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Eudoxie BESSAN  
and  
Christian AYEDOUN

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# **The role of ICTs in bilateral trade in sub-Saharan Africa: A gravity model analysis**

*By*

*Eudoxie BESSAN*

*University of Abomey-Calavi*

*&*

*Christian AYEDOUN*

*Centre d'Expertise en Evaluation du Développement*

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# Abstract

This paper aims to analyze the impact of information and communication technologies (ICTs) on bilateral trade flows among sub-Saharan African (SSA) countries. Utilizing an extended ICT gravity model, the study explores how key ICT indicators influence exports, imports, and trade in manufactured goods. The analysis covers a sample of 35 countries over the period from 2010 to 2019. To address potential over-representation of zero trade flows, the Poisson Pseudo-Maximum Likelihood (PPML) estimator is employed. The findings reveal that ICT development, particularly access to mobile telephony, mitigates the effect of distance on trade by facilitating intra-African trade flows. However, the limited availability of ICT infrastructure, especially restricted Internet access, means that physical distance remains a significant barrier to trade. Based on these insights, the study recommends strategic investments in ICT infrastructure and innovation, aimed at reducing transaction costs and improving ICT accessibility. Enhanced regional economic integration is also suggested as a pathway to facilitate these improvements and strengthen trade networks among SSA countries.

**Keywords:** ICT, Bilateral trade, Panel gravity model, SSA.

**JEL classification codes:**

# 1. Introduction

The post-2000s period has seen remarkable changes in the development of Information and Communication Technologies (ICTs)<sup>1</sup>. ICTs in general, and the internet in particular, have contributed significantly to the globalization of the economy by facilitating the cross-border flow of ideas, knowledge, expertise and innovations (Choi, 2010; Ozcan, 2018). Indeed, the significant increase in global trade has coincided with unprecedented advances in ICT. Over time, the relationship between ICT and trade and advances in the ICT sector have revived discussions in the research community about the 'death of distance' (Freund & Weinhold, 2002; Demirkan et al., 2009). The evolution of the ICT sector has removed barriers to mobility and inaccessibility to information, so that entrepreneurs and small businesses now have better access to international markets, allowing them to expand their customer base, increase scale and boost profits (Vemuri & Siddiqi, 2009; Xing, 2018; Ozcna, 2018). ICTs could play an important role in strengthening countries' trade ties by compensating for the absence of strong historical trade ties. Thus, several authors agree that countries that invest more in their ICT infrastructure can overcome these barriers and increase the volume of their bilateral trade with their trading partners (Pradhan et al., 2017; Ozcna, 2018; Bessan Ayédoun & Ayédoun, 2020).

The relationship between ICT and trade has long been a subject of debate in economic literature. Three main analyses can be deduced. First, the development of ICTs is said to have cancelled out the argument of physical distance as an obstacle to trade (Demirkan et al. 2009; Ozcan, 2018). Thus, the debate on the 'death of distance' has been current in showing that proximity could no longer be a requirement or a necessary condition for face-to-face interaction between trading partners as ICT innovations such as telephone, email, and virtual conferencing have become substitutes for face-to-face interactions (Dettmer, 2014; Nath, 2017). Second, the mechanisms by which ICTs can affect the flow of international trade (Liu & Nath, 2013; Xing, 2017)

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<sup>1</sup> ICT is a term that includes any communication device or application such as radio, television, mobile phones, computers, network hardware and software, etc., as well as various related services and applications such as videoconferencing and distance learning (see <http://searchcio.techtarget.com/definition/ICT-information-and-communications-technology-or-technologies>).

make markets more competitive and efficient by improving information flows and lowering transaction costs, such as fixed market entry costs, communication and information costs, and negotiation and coordination costs associated with trade (Jungmittag & Welfens, 2009; Park & Koo, 2005). Third, regarding communication costs, telecommunications create a means of maintaining fast, cheaper and efficient communication with trading partners to maintain business competitiveness (Bankole et al., 2015). All these explanations indicate that there would be a positive impact of ICT on trade between countries.

However, the performance of sub-Saharan Africa has steadily deteriorated. The integration of these countries into world trade is extremely low. According to the WTO (2021) report, African trade in goods and services represents on average around 3% of world exports and imports. In 2019, African countries' exports and imports in merchandise trade amounted to US\$462 billion and US\$569 billion, respectively. This represented an average decrease of 3% compared to 2018. Between 2005 and 2019, Africa's exports of commercial services almost doubled in value. This picture is incomplete, however, as the continent's exports are mainly driven by one region. North Africa accounts for around a third of all African trade in goods and services, despite encompassing just five of the continent's 55 countries. However, the share of exports from sub-Saharan Africa has risen steadily and now accounts for 70% of all African exports of goods and services. The manufacturing sector contributes only 10% to Africa's GDP, compared with 20% in East Asia and the Pacific, and 15% in Latin America and the Caribbean. On the other hand, the share of intra-regional trade in sub-Saharan Africa's total trade will not exceed 16% in 2019, a level well below that of the developing countries of Asia (around 45%) and Latin America (almost 20%), despite the proliferation of free trade areas and the establishment of two monetary and customs unions.

It is in this context that the development of information and communication technologies (ICTs) has been seen as an effective means of improving the level of sub-Saharan trade. ICTs, and more specifically broadband internet and the mobile industry, now play a leading role in economic development by contributing to the emergence and spread of innovations in trade, agriculture, financial services and transport, and to the modernization of public administrations, particularly tax administrations (World Bank, 2016;

Andrianaivo & Kpodar, 2011; Cariolle et al., 2017). According to data from the International Telecommunication Union (ITU), SSA is clearly lagging in terms of internet penetration among the population, particularly in comparison with East Asia and North Africa. While Asia, South America and North Africa were rapidly connected by CSM<sup>2</sup> to the countries of the North, Sub-Saharan Africa (SSA) remained relatively isolated until 2010. Since then, the digital infrastructure has been rapidly deployed, facilitating access and reducing the cost of broadband internet and mobile telephony. Today, virtually all coastal countries, including those in Africa, are directly connected to the global internet via MSCs. In such a context, can the argument of the death of distance be verified? Given the growth in ICT development in recent decades, what impact has this had on the dynamics of bilateral trade? How can the progress observed in access to and use of ICTs help to increase exports from sub-Saharan African countries? Can this progress change the structure of imports, which are heavily weighted towards finished products and make a major contribution to the trade deficit?

The objective of this work is to analyze the impact of ICT on bilateral trade in SSA for the period 2010-2019 using an augmented gravity model. More specifically, it will (i) determine the effect of distance on trade in the presence of ICT growth and (ii) identify trade flows and the role of regional trade agreements in the presence of ICT. The paper adds to the literature in several important ways, particularly in the context of sub-Saharan Africa. Firstly, as the measurement of ICT development is constantly improving, it can be expected that more recent data will provide more relevant and accurate information than previous data. These improvements could offer a relatively new and better insight into how the ICT environment affects business performance. Secondly, the paper will reveal which ICT indicators are most relevant to trade flows and what measures need to be implemented to bring about the required improvements.

The empirical approach taken in this work is based on a gravity model that links ICT indicators to bilateral trade flows. Two main indicators are selected: access to mobile phones and the number of internet users. Additional controls include traditional gravity variables, such as GDP, population, distance, tariffs,

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<sup>2</sup> Submarine fibre-optic cables (CSM)

languages, and border. The gravity model is estimated at an aggregate level (based on aggregate annual bilateral trade flows between 35 countries over a period from 2010 to 2019 using the Poisson pseudo-maximum likelihood method, thus considering zero trade flows and multilateral resistance terms. The rest of the paper proceeds as follows. Section 2 provides stylized facts, while Section 3 sets out the literature review. Section 4 sets out the research methodology, explaining the variables we use in our analysis and detailing our data sources. Sections 5 and 6 present the results of this research and the bibliographical references, respectively.

## **Stylized facts**

In recent years, sub-Saharan African countries have put in place a series of economic policy measures aimed at controlling economic aggregates and increasing openness to the outside world. These efforts have resulted in sustained economic growth in most of these countries, notwithstanding the economic and financial crisis of 2008/2009, followed by deteriorating economic growth rates in 2011 and 2016. Over the period spanning 2000 to 2020 (Figure 1), both import and export flows to SSA have followed a rollercoaster pattern. Between 2000 and 2004, there was a steady decline in trade flows, and the same trend was observed between 2011 and 2017. Over the latter period, economic growth fell from 4.2% in 2010 to 2.2% in 2011, because of the slowdown in growth in Nigeria and South Africa<sup>3</sup>. Similarly, the regional and global crises of 2016 slowed the pace of growth in Africa, where SSA growth stood at 3.1%. This slowdown was largely due to the recession in Nigeria, where growth contracted because of low oil prices and political challenges including delays in adjusting exchange rates. However, there were already signs of recovery in 2017<sup>4</sup>.

In 2017, sub-Saharan Africa's foreign trade in goods (exports and imports of goods) amounted to US\$346.4 billion, corresponding to 40.5% of the region's GDP. In volume terms, exports grew by 4.2% in 2017 compared with 2016, whereas imports grew by 1.0% during the same period. Exports and imports accounted for 43.7% and 56.3% respectively of Africa's trade in goods. Sub-Saharan Africa's trade in goods with the world represents 70% of the continent's total trade in goods with the world. More than three quarters of

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<sup>3</sup> SSA's two largest economies

<sup>4</sup> African Economic Outlook 2018

Africa's exports from the sub-Saharan zone consisted of raw materials (and/or commodities, hydrocarbons or minerals). The importance of manufactured goods in the composition of sub-Saharan Africa's trade in goods (as for Africa as a whole) is mainly explained by imports.

Today, the African continent is still particularly vulnerable to the shock of COVID-19 (WTO, 2021). After the upturn in SSA's foreign trade from 2017 onwards, there was a fall in 2020. Sub-Saharan African countries are therefore highly sensitive to changes in international trade and very vulnerable to trade shocks due to dependence.

**Figure 1: Development of SSA's foreign trade between 2000-2020**



**Source: authors (2021), based on data from WDI, 2021**

Moreover, the region's marginal weight in world trade can be explained by its technological backwardness, among other factors. Nevertheless, digital connectivity is increasing rapidly in sub-Saharan Africa<sup>5</sup>. Although the global digital divide remains wide, the gap with the rest of the world is narrowing rapidly<sup>6</sup>. There are also considerable disparities within countries. Most rural communities do not have access to the internet (even with mobile devices). In 2019, revenues from online commerce grew by an average of 24% in sub-Saharan Africa, and active online payment users represented a quarter of the region's population, compared with at least half the population in all other regions and 90% in advanced countries. Here too, there are major disparities within the region. While more than half the population uses e-commerce in

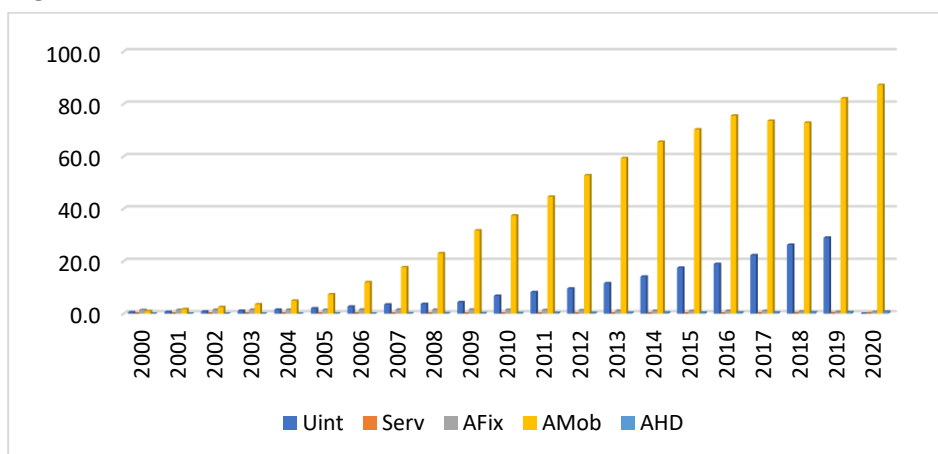
<sup>5</sup> Regional Economic Outlook: Sub-Saharan Africa

<sup>6</sup> For an overview of Asia's digital transformation, see the chapter "The Digital Revolution in Asia: Disruptor or New Growth Engine (or Both)?" in the October 2018 edition of the IMF's Regional Economic Outlook: Asia and the Pacific.

some countries (Botswana, Gabon, Nigeria and South Africa), in others the proportion remains below 15% (Chad, Democratic Republic of Congo, Malawi, Niger and Sierra Leone).

Furthermore, over the period spanning 2000 to 2020, there has been regular and sustained growth in indicators relating to internet users and mobile phone access. On the other hand, the wired broadband network and access to fixed telephony have been drastically reduced. Internet penetration in the region has increased tenfold since the beginning of the first decade of 2000, compared with a threefold increase in the rest of the world<sup>7</sup>. The proliferation of mobile technologies (Figure 2) is particularly marked in sub-Saharan Africa, where most people access the internet on their mobile rather than via the wired broadband network. The region, however, continues to lag the rest of the world. Mobile connectivity remains poor, with the average mobile download speed in the region at 7.4 Mbps, three times slower than in the rest of the world<sup>8</sup>. It is also characterised by low internet penetration, particularly broadband, poor mobile phone network coverage, and high telecoms pricing (ITU, 2016; World Bank, 2016, Cariolle and Goujon; 2019).

**Figure 2: evolution of ICT indicators in SSA between 2000-2020**



Source: authors (2021), based on data from ITU, 2021

<sup>7</sup>Internet penetration is measured as the percentage of the population that uses the internet. In 2017, it stood at 24% in sub-Saharan Africa, compared with 64% in the rest of the world.

<sup>8</sup> Download speeds vary widely across sub-Saharan Africa, from 14-20 Mbps in Botswana and South Africa to around 2.5 Mbps in the Democratic Republic of Congo and Liberia.

## 2. Literature review

### International trade theory and the gravity model

The idea that trade is a vital factor in a country's economic growth is not new and dates to Adam Smith (1776) in his book *"An Inquiry into the Nature and Causes of the Wealth of Nations"*. In the literature, Smith (1776) often stressed that trade between countries would improve economic productivity by enlarging the size of markets and increasing the scale of economies, thereby increasing economic performance. Ricardo (1821) introduced the theory of comparative advantage, which explained why it is advantageous for two countries to trade, even if one of them may be able to produce both goods or 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 compared with the other. Since then, extensive studies of developing and least developed countries have long focused on how international trade can best contribute to a country's overall economic growth and why countries participate in global trade (Krugman, 2014) in the presence of non-complementary economies and highly differentiated products.

Following a specification reminiscent of Newton's theory of gravitation, gravity models relate bilateral trade to the mass of the two countries (usually measured as the size of the countries involved) and the distance between them. This standard formulation of the model, which is consistent with standard models of international trade, is generally extended to include other factors generally perceived to affect bilateral trade relations. Indeed, the notion of distance relates not only to geographical distance (i.e. transport costs), but also to other factors affecting the transaction made. In addition to or instead of the distance variable, certain other variables can also be used, such as a dummy variable for each of the variables having a common language, a common border, being on the same territory and the same free trade arrangement (Schnatz & Bussi re, 2006). There are several reasons, however, for including distance as an explanatory variable. Batra (2004) cited by Karagoz and Saray (2021) count some of these reasons as follows:

- Distance is a proxy for cost;
- Distance is an indicator of time elapsed during shipment. For perishable goods, the probability of surviving intact is a decreasing function of transit time.

- Synchronisation costs: when plants combine several inputs, their timing must be synchronised to avoid bottlenecks. Synchronisation costs increase with distance.
- Transaction costs: distance can be correlated with the costs of finding business opportunities and establishing trust between potential business partners.
- Cultural distance: greater geographical distance may be correlated with greater cultural differences. Cultural differences can hinder trade in several ways, such as inhibited communication, conflicting negotiation styles, etc.
- To study the magnitude of trade flows between countries, the trade gravity model is considered an effective analytical tool (Tinbergen, 1962; Leamer & Levinsohn, 1995; Anderson & van Wincoop, 2003; Disdier & Head, 2008).

### **Some objections to the gravity model**

Although the empirical results obtained with the model have always been considered good, there are nevertheless a few objections to the model (Karagoz & Saray, 2021). One is the lack of a convincing derivation of the model, based on economic theory. Several authors have attempted to provide the model with a theoretical basis (Anderson, 2016;) and more recently (Deardorff, 1995). However, none of these derivations generated the gravity model in its most general form. It could only be estimated under several restrictive and unrealistic assumptions. Another imperfection of the gravity model is the absence of substitution between flows and the ignorance of the effect of the third country on bilateral trade. In the analysis of international trade, for which the gravity model is frequently used, trade creation and trade diversion are important phenomena (Bikker, 1987). However, there are many empirical applications in the international trade literature that have contributed to improving the performance of the gravity equation. For example, Matyas (1997), Breuss and Egger (1999) and Egger (2000) have improved the econometric specification of the gravity equation.

## **ICT development: what impact on bilateral trade flows?**

Technological advances in telecommunications and the resulting fall in communication costs have often been cited as the main causes of the growth in world trade over the last quarter of the twentieth century (Fink et al., 2005).

During the 1990s, information and communication technologies became a subject of increasing interest to governments and industry (see, for example, Desbois, 1995, Weieman, 1998; Sommers & Carlson, 2000). Following the seminal research of Freund and Weinhold (2002, 2004), several studies have analysed the impact of ICTs on international trade. In addition, many researchers have investigated the influence of information technology on international trade (Chung, Fleming & Fleming, 2013; Clarke, 2002; Clarke & Wallsten, 2006; Elitan, 2015; Sung & Song, 2015; Liu & Nath, 2017; Xing, 2017; Ozcan; 2018).

It is widely recognised that trade is a crucial factor in economic growth. For developing and least developed countries, revenues from the export of their goods and services to the global North are seen as a vital source of foreign exchange that eases pressure on the balance of payments and creates employment opportunities (Thangavelu & Rajaguru, 2004). They find that a 10% increase in internet adoption leads to a 0.2 percentage point increase in merchandise trade. Similarly, Vemuri and Siddiqi (2009), applying the panel gravity model framework, examining the impact of ICTs on bilateral trade between 64 countries for the years 1985 to 2005 and finding a positive and significant impact of ICTs on international trade. In fact, a 10% increase in internet use leads to a 2% increase in bilateral trade. In the same vein, Tang (2006), studies how the use of different means of telecommunications affects the US imports of differentiated goods from 1975 to 2000. Using a fixed-effect model approach, the study finds that adoptions of fixed telephones, mobile phones and internet connections between exporting countries have a significant impact on US imports of differentiated goods, indicating that a 10% increase in the rate of internet adoption by exporters increases total merchandise exports to the US by 1%. Yushkova (2014) uses the Business Internet Usage Index to estimate the effect of the internet on total exports of goods in 2011 for 40 countries (OECD countries plus Brazil, China, India, Indonesia, Russia and South Africa). The study finds that internet use in the business communities of exporting and importing countries is positively related to export flows between these countries. While Choi (2010) reports that a doubling of internet use would increase a country's services exports by 2% to

4% among 151 countries from 1990 to 2006. Furthermore, Liu and Nath (2013) find that internet subscriptions and internet hosts are positively and significantly related to trade performance in 40 emerging market economies between 1995 and 2010.

In the related literature, a few recent studies use panel data gravity models to estimate the impact of ICT on trade. The panel data study by Lin (2015) estimates the impact of internet users on bilateral trade of 200 countries from 1990 to 2006 in a gravity model. Internet use has a positive and statistically significant effect on international trade, and its effect on exports is stronger than that on imports. Choi (2010) also uses internet users to study the impact of ICTs on trade in services for 151 countries from 1990 to 2006 and finds that an increase in the number of internet users boosts total trade in services, as well as the export and import of services.

Furthermore, using a panel gravity model, Ahmad et al (2011) use different indicators as proxies for ICTs and investigate their impacts on bilateral trade between Malaysia and its 36 trading partners from 1980 to 2008. The results favor the positive and significant impacts of ICTs on bilateral trade. In another study, Freund and Weinhold (2004) examine the impact of the internet on bilateral merchandise trade between 56 countries from 1995 to 1999, first using a theoretical model and then using both a cross-sectional and a panel data gravity model. They find that the internet stimulates bilateral trade between countries. However, instead of using one or more indicators of telecommunication infrastructure development at a time, some studies have developed global composite indices or ICT sub-indices to limit multicollinearity problems. Among them we have Ozcan (2018), who using a panel data gravity model, examines the effects of four ICT indices on Turkish bilateral exports and imports for the period 2000-2014. The sample includes 35 countries that import Turkish products and 34 countries that export products to Turkey. The results indicate that ICTs have a positive and significant impact on Turkish import and export volumes. Moreover, ICTs have a quantitatively greater effect on imports than on exports. Mattes et al (2012) analyze the impact of the ICT development index on trade within the European Union (EU) and between the EU and its main trading partners for the period ranging from 1995 to 2007. The results indicate that ICTs have a significant impact on inter and extra European trade. In another study, Liu and Nath (2013) estimate the effect of ICTs on exports and imports in 40 emerging markets from 1995 to

2010. Their results show that internet subscriptions and internet hosts have significant positive effects on exports and imports.

In contrast, for a similar ICT development index also used by Liu and Nath (2017), applying a dynamic panel data model to examine the effects of ICT on exports and imports of 10 service categories for 49 countries from 2000 to 2013, the results suggest that ICT development only affects trade for a limited number of services. Timmis (2012) uses a panel gravity model to assess the role of internet adoption on trade in 34 OECD countries over the period spanning 1990 to 2010. He finds that the internet has a less clear-cut impact on international trade. As a result, using cross-sectional data on total exports of goods in 2001 for 26 developed and 72 developing countries, Clarke and Wallsten (2006) find that greater Internet penetration favors trade flows from developing to developed countries, but no significant effect is found when the trade flow is from developed to developing countries. To test whether internet use affects exports, Clarke and Wallsten (2006) used national data to assess whether internet availability increased trade and, in this respect, compared developed and developing countries. They found that higher internet penetration in developing countries was correlated with increased exports to industrialized countries, but not with trade between developing countries or exports from industrial countries.

### **ICTs and bilateral trade: what mechanisms of action?**

Analysis of previous work shows that ICTs create or improve trade. Indeed, as far as fixed market entry costs are concerned, thanks to organized exchanges with several buyers and sellers on the Internet and through powerful search engines enabling buyers and sellers to find each other at low cost, ICTs have the potential to reduce fixed entry costs, such as those of research, advertising and establishing a distribution network on a market (Freund and Weinhold 2004; Lin 2015).

In terms of communication costs, telecommunications create a means of maintaining fast and efficient communication with trading partners to maintain business competitiveness (Bankole et al. 2015). In addition, cheaper and faster communication can stimulate business transactions and expand the radius of international trade (Jungmittag & Welfens, 2009). In summary, in the case of information costs, ICT is a low-cost channel for collecting, processing and disseminating information. It also leads to improved welfare by reducing information asymmetries, as all members of a given exchange share the same information (Ahmad et al. 2011; Freund & Weinhold, 2004). In addition,

information acquisition and transmission times are reduced, and planning is more efficient and accurate thanks to advances in ICT (Liu & Nath, 2013; 2017).

### 3. Research methodology

#### Model and variable definition

This study uses an augmented version of the gravity model as a standard analytical tool for predicting bilateral trade flows. Gravity models are commonly used to predict bilateral trade flows in international trade. Using gravity models, researchers have mainly examined the effects of economic size and distance to analyze bilateral trade flows between countries (Tingergen, 1962; Poyhonen, 1963; Freund & Weinhold, 2004; Fink et al., 2005; Krugman & Obstfeld, 2000; Clarke & Wallsten, 2006; Chung et al., 2013). Krugman & Obstfeld (2000). Based on Newtown's law of universal gravitation, the basic form of the gravity model can be expressed as follows:

$$T_{ij} = A \cdot \frac{(Y_i \times Y_j)^{\alpha}}{D_{ij}^{\gamma}} \quad (1)$$

Where  $T_{ij}$  is the volume of bilateral trade between country  $i$  and country  $j$ ;  $A$  is a constant;  $Y_i$  and  $Y_j$  are the economic sizes of country  $i$  and  $j$ ;  $D_{ij}$  is the distance between the countries.

Tinbergen (1962) was the first to propose a gravity equation for bilateral trade as an empirical specification, of course taking cues from Newton's universal law of gravitation. In the gravity model of international trade, bilateral trade flows between countries are positively related to the size of the markets (economic masses) of the exporting and importing economies and negatively related to the distance between these countries. Furthermore, GDP is used as an indirect indicator of the size of the economy and should have a positive coefficient. Distance between countries is expected to have a negative impact on bilateral trade due to higher transport costs. The original version of the gravity model in Tinbergen (1962) is defined in log-log form so that the parameters are the elasticities of trade flows with respect to the explanatory variables. The variables in our model are like those in the studies by Ozcan (2018); Xing (2018) and Liu and Nath (2017). On this basis, we specify our model in Eq. (2) as an extended version of the original gravity equation.

$$\ln Y_{ijt} = \alpha_0 + \alpha_1 \ln \text{Distance}_{ij} + \alpha_2 \text{Frontiere}_{ij} + \alpha_3 \text{ComLang\_of}_{ij} + \alpha_4 \text{ComCol}_{ij} + \alpha_5 \text{ComLang\_ethno}_{ij} + \alpha_6 \text{ComLRelig}_{ij} + \alpha_7 \ln \text{POP}_{it} +$$

$$\alpha_8 \ln POP_{jt} + \alpha_9 \ln PIB_{it} + \alpha_{10} \ln PIB_{jt} + \alpha_{11} ACR_{ij} + \alpha_{12} wto_i + \alpha_{13} wto_j + \alpha_{14} \ln UseInt_{it} + \alpha_{15} \ln UseInt_{jt} + \alpha_{16} \ln ACMOB_{it} + \alpha_{17} \ln ACMOB_{jt} + \beta_i + \gamma_t + \varepsilon_{ijt} \quad (2)$$

Where the two countries (i and j) are sub-Saharan African countries. t refers to the period and  $\alpha_k$  the semi-elasticities. Moreover,  $\beta_i$  and  $\gamma_t$  are individual (country) and time effects and  $\varepsilon_{ijt}$  is an error term that is assumed to be normally distributed with zero meaning.

**lnYijt** denotes the volume of exports (respectively imports/manufacturing) from country i to country j during period t.

**lnDistance<sub>ij</sub>** is the weighted distance between country of origin i and country of destination j based on the bilateral distances between the largest cities of the two countries. Border is a dichotomous variable that takes 1 if the countries border each other

**Ln (PIB<sub>it</sub> x PIB<sub>jt</sub>)** is the GDP mass that measures the real GDP of country i and country j in period t. It should have positive effects on exports and imports.

Ln (POP<sub>it</sub> x POP<sub>jt</sub>) is the population mass which is used as an indicator of the size of the country and measures the populations of country i and country j during period t. The impact of population on exports is not clear a priori (see Liu and Nath 2013). Because a growing population can increase domestic output and exports by increasing labor supply. However, by creating domestic demand, it may also reduce exports. Nor is its impact on imports certain. On the one hand, increasing domestic demand may increase demand for imports. On the other hand, the country may decide to produce locally instead of importing, which will lead to a decrease in the volume of imports.

**ACR<sub>ij</sub>** and **wto<sub>ij</sub>** are introduced for a complete analysis, to consider the effects of Regional Trade Agreements.

**Ln (MOB<sub>it</sub> x MOB<sub>jt</sub>)** measures mobile phone subscriptions (per 100 inhabitants) in country i and country j during period t and is expected to have positive impacts on exports and imports.

**ln (UseInt<sub>it</sub> \* UseInt<sub>jt</sub>)** denotes the number of internet users (as a % of the population) in country i and country j during period t and is expected to have a positive impact on exports and imports.

The binary variables in Equation (2) are included in the gravity model to capture trade costs, such as transport costs and information costs (Nordas & Piermartini 2004). Among them, common borders are used to reflect shipping

costs which are higher for landlocked and island countries and lower for neighbouring countries. In addition, binary variables such as common official and ethnic language and religion, indicate the cultural proximity between countries and capture the information costs that go with sharing a common language.

### Estimation methods and data sources

To estimate the gravity model, we use the non-linear Poisson Pseudo Maximum Likelihood (PPML) estimator recommended by Silva and Teneyro (2006) for gravity models, to account for a possible over-representation of null bilateral trade flows, the potential heteroskedasticity bias induced by the log-linear model and bias related to the log transformation of null trade flows.

We use 04 data sources. We use bilateral trade data (exports, imports, manufactures) from COMTRADE (2021). These data describe bilateral trade flows between countries. The data used are aggregated (i.e. total exports), bilateral (i.e. from each country of origin to each country of destination) and annual in frequency. They cover the period 2010-2019 for 35 sub-Saharan African countries. Some countries have been removed from the database due to the unavailability of ICT data. ICT data comes from the International Telecommunication Union (ITU, 2021) and the World Development Indicators (WDI, 2021). Gravity data comes from CEPII's Gravity dataset (2021). Table 1 summarizes the definitions of the variables, the expected signs and their sources. The descriptive statistics for the variables used and the correlations that may exist between the main variables are shown in Tables 3 and 4 in the appendix.

**Table 1: Summary of variables and data sources**

<b>Variables</b>	<b>Definitions</b>	<b>Expected sign</b>	<b>Source of data</b>
<b>Exports<sub>ijt</sub></b>	Trade flow as reported by the exporter (in thousands currents US\$)		Comtrade (2021)
<b>Imports<sub>ijt</sub></b>	Trade flow as reported by the importer (in thousands currents US\$)		Comtrade (2021)

<b>Manufacture<sub>ijt</sub></b>	Trade flow of manufactured goods (in thousands current US\$)		BACI (2021)
<b>Macroeconomics variables</b>			
<b>GDP</b>	GDP (in thousands current US\$)	+	World Development Indicator (WDI 2021) de la Banque mondiale
<b>POP</b>	Population	+/-	
<b>TIC's indicators</b>			
<b>ACMOB</b>	Mobile phone subscriptions per 100 people	+	(WDI, 2021)
<b>UserINT</b>	Internet users (% of population)	+	(WDI, 2021)
<b>Indicateurs de la Gravité</b>			
<b>RTA</b>	Regional trade agreements: binary dummy variable which is the unit if there is an RTA.	+	<i>CEPII Gravity Dataset (2021)</i>
<b>Distance</b>	Weighted distance between country i and country j, in km	-	<i>GeoDist / CEPII Gravity Dataset (2021)</i>
<b>Frontière</b>	A binary variable which is the unit if country i and country j share a common border	+	<i>GeoDist / CEPII Gravity Dataset (2021)</i>
<b>ComLangue</b>	Language is a binary variable which is the unit if a language is spoken by at least 9% of the population of country i and country j	+	<i>GeoDist / CEPII Gravity Dataset (2021)</i>
<b>ComRelig</b>	Religious proximity index		<i>CEPII Gravity Dataset (2021)</i>
<b>ComLangue_Ethnie</b>	Ethnicity: is a binary variable which takes the value 1 if	+	<i>GeoDist / CEPII Gravity</i>

Source: Authors

## 4. Results

In this section, we present and comment on the results of the estimation of the gravity model. We regress three models: an export model, an import model and a manufacturing model. For each model, we regress three equations to first isolate the traditional gravity model; second, isolate the gravity model augmented with RTAs and WTO and third, the gravity model augmented with ICT. We assume that ICT reduces distance. The results are shown in Table 2. For comparison, we have regressed the same equations using OLS. The PPMLs offer better estimators. The results are shown in Table 5 in the appendix.

### **Confirmation of the traditional gravity model**

Firstly, the results obtained are consistent with the literature and therefore correspond to the predictions. Indeed, distance has a significant negative impact on bilateral trade, whatever the model and the equation. The estimated coefficient of distance is, however, lower (around 0.260) than the coefficients that hover around unity as found in the work of Njinkeu et al. (2008) and Seck (2017). The effect of distance is stronger for exports and imports than for manufactures, contrary to the results of the work by Kotchoni et al. (2019). In quantitative terms, these results show that 1% increase in distance between two countries leads to a decrease in export and import trade of about 0.230% and 0.226%, respectively, while it is 0.205% for trade in manufactures. These limited effects of distance on trade may be the result of countries' efforts to develop physical infrastructure (ports, roads, airports, etc.) in recent years. These infrastructures are known to facilitate trade between countries (Njinkeu et al, 2008; Portugal-Pérez & Wilson, 2010; Bessan Ayédoun & Ayédoun, 2020). The results also clearly show that there is a positive relationship between the level of bilateral trade and the GDP of each country of origin or destination in all regressed equations for all trade flows. The effect of GDP on exports is more pronounced than on imports and manufactured goods. For example, a 1% increase in GDP in the presence of RTAs and ICTs leads to a 0.205% increase in bilateral exports, compared with 0.165% and 0.158% for imports and

manufactures respectively. This result certainly captures a market effect. Similarly, the effect of the GDP of the country of origin is greater than that of the country of destination. On the other hand, the population effect is negative and significant, thus justifying that population growth can be a factor in increasing local production (Liu and Nath 2013). We also see those countries with a common border and a common colonizer trade much more often in all the equations considered. A common official language is used more in import trade, while a common ethnicity between two countries is favorable for all trade flows, particularly in the presence of regional agreements and ICTs. Indeed, the results show that countries with a common ethnic language trade 56.1% more than others, particularly for manufactured goods. Similarly, when the two countries share a border, their trade improves, particularly for export flows and manufacturing. These results are not surprising, given that most empirical studies on gravity models reveal a positive and significant effect of language and border (Docquier et al., 2016; Coulibaly et al., 2018; Kotchoni et al., 2019; Gnimassoun, 2020).

### **The effect of regional trade agreements on bilateral trade**

In all models, belonging to the same RTA contributes to improving trade and this effect is robust in all equations at 1% significance. However, this effect is more pronounced in the import and manufacturing model. This result is understandable given that the sub-Saharan region has the most RTAs, with between 5 and 20 member economies and a composition that tends to overlap. This overlap will tend to boost trade between countries. In quantitative terms, a 1% increase in trade agreements between two countries increases trade flows by 0.22%, 0.29% and 0.25% respectively for exports, imports and manufactured goods. These results confirm those of authors such as Kotchoni et al. (2019), Njinkeu et al. (2008) and Gnimassoun (2020). Furthermore, the introduction of this variable into the equations shows a small but significant reduction in the effect of distance on trade. Indeed, the effect decreases from 0.23%, 0.22%, and 0.20% to 0.17%, 0.14%, and 0.14%, respectively, for exports, imports, and manufactured products. Regarding WTO membership, although the results show an overall positive effect on trade, this impact is heterogeneous

However, inter-regional trade between African countries remains relatively low. According to data from the United Nations Conference on Trade and Development (UNCTAD), between 2015 and 2017, the share of intra-

continental trade represented 15% of trade, compared with 49% in America, 61% in Asia and 67% in Europe. Intra-regional trade represents between 2% and 11% of total exports, except in the case of SADC, where it represents 19% of exports. The increase in intra-regional trade in sub-Saharan Africa is hampered by obstacles such as inadequate infrastructure and high export and import costs, which prevent African economies from taking full advantage of their proximity to markets. Nevertheless, the entry into force of the African Continental Free Trade Area Agreement (AfCFTA) in January 2021 should help to increase trade in this part of Africa. The AfCFTA is expected to boost intra-African trade by 52.3% by 2025, increase Africa's income to \$450 billion by 2035, according to the IMF, and lift 30 million Africans out of extreme poverty.

### **Effect of ICT development on bilateral trade**

The third equation of each model incorporating the ICT variable of interest, measured here by access to mobile telephony and internet use, leads to two main results: firstly, the development of ICTs has not yet cancelled out the argument of physical distance as an obstacle to trade in sub-Saharan Africa. Efforts still need to be made to ensure that ICT innovations such as the telephone, e-mail, virtual conferencing and e-commerce become substitutes for face-to-face interaction. In fact, the effect of distance remained negative and significant in all the equations even after incorporating the ICT variables. However, the effect of distance on trade flows was potentially reduced after incorporating these variables of interest. In fact, a 1% increase in ICT access would reduce the coefficients from 0.17%, 0.14%, and 0.14% to 0.15%, 0.13%, and 0.12%, respectively, for export, import, and manufactured goods flows. Although these effects are marginal, they indicate the potential for ICTs to reduce the negative effects of distance on trade. Although this result calls into question the argument that distance is dead, efforts to develop ICTs in the sub-continent are still palpable.

Second, the results indicate that ICT access and development have great potential to improve bilateral intra-African trade and that there is a disparity in the effect of ICT on trade. There is a robust positive effect of mobile phone access for all models and a mixed effect of the internet on bilateral trade. In fact, a one-point improvement in mobile access in the country of origin could lead to improvements of 0.157%, 0.096%, and 0.201%, respectively, in the flows of exports, imports, and manufactured goods. In the country of

destination, the effect is still positive, but less pronounced, and less pronounced for import flows.

For the internet user's variable, a 1% increase in the country of origin would lead to a 0.057% drop in exports, while the effect is positive for import flows with a coefficient of 0.021%. The effect is also positive for manufactured goods, but not significant. On the other hand, a 1% improvement in internet users in the destination country would have a negative effect on all flows. As a result, we can see that the effect of ICTs is not unequivocal depending on the category of flow under consideration. Indeed, we can see that the impact of the internet is positive on imports from country *i* to country *j*; whereas for exports from country *i* to country *j*, it is the effect of mobile access that is more pronounced (see Table 3 and 4). In other words, bilateral imports are more sensitive to the improvement in internet access than bilateral exports, which are more sensitive to the development of mobile telephony. These two results are in line with most of the work on the subject, particularly that of Portugal-Pérez and Wilson (2010), which found that the internet has a less clear-cut and negative impact on bilateral trade, particularly for poor countries, whereas the effect is positive for rich countries. This result is also in line with those of Clarke and Wallsten (2006). These authors wanted to analyze whether the availability of the internet increased trade by comparing developed and developing countries. They found that higher internet penetration in developing countries was correlated with an increase in exports to industrialized countries, but not in trade between developing countries or in exports from industrial countries. This result can be explained by the development of internet access in sub-Saharan Africa, which is still characterized by low internet penetration, particularly broadband, poor mobile phone network coverage, and high telecommunications tariffs.

**Table 2 : PPML regression results**

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	lnexports	lnexports	lnexports	lnimports	lnimports	lnimports	lnmanuf_trades	lnmanuf_trades	lnmanuf_trades
Indist	-0.230*** (0.011)	-0.172*** (0.009)	-0.154*** (0.009)	-0.226*** (0.009)	-0.144*** (0.008)	-0.130*** (0.008)	-0.205*** (0.010)	-0.145*** (0.008)	-0.123*** (0.008)
contig	0.249*** (0.014)	0.201*** (0.012)	0.193*** (0.013)	0.250*** (0.014)	0.184*** (0.012)	0.165*** (0.014)	0.263*** (0.015)	0.210*** (0.013)	0.203*** (0.014)
comlang_off	0.019 (0.015)	0.015 (0.014)	-0.018 (0.016)	0.076*** (0.015)	0.080*** (0.014)	0.050*** (0.016)	-0.012 (0.015)	0.003 (0.015)	-0.038** (0.016)
comcol	0.127*** (0.013)	0.086*** (0.012)	0.083*** (0.014)	0.117*** (0.013)	0.059*** (0.012)	0.061*** (0.013)	0.136*** (0.014)	0.081*** (0.013)	0.079*** (0.014)
comlang_ethno	-0.018 (0.012)	0.009 (0.012)	0.051*** (0.014)	-0.001 (0.012)	0.024** (0.012)	0.054*** (0.014)	0.020 (0.013)	0.035*** (0.013)	0.075*** (0.014)
comrelig	0.211*** (0.039)	0.125*** (0.039)	0.114*** (0.040)	-0.006 (0.040)	-0.126*** (0.040)	-0.121*** (0.041)	-0.009 (0.040)	-0.128*** (0.039)	-0.117*** (0.039)
lnpop_i	-0.071*** (0.005)	-0.058*** (0.005)	-0.035*** (0.009)	-0.095*** (0.005)	-0.085*** (0.005)	-0.027*** (0.008)	-0.074*** (0.006)	-0.073*** (0.005)	-0.010 (0.009)
lnpop_j	-0.028*** (0.005)	-0.020*** (0.005)	-0.016** (0.008)	-0.024*** (0.005)	-0.008 (0.005)	-0.037*** (0.008)	-0.031*** (0.006)	-0.032*** (0.006)	-0.051*** (0.008)
lngdp_i	0.211*** (0.005)	0.204*** (0.005)	0.199*** (0.009)	0.219*** (0.005)	0.212*** (0.005)	0.165*** (0.008)	0.209*** (0.005)	0.208*** (0.005)	0.158*** (0.009)
lngdp_j	0.121***	0.117***	0.125***	0.140***	0.130***	0.166***	0.131***	0.131***	0.167***

	(0.005)	(0.005)	(0.007)	(0.005)	(0.005)	(0.008)	(0.005)	(0.005)	(0.007)
rta		0.222***	0.245***		0.295***	0.318***		0.254***	0.280***
		(0.013)	(0.013)		(0.012)	(0.013)		(0.012)	(0.012)
wto_i		0.178***	0.096***		0.213***	0.137***		0.094***	-0.011
		(0.023)	(0.029)		(0.024)	(0.029)		(0.022)	(0.027)
wto_j		0.078***	0.004		0.224***	0.140***		0.137***	0.074***
		(0.025)	(0.027)		(0.029)	(0.034)		(0.025)	(0.027)
lnUseINT_i			-0.057***			0.021**			-0.012
			(0.010)			(0.010)			(0.010)
lnUseINT_j			-0.071***			-0.094***			-0.110***
			(0.009)			(0.010)			(0.009)
lnAcMOB_j			0.134***			0.101***			0.156***
			(0.017)			(0.018)			(0.017)
lnAcMOB_i			0.157***			0.096***			0.201***
			(0.019)			(0.019)			(0.018)
Constant	-1.058***	-1.860***	-3.077***	-1.418***	-2.532***	-3.245***	-1.332***	-2.080***	-3.524***
	(0.111)	(0.109)	(0.141)	(0.111)	(0.103)	(0.141)	(0.115)	(0.108)	(0.145)
Observations	7,676	7,676	6,218	8,333	8,333	6,822	7,540	7,540	6,421
R-squared	0.450	0.498	0.518	0.433	0.498	0.510	0.432	0.483	0.511

Source: Authors, Robust standard errors in parentheses \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

## 5. Conclusion

In this study, we conducted a macroeconomic analysis using the gravity model to investigate trade flows between sub-Saharan African countries, considering the role of ICT and testing the "death of distance" hypothesis over the 2010-2019 period. The results, derived from the PPML (Poisson Pseudo-Maximum Likelihood) estimator, reveal several significant insights. First, factors such as geographic distance, a shared language (both official and ethnic), a common colonizer, and shared religion are key determinants of bilateral trade. Specifically, trade decreases as the distance between countries increases. Second, the existence of regional trade agreements (RTAs) substantially boosts trade flows, particularly for imports and manufactured goods. The findings indicate that trade between two countries becomes more dynamic when they are part of an RTA or are members of the WTO, reducing the negative impact of distance on trade. Lastly, regarding the "death of distance" hypothesis, the development of ICT has not completely overcome the barrier of physical distance in sub-Saharan Africa. While improved access to mobile telephony positively affects trade volumes, limited Internet access—a crucial element for the growth of e-commerce—means that physical distance remains a significant obstacle to trade. To address this, technological innovation must be further advanced to help sub-Saharan African countries mitigate geographic barriers. Additionally, strengthening regional integration is essential to enhance trade networks, improve market efficiency, and lower transaction costs. Implementing the African Continental Free Trade Area (AfCFTA) presents a viable solution, but success depends on collective efforts by African nations to eliminate barriers hindering its effective implementation.

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# Appendix

**Table 3 : Descriptive statistics**

Variable	Obs	Mean	Std0, Dev0,	Min	Max
lnexports	7,751	60,692632	30,550905	0,0010005	150,445
lnimports	8,409	60,150332	30,489685	0,0049875	150,73373
lnmanuf_tr~s	7,662	60,319932	30,400316	0,0010005	150,25352
contig	12,250	0,1036735	0,3048489	0	1
lndist	12,250	70,894108	0,7625916	20,349373	90,112163
comlang_off	12,250	0,5363265	0,498699	0	1
comlang_et~o	12,250	0,4359184	0,4958968	0	1
comcol	12,250	0,282449	0,450209	0	1
comrelig	12,250	0,1426727	0,1266328	0	0,8
wto_o	12,250	0,9571429	0,2025432	0	1
wto_d	12,250	0,9412245	0,2352137	0	1
rta	12,250	0,3542857	0,4783158	0	1
lnpop_i	12,145	90,345872	10,465395	40,470964	120,21088
lnpop_j	12,148	90,31856	10,452857	40,470964	120,21088
lngdp_j	12,148	160,44433	10,36305	130,65196	200,15851
lngdp_i	12,145	160,4999	10,342758	130,65196	200,15851
lnUseINT_i	11,165	20,415648	10,07586	-0,5447271	40,317488
lnUseINT_j	11,196	20,400884	10,073441	-0,5447271	40,317488
lnAcMOB_j	11,806	40,26542	0,5205123	20,751871	50,289035
lnAcMOB_i	11,865	40,269663	0,5250778	20,751871	50,289035

**Table 4: Correlation test between the main variables**

	lnexpo~s	contig	lndist	comlan~f	wto_o	wto_d	rta	lnpop_i	lnpop_j	lngdp_j	lngdp_i	lnUseI~i	lnUseI~j	lnAcMO~j	lnAcMO~i
lnexports	1.0000														
contig	0.4534	1.0000													
lndist	-0.4724	-0.5699	1.0000												
comlang_off	0.0302	0.0636	-0.0020	1.0000											
wto_o	0.1112	0.0668	-0.1041	-0.0186	1.0000										
wto_d	0.0877	0.0627	-0.0569	-0.0399	-0.0244	1.0000									
rta	0.3951	0.4165	-0.6203	0.0697	0.0465	-0.0012	1.0000								
lnpop_i	0.2217	0.0494	-0.0438	-0.1535	-0.0708	0.0035	-0.0590	1.0000							
lnpop_j	0.1315	0.0581	-0.0304	-0.1402	0.0136	0.0730	-0.0461	-0.0562	1.0000						
lngdp_j	0.2114	0.0243	0.0288	-0.0804	0.0128	0.1239	-0.0591	-0.0656	0.7138	1.0000					
lngdp_i	0.3729	0.0057	0.0759	-0.1058	-0.0411	0.0067	-0.0949	0.7068	-0.0731	-0.0691	1.0000				
lnUseINT_i	0.1600	-0.0611	0.1286	0.0583	0.0360	0.0388	0.0118	-0.2168	0.0003	0.0362	0.3484	1.0000			
lnUseINT_j	0.0855	-0.0413	0.0820	0.0831	0.0158	0.0648	0.0236	-0.0093	-0.1782	0.3535	0.0534	0.3350	1.0000		
lnAcMOB_j	0.0960	-0.0159	0.0650	0.0945	-0.0015	0.1544	-0.0086	-0.0042	-0.3452	0.1813	0.0249	0.2050	0.7761	1.0000	
lnAcMOB_i	0.1790	-0.0196	0.0696	0.0773	0.2378	0.0115	-0.0048	-0.3627	0.0074	0.0225	0.1900	0.7795	0.2205	0.1324	1.0000

	lnmanu~s	contig	lndist	comlan~f	wto_o	wto_d	rta	lnpop_i	lnpop_j	lngdp_j	lngdp_i	lnUseI~i	lnUseI~j	lnAcMO~j	lnAcMO~i
lnmanuf_tr~s	1.0000														
contig	0.3973	1.0000													
lndist	-0.4363	-0.5642	1.0000												
comlang_off	-0.0006	0.0628	0.0075	1.0000											
wto_o	0.0724	0.0621	-0.0943	-0.0241	1.0000										
wto_d	0.1175	0.0565	-0.0812	-0.0359	-0.0280	1.0000									
rta	0.3909	0.4167	-0.6075	0.0204	0.0155	0.0027	1.0000								
lnpop_i	0.2189	0.0742	-0.0561	-0.1795	0.0566	0.0016	-0.0067	1.0000							
lnpop_j	0.1797	0.0784	-0.0737	-0.1986	-0.0013	0.1573	0.0070	-0.0369	1.0000						
lngdp_j	0.2571	0.0129	0.0153	-0.1433	-0.0005	0.1279	-0.0506	-0.0446	0.7319	1.0000					
lngdp_i	0.3811	0.0026	0.0203	-0.1369	0.0121	0.0110	-0.0510	0.7257	-0.0416	-0.0565	1.0000				
lnUseINT_i	0.2241	-0.0823	0.0944	0.0445	-0.0418	0.0460	0.0034	-0.1816	0.0103	0.0258	0.3500	1.0000			
lnUseINT_j	0.0878	-0.0777	0.1139	0.0553	0.0185	-0.0060	-0.0118	0.0072	-0.1867	0.3389	0.0288	0.2783	1.0000		
lnAcMOB_j	0.1195	-0.0354	0.0654	0.1008	-0.0008	0.0989	-0.0121	0.0078	-0.3278	0.1729	0.0154	0.1914	0.7868	1.0000	
lnAcMOB_i	0.2133	-0.0434	0.0537	0.0814	0.1375	0.0168	-0.0072	-0.3373	-0.0034	0.0033	0.1664	0.7779	0.1880	0.1283	1.0000

**Table 5: Estimation results based on MCOs.**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	lnexport	lnexport	lnexport	lnimport	lnimport	lnimport	lnmanuf_trade	lnmanuf_trade	lnmanuf_trade
lndist	-1.829*** (0.051)	-1.338*** (0.057)	-1.219*** (0.062)	-1.662*** (0.052)	-0.978*** (0.058)	-0.906*** (0.063)	-1.600*** (0.049)	-1.094*** (0.054)	-0.954*** (0.056)
contig	2.340*** (0.115)	2.138*** (0.113)	2.056*** (0.124)	2.276*** (0.120)	1.974*** (0.117)	1.782*** (0.128)	2.238*** (0.116)	1.995*** (0.113)	1.911*** (0.121)
comlang_off	0.130 (0.102)	0.074 (0.107)	-0.085 (0.119)	0.521*** (0.105)	0.477*** (0.107)	0.317*** (0.119)	-0.076 (0.108)	-0.061 (0.111)	-0.292** (0.117)
comcol	0.685*** (0.084)	0.482*** (0.084)	0.401*** (0.093)	0.603*** (0.085)	0.297*** (0.084)	0.259*** (0.092)	0.689*** (0.084)	0.431*** (0.084)	0.377*** (0.089)
comlang_ethno	0.040 (0.093)	0.194** (0.096)	0.470*** (0.109)	0.182* (0.095)	0.366*** (0.096)	0.579*** (0.109)	0.259** (0.101)	0.377*** (0.103)	0.634*** (0.109)
comrelig	0.896*** (0.286)	0.442 (0.282)	0.363 (0.298)	-0.543* (0.281)	-1.137*** (0.272)	-1.098*** (0.287)	-0.763*** (0.258)	-1.438*** (0.254)	-1.381*** (0.261)
lnpop_i	-0.429*** (0.032)	-0.350*** (0.032)	-0.205*** (0.055)	-0.628*** (0.031)	-0.582*** (0.030)	-0.242*** (0.051)	-0.506*** (0.033)	-0.490*** (0.033)	-0.107** (0.051)
lnpop_j	-0.196*** (0.032)	-0.152*** (0.032)	-0.127** (0.053)	-0.117*** (0.031)	-0.038 (0.030)	-0.198*** (0.051)	-0.223*** (0.033)	-0.219*** (0.032)	-0.336*** (0.051)
lngdp_i	1.442*** (0.034)	1.415*** (0.034)	1.399*** (0.057)	1.494*** (0.034)	1.472*** (0.032)	1.227*** (0.051)	1.422*** (0.032)	1.416*** (0.031)	1.132*** (0.050)
lngdp_j	0.860***	0.835***	0.903***	0.895***	0.844***	1.062***	0.877***	0.872***	1.100***

	(0.032)	(0.032)	(0.052)	(0.033)	(0.032)	(0.051)	(0.032)	(0.031)	(0.049)
rta		1.375***	1.604***		1.889***	2.093***		1.592***	1.808***
		(0.081)	(0.091)		(0.081)	(0.091)		(0.079)	(0.085)
wto_i		0.989***	0.524***		1.173***	0.747***		0.461***	-0.133
		(0.148)	(0.175)		(0.151)	(0.179)		(0.143)	(0.164)
wto_j		0.489***	0.043		1.118***	0.516***		0.694***	0.324**
		(0.138)	(0.156)		(0.140)	(0.163)		(0.127)	(0.139)
lnUseINT_i			-0.345***			0.070			-0.112*
			(0.066)			(0.062)			(0.059)
lnUseINT_j			-0.548***			-0.601***			-0.709***
			(0.062)			(0.064)			(0.059)
lnAcMOB_j			1.028***			0.704***			1.025***
			(0.115)			(0.119)			(0.107)
lnAcMOB_i			0.969***			0.628***			1.262***
			(0.123)			(0.117)			(0.110)
Constant	-12.294***	-18.300***	-27.287***	-14.371***	-22.501***	-27.725***	-12.913***	-18.448***	-28.040***
	(0.703)	(0.765)	(1.040)	(0.737)	(0.786)	(1.036)	(0.695)	(0.736)	(0.982)
Observations	7,676	7,676	6,218	8,333	8,333	6,822	7,540	7,540	6,421
R-squared	0.487	0.508	0.530	0.454	0.492	0.508	0.476	0.505	0.530



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### Contact Us

African Economic Research Consortium  
Consortium pour la Recherche Economique en Afrique  
Middle East Bank Towers,  
3rd Floor, Jakaya Kikwete Road  
Nairobi 00200, Kenya  
Tel: +254 (0) 20 273 4150  
[communications@ercafrica.org](mailto:communications@ercafrica.org)