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Does ICTs diffusion increase bilateral trade in Africa? Empirical evidence using an extended 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), Gamma and Negative Binomial (NEGBIN) 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 to improve ITCs infrastructures, transport governance and taking effective measures against antitrust and corruption to boost African trade.

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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). 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, and Africa remains among the least internally traded. According to the UNCTAD's Report (2019) on African Development, the average total value of exports from Africa to the rest of the world 760 billion of US dollars (USDs) 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 his trade and perfect its development process, the literature mentions 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, 2020; 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). However, this abundant literature seems to neglect the opportunity that the new 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 opportunities for trade as well as for other sectors of the economy.

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, 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 at the continent level, especially 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 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

[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.

corruption practices as traders have the possibility to interact directly through internet or mobile communications without intermediaries (Vinod, 1999). In addition, Choi (2003) argues that ICTs and internet in particular can lower prices by lowering 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 large panel of suppliers to bypass retailers and connect directly sellers and customers from one country to another. 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 engage investments.

According to this argument, Freund and Weinhold (2000) performed the cross-countries regressions based on the gravity model and find that internet positively and significantly impacts bilateral trade. Internet and mobile also offer the possibility of sailing 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 ICT 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 applying a gravity model. Our study employs a many index of ICTs.

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

This section summarizes the theory and empirical evidence on the effect of ICTs on trade.

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 in 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). 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 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 country 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 trade in education. Similary, Nath and Liu (2017) using panel data for 49 countries from 2000-2013, argue that captures the access, use, and skill aspects of the technology contribute to the growth of international trade. Others 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) 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 income of the exporting/importing country significantly contribute to accelerate 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 the 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) analyze the effect of three different technologies on exports: internet, mobile phones, and broadband, finding a positive effect of ICTs on trade. Similarly, 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. Crespo and Zarzoso (2019) 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, show that internet use increases bilateral exports. Tay (2020) using data from the US to 34 partnering countries from 2000-2016, find that ICTs performs better on bilateral trade in service than bilateral trade in goods. Recently, Abeliansky et al. (2021) through an augmented Gravity Model of trade, by using panel data and

controlling for multilateral resistance in a sample of 150 countries over 1995-2014 found robust evidence that ICTs matter for the extensive margin of trade.

3. Empirical strategy

This section presents the empirical model, the different estimation techniques and the data.

3.1. Empirical model

The empirical gravity model of trade used in this paper results from the work of Tinbergen (1962) and Poyhonen (1963), formally applied to explain bilateral trade flows between distant countries using the functional form of Newtonian gravity. Based on the Newton's law of universal gravitation, the basic form of gravity model is specified by equation (1).

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

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} is the distance between trading countries. and μ_{ij} is 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 from country i to country j at time t, the current study apply the panel data technique of fixed-effects estimation 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:

$$\begin{aligned} ln(EXP_{ijt}) = {} & a_0 + a_1 \ln(GDP_{ij}) + a_2 \ln(GDP_{jt}) + a_3 \ln(Pop_{it}) + a_4 \ln(Pop_{jt}) + a_5 \ln(Dist_{ijt}) + a_6 Com\_border_{ij} \\ & + a_7 Com\_Lang_{ij} + a_8 Com\_colony_{ij} + a_9 Internet_{it} + a_{10} Mobile\_phone_{it} + a_{11} Fixed\_phone_{it} \\ & + a_{12} Broadband_{it} + a_{13} Internet_{jt} + a_{14} Mobile\_phone_{jt} + a_{15} Fixed\_phone_{jt} + a_{16} Broadband_{jt} + \ln(\mu_{ijt}) \end{aligned} \tag{3}$$

The distance and other control variables are standard in the gravity literature. ICTs are introduced since they are considered as a trade cost (Abeliansky and Hilbert, 2017). Distance has been included in gravity models since the early contributions of Tinbergen (1962), which considered that countries traded more with those countries less distant. Table A3 of appendices gives a description of different variables.

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 model because the logarithm of zero is undefined. Two competing approaches are generally used to overcome these issues, namely log-linear and non-linear approaches. The former generally leads to biased results as a result of the logarithmic transformation generates an indeterminacy of the zeros values on the dependent variable. The approach of Santos-Silva and Tenreyro (2006) to overcome the shortcoming of log-linear approaches in the presence of heteroscedasticity and zero trade flows (endogenous variable) is highly recommended.

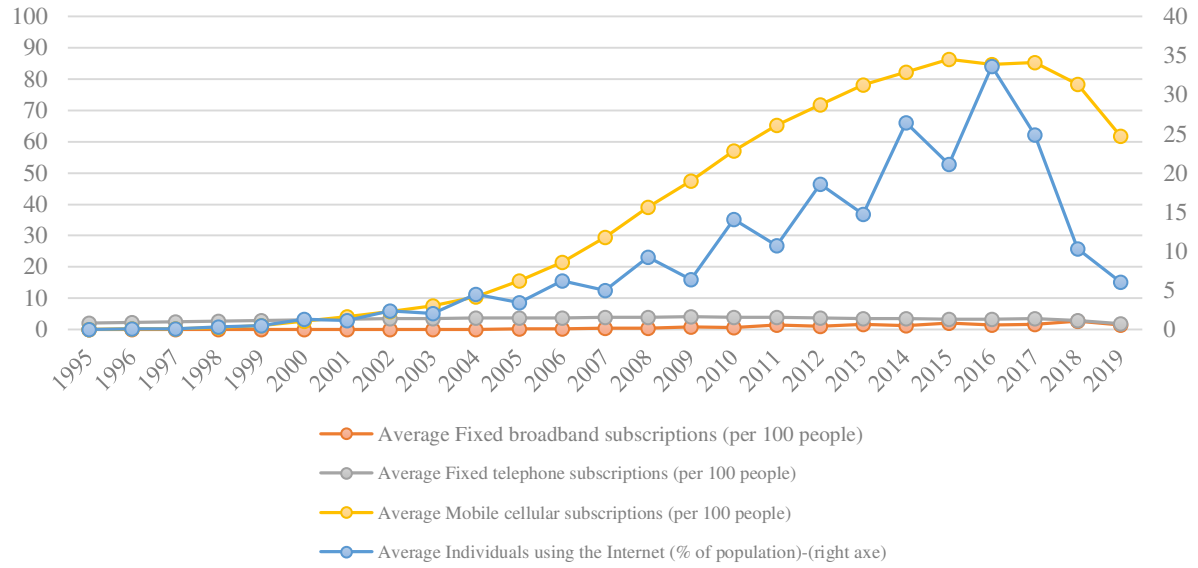
To solve these problems and obtain correct results, the literature recommends to proceed by the Poisson Pseudo-Maximum Likelihood (PPML) estimator which has the same robustness as the Gamma estimator, because of the similarity of their first-order conditions (Head and Mayer, 2014). Most importantly, 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 in order to use their results as a function of significance. Thus, we use the GAMMA estimator and the Negative Binomial Distribution to correct a potential bias relative to endogenous over-dispersion (De Benedictis and Taglioni, 2011)[2].

3.3. Data

Data on the 32 sample countries from 1995 to 2019 are from World Development Indicators (2020). Figure 1 shows the evolution of internet, mobile phone, fixed phone and broadband diffusion in Africa over the studied period. 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%.

[2] Head and Mayer (2014) advise against the use of the negative binomial distribution, even in the case of a fairly large dispersion of the dependent variable, because of the high sensitivity of this estimator to the unit of measurement of the dependent variable.

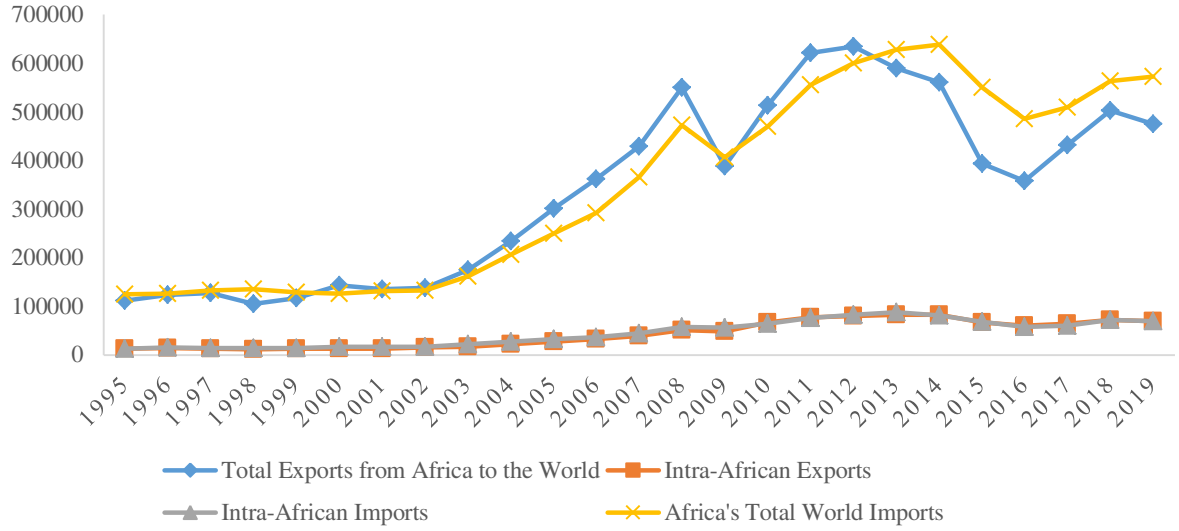
Figure 1: Evolution of ICT variables in Africa



Source: Author's construction using data from WDI (2020).

Figure 2 shows the evolution of intra-African trade and African international trade[3]. Therefore, African countries do not really 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.

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



Source: Author's using data from WDI (2020).

4. Results and discussion

This section presents and discusses the results of the basic model as well as those of the robustness analysis.

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

4.1. Baseline results

Table 1 presents the results pertaining to the estimation of three different estimation techniques (PPML, GAMMA and NEGBIN) of Equation (3). Our results show that ICTs 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 are positively and negatively affect trade, respectively.

Specifically, results from PPML estimator show that Internet usages in exporting country, broadband of exporting and importing country negatively affect bilateral exports of African countries at 1% level of significance. For example, a 1% decrease in Internet users (% of population), fixed broadband subscriptions (per 100 people) in the exporting country and fixed broadband subscriptions (per 100 people) in the importing country positively affects the level of African bilateral exports by 0.12%, 6.3% and 6.22% respectively. Indeed, having better access to the 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 (Colum 1), the estimated coefficients of Internet (% of population)jt, Fixed telephone (per 100 persons)it, Fixed telephone subscriptions (per 100 persons)jt, Mobile telephone (per 100 persons)it, Mobile cellular subscriptions (per 100 persons)jt have a positive and significant effect on trade flows between country i and country j in Africa. One possible explanation is that an increase in access to ICT contributes to an increase in domestic demand for these services and, as a result, exports and total trade decrease. However, ICT diffusion has significant negative effects on bilateral trade in some estimators. This may reflect an increase in domestic demand for goods and services as people use more ICT. These results suggest that increased ICT improves the accessibility of foreign markets and reduces transaction costs for bilateral trade in goods and services. These results seem to resonate well with the results reported by Liu and Nath (2013), who conclude that effect of ICTs on trade do not depend on ICTs infrastructure or ICT capacity, but on the ICTs use.

Table 1: The effect of ICTs on bilateral exportations

Dependent variable: Bilateral exportation			
	PPML	**GAMMA**	**NEGBIN**
Ln (GDP) $_{it}$	1.385***	0.141***	0.141***
	(0.0001)	(0.009)	(0.00926)
Ln (GDP)$_{it}$	0.900***	0.126***	0.126***
	(0.0001)	(0.009)	(0.0100)
Ln (Population) $_{it}$	0.410***	1.264***	1.264***
	(0.0001)	(0.0278)	(0.0279)
Ln (Population) $_{jt}$	0.340***	1.059***	1.059***
	(0.0001)	(0.0306)	(0.0307)
Ln of Distance (in km) $_{ijt}$	-2.381***	-3.504***	-3.504***
	(0.0001)	(0.0686)	(0.0688)
Border	0.111***	0.118**	0.118**
	(0.0001)	(0.0560)	(0.0561)
Language	0.555***	0.309***	0.309***
	(0.0001)	(0.0339)	(0.0340)
Colonial Origin	-0.164***	-0.0571	-0.0572
	(0.0001)	(0.0378)	(0.0379)
Internet (% of population)$_{it}$	-0.0012***	0.0036**	0.0036**
	(3.75e-06)	(0.0018)	(0.0018)
Broadband (per 100 people) $_{it}$	0.0630***	-0.166***	-0.166***

	(3.60e-05)	(0.0176)	(0.0177)
Fixed phone (per 100 people)$_{it}$	0.0225***	0.134***	0.134***
	(1.35e-05)	(0.0052)	(0.0052)
Mobile phone (per 100 people)$_{it}$	0.0048***	0.0085***	0.0085***
	(1.40e-06)	(0.0005)	(0.0005)
Internet (% of population)$_{jt}$	0.0007***	-0.0035*	-0.0035*
	(3.76e-06)	(0.0018)	(0.0018)
Broadband (per 100 people)$_{jt}$	-0.0622***	-0.0395**	-0.0395**
	(3.61e-05)	(0.0186)	(0.0186)
Fixed phone (per 100 people)$_{jt}$	0.0282***	0.106***	0.106***
	(1.29e-05)	(0.0054)	(0.0054)
Mobile phone (per 100 people)$_{jt}$	0.00655***	0.0079***	0.007***
	(1.37e-06)	(0.0005)	(0.0005)
Constant	-12.43***	0.334	0.333
	(0.00121)	(0.326)	(0.327)
Observations	19784	19784	19784
Countries	32	32	32
Log(α)-cons		0.6448***	1.294***
Log likelihood	-6.537e+08	-180381.98	-180690.47
Wald chi2(11)	1.29e+09	13432.95	13365.46
Prob > chi2	0.0000	0.0000	0.0000

Source: Authors

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

The coefficients of ICTs variables are positive and significant, indicating that two-way telecommunications between exporters and importers with good ICTs facilities benefit both trading partners in Africa. 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).

In addition, we can also conclude that the greater the size of a country, in terms of population or GDP, the impacts of ICTs on bilateral trade, service export and service import are positive and statistically significant. Also, common language and common border play such significant roles in bilateral trade in Africa. The coefficients yielded by the structural gravity estimations are in general higher in magnitude. One major reason may be that the internet has reduced trade barriers, physical distances, language gaps, and thus, confirms our implicit hypotheses that ICTs have allowed greater access to information, cut across countries, trade zones, and regulatory boundaries never possible before. The coefficient of geographical distance is negative and significant in all specifications, suggesting that the combination of longer distance and shipment time would discourage trading partners to trade for goods that required speedy transactions (Nath and Liu, 2017).

4.2. Robustness analysis

To test the robustness of our results, we use an alternative estimation specification, adding the ICTs variables in basic model and using a PPML estimator. An advantage of this estimation strategy is that it has good asymptotic and finite sample properties, and provides unbiased,

convergent, and efficient estimation when endogenous bias is suspected in the model. 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 and least-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 contributes positively to the bilateral trade of goods and services in Africa overall. Compared with the baseline results, all the coefficients conserve their sign and significance. The plausible explanations of our results are that, to unlock Africa export potential and improve its participation in global trade, development efforts have been made through the Backhaul System (EABS) providing Africa countries with access to submarine cables. Also, the recent development in ICTs such as fibre-optic cables has encircled Africa's coastlines. Telecommunications providers are investing in 3G and subsidizing smartphone ownership. 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 general 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

	Dependent variable : Bilateral exportations				
	Estimation technique : PPML Estimator				
Ln (GDP for exporting country) $_{it}$	1.513***	1.600***	1.544***	1.445***	1.385***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Ln (GDP for exporting country) $_{ij}$	1.176***	1.301***	1.175***	1.003***	0.900***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Ln (Population) $_{it}$	0.244***	0.200***	0.290***	0.292***	0.410***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Ln (Population) $_{jt}$	0.0010***	-0.074***	0.0912***	0.182***	0.340***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Ln (Distance)	-2.418***	-2.442***	-2.545***	-2.338***	-2.381***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Border	0.124***	0.0887***	0.0187***	0.150***	0.111***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Language	0.566***	0.550***	0.510***	0.600***	0.555***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Colonial origin	-0.214***	-0.155***	-0.104***	-0.255***	-0.164***
	(0.0001)	(2.47e-05)		(0.0001)	(0.0001)
Internet (% of population)$_{it}$	0.00647***				-0.0012***
	(2.60e-06)				(3.75e-06)
Broadband (per 100 people) $_{it}$		0.0254***			-0.0630***
		(2.47e-05)			(3.60e-05)
Fixed phone (per 100 people)$_{it}$			0.0173***		0.0225***
			(1.16e-05)		(1.35e-05)
Mobile phone (per 100 people)$_{it}$				0.0035***	0.0048***
				(1.12e-06)	(1.40e-06)
Internet (% of population)$_{jt}$	0.0090***				0.0007***
	(2.66e-06)				(3.76e-06)
Broadband (per 100 people)$_{jt}$		0.0375***			0.0622***
		(2.47e-05)			(3.61e-05)
Fixed phone (per 100 people)$_{jt}$			0.0302***		0.0282***
			(1.11e-05)		(1.29e-05)
Mobile phone (per 100 people)$_{jt}$				0.0061***	0.0065***

				(1.14e-06)	(1.37e-06)
Constant	-12.30***	-13.44***	-13.15***	-12.11***	-12.43***
	(0.0011)	(0.0011)	(0.0011)	(0.0011)	(0.0012)
Observations	19,784	19,784	19,784	19,784	19,784
Countries	32	32	32	32	32
Log likelihood	-6.883e+08	-6.9e+08	-6.9e+08	-6.61e+08	-6.53e+08
Wald chi2(11)	1.22e+09	1.20e+09	1.21e+09	1.28e+09	1.29e+09
Prob > chi2	0.0000	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.*

5. Conclusion

This paper has 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), Gamma and Negative Binomial (NEGBIN) estimators on the gravity model, show that ICTs diffusion significantly increases 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 services 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 participations 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.

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

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.

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

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. (2003) "Does the Internet Stimulate Inward Foreign Direct Investment?" *Journal of Policy Modeling* **25**, 319-326.
Clarke, G. and Wallsten, G. (2006) "Has the Internet increased trade? Developed and Developing country evidence" *Economic Inquiry* **44**, 465-484.
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.
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
Eyike, M. L. B. (2019) "ICT diffusion and employment in Africa" *Economic Bulletin*, **39**, 521-532.
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.
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.
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*, Vol: 65.

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.

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.

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.

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.

Shepherd, B., Doytchinova, H. S. & Kravchenko, A.(2019) "The gravity model of international trade": *a user guide [R version].* Bangkok: United Nations ESCAP.

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.
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.
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.
Westurlund, J. and Wilhelmsson, F. (2011) "Estimating the gravity model without gravity using panel data" *Applied Economics* **43**, 641-649.

Appendices

Table A1: List of countries

Algeria, Angola, Benin, Burkina-Faso, Cameroon, Capo Verde, Chad, Congo, Côte d'Ivoire, 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
$Ln(Export)_{ijt}$	19784	29154.52	141330.6	0.001	5382038
Ln of GDP for exporting country $_{it}$	19784	10.242	1.033	0	11.680
Ln of GDP for exporting country $_{ij}$	19784	10.208	1.056	0	11.680
Ln of Population of exporting country $_{it}$	19784	7.131	0.535	5.586	8.303
Ln of Population of exporting country $_{jt}$	19784	7.116	0.539	5.586	8.303
Ln of Distance (in km) $_{ijt}$	19784	3.402	0.317	1.853	3.941
Border	19784	0.111	0.314	0	1
Language	19784	0.500	0.500	0	1
Colonial origin	19784	0.363	0.480	0	1
Internet (% of population)$_{it}$	19784	8.41208	13.7907	0	74.376
Broadband (per 100 people) $_{it}$	19784	0.499	1.310	0	10.204
Fixed phone (per 100 people)$_{it}$	19784	2.831	4.026	0	23.948
Mobile phone (per 100 people)$_{it}$	19784	44.847	45.477	0	175.872
Internet (% of population)$_{jt}$	19784	8.228	13.600	0	74.376
Broadband (per 100 people)$_{jt}$	19784	0.484	1.285	0	10.204
Fixed phone (per 100 people)$_{jt}$	19784	2.763	3.990	0	23.948
Mobile phone (per 100 people)$_{jt}$	19784	44.135	45.216	0	175.872

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*