****	*-5.224****	*-5.449****	*-4.836****
	(0.0001)	*(0.0789)*	*(0.0764)*	*(0.0787)*
Border$_{ij}$	*0.790****	*-0.292****	*-0.420****	*-0.240****
	(0.0001)	*(0.0728)*	*(0.0691)*	*(0.0731)*
Language$_{ij}$	*0.0885****	*0.0484*	*-0.0778*	*0.257****
	(0.0001)	*(0.0500)*	*(0.0482)*	*(0.0499)*
Colonial ties$_{ij}$	*0.552****	*0.615****	*0.802****	*0.497****
	(0.0001)	*(0.0521)*	*(0.0507)*	*(0.0515)*
Internet (% of population)$_{it}$	*0.0066****			
	(2.64e-06)			
Broadband (per 100 people) $_{it}$		*0.258****		
		(0.0135)		
Fixed phone (per 100 people)$_{it}$			*0.112****	
			(0.00421)	
Mobile phone (per 100 people)$_{it}$				*0.0093****
				(0.0004)
Internet (% of population)$_{jt}$	*0.0094****			
	(2.71e-06)			
Broadband (per 100 people) $_{jt}$		*0.0489****		
		(0.0130)		
Fixed phone (per 100 people)$_{jt}$			*0.0478****	
			(0.00425)	
Mobile phone (per 100 people)$_{jt}$				*0.0016****
				(0.0004)
Multilateral resistance	*Yes*	*Yes*	*Yes*	*Yes*
Constant	*-11.40****	*15.75****	*15.31****	*13.08****
	(0.0017)	*(0.479)*	*(0.464)*	*(0.477)*
Observations	*19,784*	*19,784*	*19,784*	*19,784*
Countries	*32*	*32*	*32*	*32*
Log(α)-cons	*1.26843*	*1.2791*	*1.2660*	*1.2615*
Log likelihood	*-6.33e+08*	*-180450.71*	*-180243.12*	*-180172.29*
Wald chi2(14)	*1.34e+09*	*12781.13*	*14273.06*	*13608.38*
Prob > chi2	*0.0000*	*0.0000*	*0.0000*	*0.0000*

Source: Authors

***Notes**: *, **, and *** significance at 10%, 5%, and 1% respectively. Standard deviations robust to heteroscedasticity are in brackets.*

Table 3: The linear impact of ICTs on bilateral exportation using ZIP estimator

VARIABLES	*Dependent variable: Bilateral Exportation*			
	(1)	*(2)*	*(3)*	*(4)*
	Internet	*Broadband*	*Fixed phone*	*Mobile phone*

Ln (GDP for exporting country) $_{it}$	*0.0548****	*1.638****	*1.514****	*1.628****
	(0.0089)	*(0.0001)*	*(0.0001)*	*(0.0001)*
Ln (GDP for importing country) $_{jt}$	*0.0546****	*1.203****	*0.976****	*1.022****
	(0.0103)	*(0.000136)*	*(0.000154)*	*(0.000141)*
Ln (Population) $_{it}$	*0.700****	*0.185****	*0.339****	*0.216****
	(0.0311)	*(0.0001)*	*(0.0001)*	*(0.0001)*
Ln (Population) $_{jt}$	*0.562****	*-0.0396****	*0.220****	*0.187****
	(0.0319)	*(0.0001)*	*(0.0001)*	*(0.0001)*
Ln of Distance (in km) $_{ij}$	*-5.086****	*-2.929****	*-3.077****	*-2.747****
	(0.0779)	*(0.0001)*	*(0.0001)*	*(0.0001)*
Border$_{ij}$	*-0.237****	*0.740****	*0.668****	*0.792****
	(0.0734)	*(0.0001)*	*(0.0001)*	*(0.0001)*
Language$_{ij}$	*0.0492*	*0.0643****	*-0.120****	*0.171****
	(0.0497)	*(0.0001)*	*(0.0001)*	*(0.0001)*
Colonial ties$_{ij}$	*0.651****	*0.592****	*0.765****	*0.489****
	(0.0515)	*(0.0001)*	*(0.0001)*	*(0.0001)*
Internet (% of population)$_{it}$	*0.0262****			
	(0.0011)			
Broadband (per 100 people) $_{it}$		*0.0454****		
		(2.50e-05)		
Fixed phone (per 100 people)$_{it}$			*0.0322****	
			(1.22e-05)	
Mobile phone (per 100 people)$_{it}$				*0.0029****
				(1.10e-06)
Internet (% of population)$_{jt}$	*0.0087****			
	(0.00116)			
Broadband (per 100 people) $_{jt}$		*0.0526****		
		(2.50e-05)		
Fixed phone (per 100 people)$_{jt}$			*0.0489****	
			(1.15e-05)	
Mobile phone (per 100 people)$_{jt}$				*0.0060****
				(1.12e-06)
Multilateral resistance	*Yes*	*Yes*	*Yes*	*Yes*
Constant	*15.01****	*-11.62****	*-10.62****	*-12.52****
	(0.476)	*(0.0017)*	*(0.0017)*	*(0.0017)*
Observations	*19784*	*19784*	*19784*	*19784*
Countries	*32*	*32*	*32*	*32*
Log likelihood	*-180280.41*	*-6.40e+08*	*-6.31e+08*	*-6.12e+08*
Wald chi2(14)	*13100.46*	*1.32e+09*	*1.34e+09*	*1.38e+09*
Prob > chi2	*0.0000*	*0.0000*	*0.0000*	*0.0000*

Source: Authors

***Notes**: *, **, and *** significance at 10%, 5%, and 1% respectively. Standard deviations robust to heteroscedasticity are in brackets.*

The signs of the other coefficients are consistent with the literature and show that colonial ties, common border and language, and market size (population) increase bilateral trade between African countries.

5. Conclusion

This paper analyzed the impact of ICTs diffusion on bilateral trade in Africa. Based on panel data of 32 countries over the period 1995-2019, results obtained by the Poisson Pseudo Maximum Likelihood (PPML), Zero Inflated Poisson (ZIP) and Negative Binomial (NEGBIN) estimators on the gravity model, showed that ICTs diffusion significantly increased bilateral trade of goods and services in Africa. The paper highlights the opportunity that the high diffusion of ICTs represents for intra-African trade. Through productivity gains, reduction of transaction costs, attractiveness to Foreign Direct Investments and reduction of corruption, ICTs offer enormous opportunities for African countries to drive long-term development through bilateral trade. Therefore, ICTs diffusion requires relevant skills, opportunities and capacities, thus it is vital to extend access to digital education and new capability training schemes. We recommend improving national roads and railway networks, reinforcing import and export procedures for e-commerce and the upgrade of ICTs infrastructures with tax incentives for private sector's participation and encouraging foreign investment in ICT-related sectors.

References

Abeliansky A. L., Barbero J. and Rodriguez-Crespo, E. (2021) "ICTs quality and quantity and the margins of trade" *Telecommunications Policy* **45**, 102056.

Abeliansky, A. L. and Hilbert, M. (2017) "Digital technology and international trade: Is it the quantity of subscriptions or the quality of data speed that matters?" *Telecommunication Policy* **41**, 35-48.

Adam, S. (1776) "Research on the nature and causes of the wealth of nations" Book IV: Systems of political economy.

Ahmad, N. A., Ismail, N. W. and Law, S. H. (2011) "The role of ICT infrastructure on Malaysian trade" *International Journal of Economics and Management* **5**, 140-148.

Ali, M. A., Alam, K., Taylor, B and Rafiq, S. (2020) "Does ICT maturity catalyse economic development? Evidence from a panel data estimation approach in OECD countries" *Economic Analysis and Policy* **68**, 163-174.

Anderson, J. E. and Van-Wincoop, E. (2003) "Trade costs" *Journal of Economic Literature* **42**, 691-751.

Anderson, J. E., and Van Wincoop, E. (2003) "Gravity with gravitas: A solution to the border puzzle" *American economic review*, **93**, 170-192.

Asongu, S. A. and Le Roux, S. (2017) "Enhancing ICT for inclusive human development in Sub Saharan Africa" *Technological Forecasting and Social Change* **118**, 44-54.

Avom, D. and Melingui. B. A. (2020) "The effect of information and communication technologies on foreign direct investments attractiveness in Africa" *Economics Bulletin* **40**, 2304-2319.

Avom, D., Nkengfack, H., Kaffo Fotio, H. and Totouom, A. (2020) "ICT and environment quality in Sub-Saharan Africa: Effects and transmission channels" *Technological Forecasting and Social Change* **155**, 1-12.

Baier, S. L., and Bergstrand, J. H. (2009) "Bonus vetus OLS: A simple method for approximating international trade-cost effects using the gravity equation" *Journal of International Economics* **77**, 77-85.

Baldwin, R. (2016) "The Great Convergence: Information technology and the New Globalization" Harvard University Press, Cambridge.

Baldwin, R., and Taglioni, D. (2007) "Trade effects of the euro: A comparison of estimators" *Journal of Economic Integration* **22**, 780-818.

Caselli, F., Esquivel, G. and Lefort, F. (1996) "Reopening the convergence debate: a new look at cross-country growth empirics" *Journal of Economic Growth* **1**, 363-389.

Choi, C. (2010) "The Effect of the Internet on Service Trade" *Economics Letters* **109**, 102-104.
Clarke, G. and Wallsten, G. (2006) "Has the Internet increased trade? Developed and Developing country evidence" *Economic Inquiry* **44**, 465-484.
Correia, S., Guimarães, P., and Zylkin, T. (2020) "Fast Poisson estimation with high-dimensional fixed effects" *The Stata Journal* **20**, 95-115.
Coughlin, C. C., and Bandyopadhyay, S. (2015) "Determinants of trade margins: Insights using state export data" *IZA discussion papers*, No. 9520. Bonn: Institute for the Study of Labor (IZA).
Crespo, R. E. and Zarzoso, I.,M. (2019) "The effect of ICT on trade: Does product complexity matter?" *Telematics and Informatics* **41**, 182-196.
Daly, A. J. and Miller, R. R. (1998) "Corporations' use of the Internet in developing countries" Washington, D.C. World Bank, c1998 ix, 21 p: 28 cm. ISBN: 0821342568 (paperback)
Davis, L. E. and North, D. C. (1971) "Institutional Change and American Economic Growth" Cambridge (UK): Cambridge University Press.
Deardorff, A. V. (1995) "Determinants of bilateral trade: does gravity work in a neoclassical world?" *The Regionalization of the World Economy* **7**, 7-28.
DePrince, A. E. and Ford, W. (1999) "A primer on Internet economics" *Business Economics* **34**, 42-50.
De Benedictis, L. and Taglioni, D. (2011) "The Gravity Model in International Trade" In L. De Benedictis, & L. Salvatici (Eds.), The Trade Impact of European Union Preferential Policies: An Analysis through Gravity Models (pp. 55-90). Berlin: Springer https://doi.org/10.1007/978-3-642-16564-1.
De Brauw, A., Mueller, V and Lee, H. L. (2014) "The role of rural-urban migration in the structural transformation of Sub-Saharan Africa" *World Development* **63**, 33-42.
De Sousa, J. and J. Lochard (2009) "Histoire coloniale et commerce international" *Revue économique* **60**, 635-646.
Djoumessi, Y. F. (2021) "What innovations impact agricultural productivity in Sub-Saharan Africa?" *Journal of Agriculture and Food Research*, *6*, 100228.
Djoumessi, Y. F., and Mbongo, L. D. B. E. (2021) "An analysis of information Communication Technologies for natural disaster management in Africa" *International Journal of Disaster Risk Reduction*, 102722.
Egger, P. and Lassman, A. (2012) "The language effect in international trade: a meta-analysis" *Economics Letters* **116**, 221-224.
Ejemeyovwi, J.O. and Osabuohien, E.S. (2018) Investigating the relevance of mobile technology adoption on inclusive growth in west Africa. *Contemporary Social Science* **15**, 48-61.
Epo, N. B. and Nguenkwe, R. B. (2020) "Information and Communication Technology and Intra-Regional Trade in the Economic Community of West African States: Ambivalent or Complementary?" *Economics Bulletin* **40**, 1397-1412.
Eyike, M. L. B. (2019) "ICT diffusion and employment in Africa" *Economic Bulletin*, **39**, 521-532.
Feenstra, R. C. (2002) "Border effects and the gravity equation: Consistent methods for estimation" *Scottish Journal of Political Economy* **49**, 491-506.
Fernandes, A. M., Mattoo, A., Nguyen, H. and Schilffbauer, M. (2019) "The Internet and Chinese exports in the pre-alibaba era" *Journal of Development Economics* **138**, 57-76.
Freund, C. and Weinhold, D. (2002) "The Internet and International Trade in Services" *American Economic Review* **92**, 236-240.

Freund, C. and Weinhold, D. (2004) "The effect of the Internet on International Trade" *Journal of International Economics* **62**, 171-189.

Grossman, G. M. and Helpman, E. (1995) "Technology and Trade. In: Grossman, G.M. and Rogoff, Eds., Handbook of International Economics", Vol.3, North Holland, Amsterdam.

Grossman G. M. and E. Helpman (1990) "Comparative Advantage and Long-Run Growth" *American Economic Review* **80**, 796-815.

Hall RE and Jones, C. I. (1999) "Why do some countries produce so much more output per worker than others?" *Quarterly Journal Economic* **114**, 83-116.

Haveman, J., and D. Hummels. (2004) "Alternative Hypotheses and the Volume of Trade: The Gravity Equation and the Extent of Specialization." *Canadian Journal of Economics*, 37(1): 199-218.

Head, K. and Mayer, T. (2014) "Gravity equations: Workhorse, toolkit, and cookbook" *In Handbook of international economics* **4**, 131-195.

Helpman, E. (1988) "Trade Patterns under Uncertainty with Country Specific Shocks" *Econometrica, Econometric Society* **56**, 645-659.

Huang, X., Song, X., & Hu, X. (2018) "Does "internet plus" promote new export space for firms? Evidence from China" *China and World Economy* **26**, 50-71.

Krugman, P. (1979) "Increasing Returns, Monopolistic Competition, and International Trade" *Journal of International Economics* **9**, 469-479.

Lawless, M. (2010) "Deconstructing gravity: Trade costs and extensive and intensive margins" *Canadian Journal of Economics* **43**, 1149-1172.

Lin, B and Ge, J. (2021) Does institutional freedom matter for global forest carbon sinks in the face of economic development disparity, *China Economic Review* **65**, DOI: 10.1016/j.chieco.2020.101563.

Lin, F. (2015) "Estimating the effect of the internet on international trade" *The Journal of International Trade & Economic Development: An International and Comparative Review* doi:10.1080/ 09638199.2014.881906.

Linders, G-J. and Groot, H. L. F. (2006) "Estimation of the Gravity Eq. in the Presence of Zero Flows" *Tinbergen Institute Discussion Paper* No. 06-072/3.

Levine, R. (2005) "Finance and Growth: Theory and Evidence" in Aghion P. et Durlauf S. (éd.), Handbook of Economic Growth, edition 1, vol. 1, chap. 12, pp. 865-934.

Liu, L. and Nath, H. K. (2013) "Information and communications technology (ICT) and trade in emerging market economies" *Emerging Mark Finance Trade* **49**, 67-87.

Meijers, H. (2014) "Does the internet generate economic growth, international trade, or both?" *International Economics and Economic Policy* **11**, 137-163.

Moïsé, E. and Sorescu, S. (2014) "Indicateurs sur la facilitation des échanges : Effets possibles de la facilitation sur les échanges des pays en développement" *Éditions OCDE*, Paris.

Nath, H. K. and Liu, L. (2017) "Information and communications technology (ICT) and services trade" *Information Economics and Policy* **41**, 81-87.

Nkoumou-Ngoa B.H., Song J.S. (2021) Female participation in African labor markets: The role of information and communication technologies. *Telecommunications Policy*, 45, 102174.

Njangang, H. and Nounamo, Y. (2020) "Is information and communication technology a driver of industrialization process in African countries?" *Economics Bulletin* **40**, 2654-2662.

Nordas, H. K. and Piermartini, R. (2004) "Infrastructure and Trade" *Staff Working Paper*, World Trade Organization.

Ogunsola, L. A. (2005) "Information and Communication Technologies and the Effects of Globalization: TwentyFirst Century "Digital Slavery" for Developing Countries—Myth or Reality?" *E-JASL 1999-2009* **58,** 1-10.
Olivero, M. P. and Yotov, Y. V. (2012) "Dynamic gravity: endogenous country size and asset accumulation" *Canadian Journal of Economics/Revue canadienne d'économique* **45**, 64-92.
Ongo, N. B. and Song, J. S. (2018) "La qualité des institutions réduit-elle la volatilité des investissements directs étrangers en Afrique ? " *Mondes en développement*, **183**, 113-131.
Osnago, A. and Tan, S. W. (2016) "Disaggregating the Impact of the Internet on International Trade" *Policy Research Working Paper* 7785.
Porojan, A. (2001) "Trade Flows and Spatial Effects: The Gravity Model Revisited" *Open Economies Review* **12**, 265-280.
Poyhonen, P. (1963) "A tentative model for the volume of trade between countries" *Weltwirtschafeliches Archiv* **90**, 93-100.
Rodriguez-Crespo, E. and Martínez-Zarzoso, I. (2019) "The Effect of ICT on Trade: Does Product Complexity Matter?" *Telematics and Informatics* **41**, 182-196.
Roztocki, N., Soja, P. and Weistroffer, R. (2019) "The role of information and communication technologies in socioeconomic development: Towards a multi-dimensional framework" *Information Technology for Development* **25**, 171-183.
Santos-Silva, J. M. C. and Tenreyro, S. (2006) "The Log of Gravity" *The Review of Economics and Statistics* **88**, 641-658.
Santos-Silva, J. and Tenreyro, S. (2010) "On the Existence of the Maximum Likelihood Estimates in Poisson Regression" *Economics Letters* **107**, 310-12.
Santos-Silva, J. and Tenreyro, S. (2011) "Further Simulation Evidence on the Performance of the Poisson-PML Estimator" *Economics Letters* **112**, 220-22.
Shepherd, B., Doytchinova, H. S. & Kravchenko, A. (2019) "The gravity model of international trade": *a user guide [R version].* Bangkok: United Nations ESCAP.
Sorgho, Z. (2013) "Modèle gravitationnel appliqué au commerce : une "success history" dans l'étude des déterminants des flux commerciaux bilatéraux – vue d'ensemble sur le modèle" *Document de Formation* – Réf. : F.2013(07).01.
Tang, L. (2006) "Communication costs and trade of differentiated goods" *Review of International Economics* **14**, 54-68.
Tay, C. (2015) "The Impact of the Internet on Trade in Education" *Technological and Economic Development of Economy* **21**, 833-854.
Tay, C. (2018) "The Impact of Information and Communication Technologies on Bilateral Trade in Services" *International Journal of Services Operations and Informatics* **9**, 40-61.
Tay, C. (2020) "Comparison of the Impact of Information and Communication Technology between Bilateral Trade in Goods and Services" *Journal of System and Management Sciences* **10**, 1-31.
Tinbergen, J. (1962) "Shaping the world economy: suggestions for an international economic policy" Twentieth Century Fund, New York.
Vemuri, V. K. and Siddiqi, S. (2009) "Impact of commercialization of the internet on international trade: A panel study using the extended gravity model" *The International Trade Journal* **23**, 458-484.
Vinod, H. D. (1999) "Statistical analysis of corruption data and using the Internet to reduce corruption" *Journal of Asian Economics* **10**, 591-603.
Visser, R. (2019) The effect of the internet on the margins of trade. Information Economics and Policy, https://doi.org/10.1016/j.infoecopol.2018.12.001

Wadhwani, S. B. (2000) "The impact of the Internet on UK inflation" *Bank of England Quarterly Bulletin*, Bank of England: 184-198.
Wang, Y. and Li, J. (2017) "ICTs effect on trade: perspective of comparative advantage" *Economics Letters* **155**, 96-99.
Westerlund, J. and Wilhelmsson, F. (2011) "Estimating the gravity model without gravity using panel data" *Applied Economics* **43**, 641-649.
Xing, Z. (2018) "The impacts of Information and Communications Technology (ICT) and E-commerce on bilateral trade flows" *International Economics and Economic Policy* **15**, 565-586.
Yushkova, E. (2014) "Impact of ICT on trade in different technology groups: analysis and implications" *International Economics and Economic Policy*, **11**, 165-177.

Appendices

Appendix 1. *Multilateral Resistances (MRs) calculation*

Following existing literature, Baier and Bergstrand (2009) proposed to calculate MRs terms based on the cost of bilateral trade between all pairs of countries and the size of an economy relative to that of all others.

$$MR\_B_{ij} = \sum k\left(\frac{Y_k}{Y_w} * \ln(B_{ik})\right) + \sum m\left(\frac{Y_m}{Y_w} * \ln(B_{mj})\right) - \sum k \sum m\left(\frac{Y_k}{Y_w} * \frac{Y_m}{Y_w} * \ln(B_{km})\right)$$

Where: Bij is the cost variable for bilateral trade and Yw the total GDP. This specification allows including in the model explanatory variables that change only in the country dimension. In this paper, we account for distance, common border, common language and common colonization as suggested by De Sousa and Lochard (2009) and Moïsé and Sorescu (2014).

Table A1: List of countries

Algeria, Angola, Benin, Burkina-Faso, Cameroon, Capo Verde, Chad, Congo, Côte d'Ivoire, Egypt, Equatorial Guinea, Guinea Bissau, Ethiopia, Gabon, Gambia, Ghana, Kenya, Liberia, Libya, Madagascar, Mali, Mauritania, Morocco, Niger, Nigeria, Rwanda, Senegal , Sierra Leone, South Africa, Tanzania, Togo, Tunisia

Source: Authors

Table A2: Descriptive statistics

Variables	*Obs*	*Mean*	*Std. Dev.*	*Min*	*Max*
$Export_{ijt}$	24748	23306.65	126901.5	0	5382038
Ln (GDP for exporting country) $_{it}$	24748	10.115	1.270	0	11.680
Ln (GDP for importing country) $_{jt}$	24748	10.103	1.261	0	11.680
Ln (Population) $_{it}$	24748	7.057	0.568	5.586	8.303
Ln (Population) $_{jt}$	24748	7.057	0.568	5.586	8.303
Ln of Distance (in km) $_{ij}$	24748	3.419	0.306	1.853	3.941
$Border_{ij}$	24748	0.094	0.292	0	1
$Language_{ij}$	24748	0.455	0.497	0	1
$Colonial\ ties_{ij}$	24748	0.310	0.462	0	1
$Internet\ (\%\ of\ population)_{it}$	24748	7.477	13.002	0	74.376
Broadband (per 100 people) $_{it}$	24748	0.4414	1.229	0	10.204
$Fixed\ phone\ (per\ 100\ people)_{it}$	24748	2.809	4.1466	0	23.948
$Mobile\ phone\ (per\ 100\ people)_{it}$	24748	40.517	44.553	0	175.872

Internet (% of population)$_{jt}$	*24748*	*7.446*	*12.935*	*0*	*74.376*
Broadband (per 100 people) $_{jt}$	*24748*	*0.436*	*1.213*	*0*	*10.204*
Fixed phone (per 100 people)$_{jt}$	*24748*	*2.810*	*4.146*	*0*	*23.948*
Mobile phone (per 100 people)$_{jt}$	*24748*	*40.457*	*44.504*	*0*	*175.872*
Multilateral resistance Border$_{ij}$	*24748*	*5.74e-06*	*0.000030*	*0*	*0.0003*
Multilateral resistance Language$_{ij}$	*24748*	*0.0000302*	*0.000068*	*0*	*0.0006*
Multilateral resistance Colonial ties$_{ij}$	*24748*	*0.0000143*	*0.000038*	*0*	*0.0004*
Multilateral resistance Distance $_{ij}$	*24,748*	*0.292*	*0.4510*	*0*	*3.661*

Source: Authors

Table A3: Variables description

Variables	***Description***	***Source***
Ln(EXP)$_{ijj}$	*Value of bilateral exports from i to j at time t*	*WDI 2020*
Ln(GDP)$_{ij}$	*Natural log of nominal GDP per capita from i to j*	*WDI 2020*
Ln(GDP)$_{jt}$	*Natural log of nominal GDP per capita from j to i*	*WDI 2020*
(Internet)$_{it}$	*Internet users (per 100 people) of country i at time t*	*WDI 2020*
(Internet)$_{jt}$	*Internet users (per 100 people) of country j at time t*	*WDI 2020*
(Mobile phone)$_{it}$	*Mobile cellular subscriptions (per 100 people) of country i at time t*	*WDI 2020*
(Mobile phone)$_{jt}$	*Mobile cellular subscriptions (per 100 people) of country j at time t*	*WDI 2020*
(Fixed phone)$_{it}$	*Fixed telephone subscriptions (per 100 people) of country i at time t*	*WDI 2020*
(Fixed phone)$_{jt}$	*Fixed telephone subscriptions (per 100 people) of country j at time t*	*WDI 2020*
(Broadband)$_{it}$	*fixed broadband subscriptions (per 100 people) of country i at time t*	*WDI 2020*
(Broadband)$_{jt}$	*fixed broadband subscriptions (per 100 people) of country j at time t*	*WDI 2020*
Ln(Distanceijt	*log of physical distance between the capital cities of country i and country j (in kilometers) at time t*	*CEPII*
(Language)$_{ij}$	*Dummy variable that takes 1 if the country i and country j shares at least one common language and 0 otherwise*	*CEPII*
(Colonial Origin)$_{ij}$	*Dummy variable that takes 1 if the country i and country j have a former colonial link*	*CEPII*
(Common border)$_{ij}$	*Countries trading share the same border (1=yes and 0=otherwise) of country i at time t*	*CEPII*
Ln(Population)$_{it}$	*Log of Population of exporting of country i at time t*	*WDI 2020*
Ln(Population)$_{jt}$	*Log of Population of exporting of country j at time t*	*WDI 2020*

Source: Authors

***Notes**: WDI: World Development Indicators; CEPII: Center for Prospective Studies and International Information*

Table A4: VIF test for multicollinearity

Variables	*VIF*	*1/VIF*
Ln (GDP for exporting country) $_{it}$	*1.43*	*0.698701*
Ln (GDP for importing country) $_{jt}$	*1.42*	*0.704739*
Ln (Population) $_{it}$	*1.64*	*0.609661*
Ln (Population) $_{jt}$	*1.59*	*0.627206*
Ln of Distance (in km) $_{ij}$	*1.87*	*0.535849*
Border$_{ij}$	*2.19*	*0.455944*
Language$_{ij}$	*2.69*	*0.371402*
Colonial ties$_{ij}$	*2.70*	*0.370919*
Internet (% of population)$_{it}$	*3.34*	*3.31*
Internet (% of population)$_{jt}$	*0.299038*	*0.302066*
Broadband (per 100 people) $_{it}$	*2.55*	*0.392317*
Broadband (per 100 people) $_{jt}$	*2.53*	*0.395521*
Mobile phone (per 100 people)$_{it}$	*3.01*	*2.99*

Mobile phone (per 100 people)$_{jt}$	*0.331933*	*0.333924*
Fixed phone (per 100 people)$_{it}$	*1.61*	*0.620241*
Fixed phone (per 100 people)$_{jt}$	*1.61*	*0.621163*
Multilateral resistance Border$_{ij}$	*1.70*	*0.589622*
Multilateral resistance Language$_{ij}$	*2.47*	*0.404451*
Multilateral resistance Colonial ties$_{ij}$	*2.06*	*0.484812*
Multilateral resistance Distance $_{ij}$	*2.26*	*0.441535*
Mean VIF	*2.25*	

Source: Authors

***Note**: Statistics are less than 10 for all variables. Therefore, there is a presumption of no multi-colinearity.*