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Fabrice Nzepang

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RESEARCH ARTICLE

Effects of ICTs on the Terms of Trade of Sub-Saharan African Economies

Fabrice Nzepang[1,2] · **Saturnin Bertrand Nguenda Anya**[1,2]

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Abstract
This paper argues that the increasing adoption of information and communication technologies (ICTs) is a factor that improves the terms of trade of sub-Saharan African (SSA) economies. According to new theories of international trade, ICTs can change the terms of trade by increasing productivity, reducing costs, and increasing human capital endowment and specialization. Here, we use World Development Indicators (WDI) and United Nations Conference on Trade and Development (UNCTAD) data over the period from 2005 to 2017 and a vector autoregression (VAR) model on a panel of 39 SSA countries to illustrate the importance of ICTs in this regard. Our results show that the change in the terms-of-trade index is positively affected by the change in the number of internet users as a percentage of mobile phone subscribers in SSA. Furthermore, an impulse response function shows that a shock that would increase the number of internet users by 10 percent of mobile phone subscribers would result in the terms-of-trade index gains of more than 5% within about a year.

Keywords Terms of trade · Internet · Telephony · Sub-Saharan Africa · Panel VAR

1 Introduction

Information and communication technologies (ICTs) represent a source of skill accumulation that can change the nature of comparative advantage and thereby affect the terms of trade. According to the Prebisch (1950) hypothesis, countries dependent on primary commodity exports should show a worsening in their terms of trade. However, sub-Saharan African (SSA) countries have experienced improved terms of trade over the past two decades, even though they remain heavily dependent on exports of primary commodities

✉ Fabrice Nzepang
fabricenzepang@gmail.com

Saturnin Bertrand Nguenda Anya
nguenduz_144@yahoo.fr

[1] Faculty of Economics Sciences and Applied Management, University of Douala, Douala, Cameroon

[2] Researcher, Research Center on Innovation, Institutions, and Inclusive Development, Douala, Cameroon

whose prices on world markets are particularly volatile. Similarly, these countries are experiencing a growing adoption of ICTs, in particular the internet and telephony, over this period. The Prebisch hypothesis states that the terms of trade have a long-term tendency to depreciate in the Global South compared to the Global North because technical progress that allows raw materials to be saved in the North does not take into account the effects of the diffusion of technology and therefore the diffusion of ICTs in the countries of the South.

ICTs are a crucial component of economic systems, with changes over the past decade that have been significant enough to increase value added in all economic sectors. These changes include lowering the cost of production, increasing output, boosting competitiveness, improving public sector management, and enhancing productive capacity (Chadwick, 2005). ICTs have also stimulated innovation (Oliva et al., 2019), knowledge exchange (Singh et al., 2019), and knowledge management (Al Ahbabi et al., 2019), which are relevant to public and private sector performance. In comparison to the African case concerning frontier economies in the Organisation for Economic Cooperation and Development (OECD) and Asia, which are witnessing saturation levels in ICT penetration, there is more ICT growth potential in African peripheral markets (Penard et al., 2012). In 2010, internet and mobile penetration rates on the African continent were 9.6% and 41%, respectively. The SSA region has the lowest ICT penetration rate, but at the same time, it has the highest ICT growth rate (Penard et al., 2012).

The relationship between ICTs and terms of trade is situated within the framework of new theories of international trade. In this framework, at least two channels make it possible to explain the relationship between ICTs and the terms of trade. The first channel, known as the direct channel, involves the extension of markets and the possibility for suppliers to offer their products to several applicants at the same time through digital channels, enabling them to select the highest bidders, increase their profit margins, and benefit from economies of scale (Maman & Sugiarti, 2016). The second and more important is the indirect channel, which involves the effects of ICTs on improving human capital and reducing the costs of purchasing factors of production. These can modify the nature of comparative advantage and therefore affect the terms of trade. Indeed, ICTs affect the terms of trade by increasing productivity, reducing production costs, enhancing human capital endowment, and directing or determining firm specialization (Caroli & van Reenen, 2001; Porter, 1986, 2009; Renders & Sleuwaegen, 2012; Thapa & Sæbø, 2014; Varian, 2016).

ICTs are relevant to a country's economic prosperity because they help boost the country's productive capacity in many economic sectors (Hong, 2016). In addition, ICTs link a country's production activities to global value chains, increase competitiveness, reduce poverty, and enhance transparency and efficiency in public sector management (Sassi & Goaied, 2013). The importance of ICTs in fostering economic prosperity is also supported by an evolving stream of development literature that focuses on how information technology can be harnessed for positive macroeconomic externalities in Africa (Abor et al., 2018; Tchamyou, 2019). The merit of ICTs in driving the comparative development of SSA relative to other regions of the world is based on the relative importance of ICTs in the subregion compared to other regions. Accordingly, the contemporary IT literature is consistent with the position that there is still significant scope for ICT penetration in SSA compared to other regions of the world that are saturated (Asongu & Odhiambo, 2019). This research extends the underlying strand of the literature by assessing the effects of ICTs on the terms of trade in SSA.

Empirical literature on the effects of ICTs on the terms of trade remains almost entirely absent. Existing studies usually treat terms of trade as an exogenous variable to explain

macroeconomic performance (Choudhri & Schembri, 2010; Deaton & Miller, 1995, 1996; Gbemenou et al., 2019; Idrisov et al., 2016; Reinsdorf, 2010; Spinola, 2020), welfare, inequality, and development (Bowden & Zhu, 2006; Cashin & McDermott, 2003; Hatzipanayotou et al., 2008; Heintz, 2003; Sarkar, 2001; Sen, 1998; Wong, 2010), and trade openness and external balance (Adler et al., 2018; Dion & Létourneau, 1980; Epifani & Gancia, 2009; Erauskin & Gardeazabal, 2017; Gbemenou et al., 2019; Jawaid & Waheed, 2011; Spinola, 2020). Other works have focused instead on terms-of-trade volatility (Baxter & Kouparitsas, 2006; Cashin & McDermott, 2003; Guillaumont & Combes, 2001; Jawaid & Waheed, 2011; Kassouri & Altıntaş, 2020; Kulish & Rees, 2017; Marcy, 1956) or on the relationship between terms of trade and macroeconomic indicators such as exchange rates and business cycles (Adler et al., 2018; Kang, 2019; Kassouri & Altıntaş, 2020; Kulish & Rees, 2017; Spinola, 2020). Yet, for small economies and developing countries specifically, the terms of trade represent an important economic variable for understanding the improvement of people's living conditions, the indebtedness of states, and the level of activity in these economies (Akhand Akhtar, 2008; Erauskin & Gardeazabal, 2017; Sen, 1998). ICTs in particular are now emerging as a lever that SSA countries can use to benefit from international trade.

The objective of this paper is to investigate the effects of ICT on the terms of trade in SSA. The contribution of the paper lies particularly in highlighting the effects of ICTs on the improvement of the terms of trade in SSA, an aspect that remains poorly understood in the literature. This paper has a triple interest. First, it allows us to reposition the terms of trade at the center of development policies. International trade is vital for the development of emerging nations, and terms of trade are a tool to capture maximum gains from international trade. Second, this paper fills a gap in the empirical literature on the role of ICT as a determinant of the terms of trade. Finally, this paper reinforces the place of the digital economy within sub-Saharan economies and promotes the widespread integration of ICTs in all sectors of activities of the sub-Saharan economies. By fostering the emergence and diffusion of innovations in trade, agriculture, financial services, and transport, and by driving the modernization of public administrations (especially tax administrations), the digitalization of the economy has the potential to stimulate growth and employment, reduce poverty, and revolutionize economic exchanges (Cariolle & Goujon, 2019).

The rest of the paper is organized as follows. Section 2 presents the evolution of the terms of trade and ICT adoption in SSA. Section 3 focuses on the methodology. Section 4 reports and discusses the results, and Sect. 5 concludes.

2 Terms of Trade and ICT Developments in SSA

SSA remains highly dependent on exports of primary commodities and natural resources. The region has a very low share in global manufacturing exports (Adams & Akobeng, 2021). However, there is increasing adoption of ICT by SSA economies, although this is low compared to other regions of the world. Moreover, the number of internet users is positively correlated with the terms of trade in SSA (Adams & Akobeng, 2021). Taking the four SSA economic regions separately—namely the Economic Community of West African States (ECOWAS), the Economic Community of Central African States (ECCAS), the Southern African Development Community (SADC), and the East African Community (EAC)—we observe the evolution of the terms-of-trade index and the evolution of the number of internet users as a percentage of the

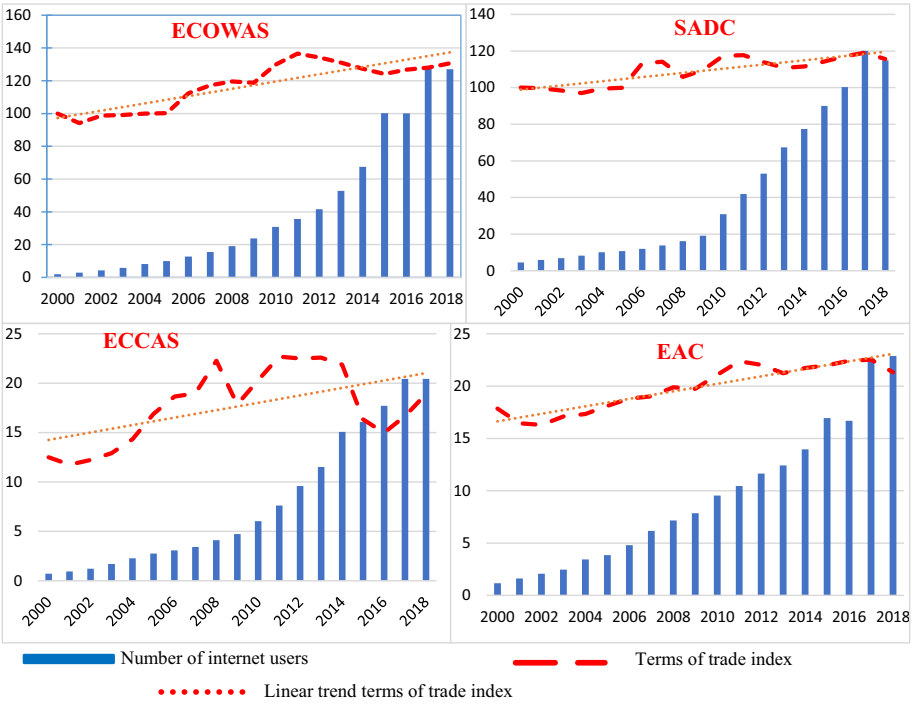

Fig. 1 Evolution of terms of trade and number of internet users in SSA. Sources: Authors with data from WDI and UNCTAD

population. These variables are obtained by taking an arithmetic average of the variables over all countries belonging to each region. This average, however, hides the heterogeneity between countries but allows us to see an average evolution in each subregion of SSA.

Figure 1 shows the evolution of the terms-of-trade index and the evolution of the number of internet users as a percentage of the population. Likewise, there is a similar evolution between the terms of trade and the number of internet users in ECOWAS countries. The terms of trade initially stagnated between 2000 and 2005, grew strongly between 2006 and 2011, then decreased until 2015 before increasing again in 2016. This decline after 2011 can be explained by the consequences of the 2008 financial crisis, but a plausible argument is that of the socio-political crises experienced by several countries in this region. In the case of SADC, although internet adoption has increased rapidly, the evolution of SADC terms of trade has a much lower slope than in the case of ECOWAS. However, the terms of trade of this region seem to move in the same direction as the number of internet users. In ECCAS, the terms of trade are subjected to stronger variations around its trend than in the other two regions presented above. The terms of trade are above the trend around the year 2005, when the number of Internet users in this region grew considerably. In the EAC, it can be observed that as the number of internet users increases, the terms of trade grow steadily around the trend. The general finding in SSA is that there is a positive relationship between the terms of trade and the number of internet users.

We now examine the current terms-of-trade trend together with the most widely used ICT indicators in SSA: the number of telephony subscribers. We present the two main variants (fixed and mobile) of telephony in percentage terms on the same graph with the evolution of the terms-of-trade index, separately for the four SSA economic regions, namely, ECOWAS, ECCAS, SADC, and EAC.

In Fig. 2, the number of fixed-line subscribers is generally lower than the number of mobile subscribers. More importantly, the terms of trade move in the same direction generally as the number of mobile subscribers in all sub-regions of SSA. Both variables trend upward over the period, but with greater or lesser fluctuations in the terms of trade depending on the region. Regarding fixed telephony, the number of subscribers, which was practically constant, has been decreasing slightly but steadily since 2014. The different figures presented so far show the possibility of a statistical relationship between ICT indicators and terms of trade.

3 Methodology

This section more formally assesses the effects of ICT on terms of trade. The methodology focuses on two points: first, the data sources and the justification of the choice of variables, and second, the specification of the econometric model.

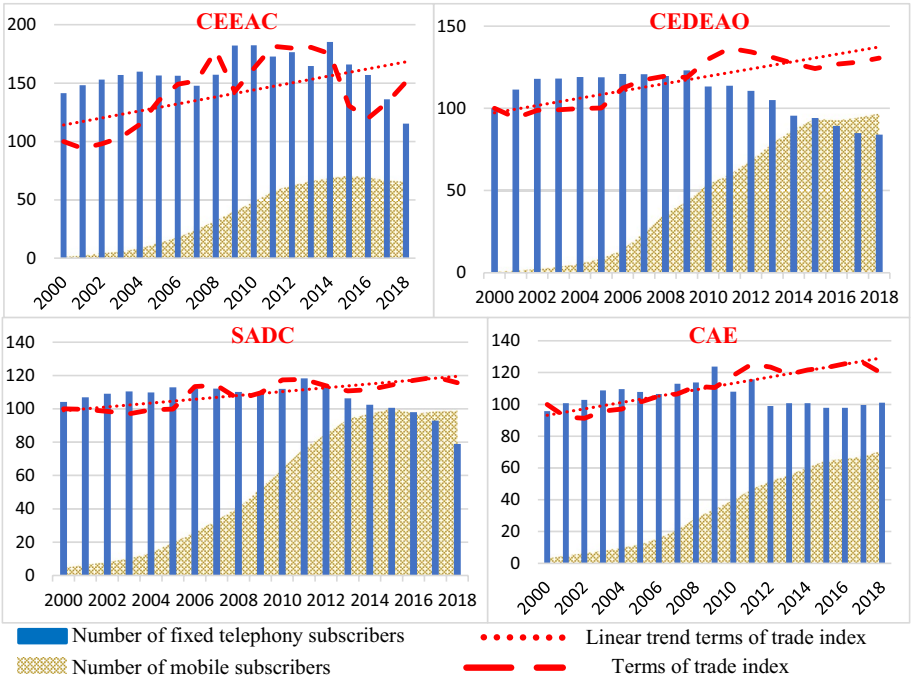

Fig. 2 Evolution of the terms of trade and the number of telephone subscribers in SSA. Sources: Authors with data from WDI and UNCTAD

Table 1 Summary of the different variables. Sources: Authors with data from WDI and UNCTAD

Variables	Sources
Terms-of-trade index	UNCTAD
Real effective exchange rate index	UNCTAD
Internet users as a percentage of mobile subscribers	WDI
Natural resource rent	WDI
Export trade ratio (exports/imports)	WDI
GDP per capita growth rate	WDI
Number of countries	39
Period of analysis	2005–2017

3.1 Data Sources and Choice of Variables

The data come from two different sources: the United Nations Conference on Trade and Development (UNCTAD) World Development Indicators (WDI) databases. The period of study extends from 2005 to 2017 because we avoid using observations that come before the base year (the year 2005) of the terms-of-trade calculation available on the UNCTAD website.

In addition to the terms of trade index, the number of internet users as a percentage of the number of mobile phone subscribers is included in the model as the measure for ICT. The other variables are: the ratio of exports to imports and the real effective exchange rate (Dion & Létourneau, 1980; Epifani & Gancia, 2009; Yousefvand et al., 2017), the growth rate of GDP per capita (Fleming, 2007), and natural resource rent (Sachs and Warner, 2001). Table 1 summarizes all the variables used and their data sources, as well as the number of countries and sample period.

3.2 Econometric Model Specification and Estimation Method

To estimate the direct and indirect effects of ICT on the terms of trade in SSA, a model is needed that allows for both long- and short-run effects. Indeed, the direct effect of ICT on the terms of trade is likely to short-run, while the indirect effect likley long-run. From this perspective, a panel vector autoregression (VAR) model is the most appropriate, as it does not impose any restrictions on the exogeneity or endogeneity of variables (Gossé & Guillaumin, 2014). Also, it accommodates both static and dynamic interdependencies. The specification of the VAR model is as follows:

$$\boldsymbol{Y}_{\boldsymbol{it}} = \boldsymbol{A}_0 + \boldsymbol{A}_1 \boldsymbol{Y}_{\boldsymbol{it-1}} + \boldsymbol{A}_2 \boldsymbol{Y}_{\boldsymbol{it-2}} + \cdots + \boldsymbol{A}_{\boldsymbol{P}} \boldsymbol{Y}_{\boldsymbol{it-P}} + \boldsymbol{v}_{\boldsymbol{it}},$$

where $\boldsymbol{Y}_{\boldsymbol{it}}$ is the vector of dependent variables/independent, $\boldsymbol{Y}_{\boldsymbol{it-1}}$, …, $\boldsymbol{Y}_{\boldsymbol{it-p}}$ are vectors of the lagged variables of $\boldsymbol{Y}_{\boldsymbol{it}}$ at periods $\boldsymbol{t}-1,\ldots\ \boldsymbol{t}-\boldsymbol{p}$, $\boldsymbol{A}_0$ is the vector of constant parameters, $\boldsymbol{A}_{\boldsymbol{j}\neq 0}$ is the vector of parameters associated with the lagged variables, $\boldsymbol{i}$ represents the country, $\boldsymbol{t}$ the period and $\boldsymbol{v}_{\boldsymbol{it}}$ the error term. Moreover, the VAR model on panel data allows for the estimation of parameters that are consistent and robust to problems of variable omission, simultaneity, and endogeneity (Anderson & Hsiao, 1981).

The parameters of the VAR process can only be estimated on stationary series. Thus, we first examine the stationarity of the variables. In this work, we apply the Harris–Tzavalis test and the Hadri test. The Harris–Tzavalis test tests the null hypothesis that all panels

Table 2 Unit root tests for stationarity of variables. Sources: Authors with data from WDI and UNCTAD

Variables	Harris-Tzavalis		Hadri	
	I(0)	I(1)	I(0)	I(1)
Terms-of-trade index	No	Yes	No	Yes
Real effective exchange rate index	Yes	–	No	Yes
Internet users as a percentage of mobile subscribers	No	Yes	No	Yes
Natural resource rent	Yes	–	No	Yes
Export trade ratio (exports/imports)	Yes	–	Yes	–
GDP per capita growth rate	Yes	–	No	Yes

Table 3 Description of the different variables. Sources: Authors with data from WDI and UNCTAD

Variables	Observations	Means	Std. dev
Terms-of-trade index	507	126.84	41.08
Real effective exchange rate index	507	108.43	17.41
Internet users as a percentage of mobile subscribers	507	16.66	11.65
Resource rents	507	2.71	2.50
Export trade ratio (exports/imports)	507	0.82	0.49
GDP per capita growth rate	507	1.90	4.43

contain a unit root and the alternative hypothesis that all panels are stationary (Mignon & Hurlin, 2005). This studyuses this test as the main one, as the number of countries is greater than the number of time units. The Hadri method tests the null hypothesis that all panels are stationary and the alternative hypothesis that some panels contain a unit root (Mignon & Hurlin, 2005). This test serves as robustness for the Harris–Tzavalis test. The results of the unit root tests are presented in Table 2. The test results are performed at the 5% threshold level.

According to the Harris–Tzavalis tests, all the variables are stationary at their levels, except for the terms-of-trade index and the number of internet users as a percentage of mobile phone subscribers, which are stationary in the first difference. The Hadri test generally agrees with the Harriss-Tzavalis, except for the real effective exchange rate index, natural resource rent, and GDP per capita growth rate. However, the Harris–Tzavalis test is retained because it is the more suitable for this study, since the number of countries exceeds the number of years, while the Hadri test is asymptotic in nature. We determine the optimal lag by regressing our model at several orders of lag and retain that which minimizes the Akaike information criterion, which turns out to be first-lag model.

4 Results and Discussion

Table 3 gives descriptive statistics of the different variables over the study period in SSA.

As shown in Table 3, the terms-of-trade index is on average 24 percent above its value in 2005, suggesting considerable improvements over the 2005-2017 sample period.

Table 4 VAR panel model estimates. Sources: Authors with data from WDI and UNCTAD

Number of observations = 390				Panel members = 39		
Variables	dTerm	dU_telm	CPIBhbt	Reer	RSSES	Cov
	Coef (P > z)	Coef (P > z)	Coef (P > z)	Coef (P > z)	Coef (P > z)	Coef (P > z)
dTerm (t-1)	**0.449**** (0.005)	0.016 (0.336)	0.015 (0.301)	0.032 (0.295)	**0.016***** (0.000)	**0.003***** (0.000)
dU_telm (t-1)	**0.539*** (0.10)	**– 0.590***** (0.000)	**0.015**** (0.011)	0.105 (0.225)	0.010 (0.453)	– 0.00 (0.966)
CPIBhbt (t-1)	0.731 (0.201)	0.040 (0.444)	**– 0.242**** (0.021)	0.074 (0.411)	**0.024*** (0.094)	0.001 (0.640)
Reer (t-1)	– 0.348 (0.380)	0.041 (0.476)	**0.132**** (0.008)	0.012 (0.893)	– 0.001 (0.950)	0.001 (0.506)
RSSES (t-1)	**– 23.669***** (0.000)	**1.371***** (0.000)	**1.242**** (0.008)	**3.056***** (0.000)	– 0.079 (0.542)	**– 0.065**** (0.001)
Cov (t-1)	**– 15.966***** (0.000)	**– 20.995***** (0.000)	**18.993***** (0.000)	**39.709***** (0.000)	**– 5.800***** (0.000)	**– 0.652***** (0.000)

Notes: dTerm first differencein the terms-of-trade index, *dU_telm* first difference in the number of internet users as percentage of mobile subscribers, *CPIBhbt* GDP per capita growth rate, *Reer* real effective exchange rate index, *RSSES* resource rents, *Cov* export coverage (exports/imports). Note that all variables in the VAR model are stationary.

*$P < 10\%$, **$P < 5\%$, ***$P < 1\%$

However, although the number of mobile phone subscribers and the number of internet users have been both increasing, the percent of internet users is rather low, at nearly 17%. It is also noteworthy that the export coverage of imports is short by nearly 20%. Table 4 summarizes the results of the panel VAR model estimates.

Focusing on the main objective of the study, that is, the importance of ICT for terms of trade, we focus on column 1 of table 4. The results show that the change in the terms-of-trade index is positively affected by the change in the number of internet users as a percentage of mobile subscribers. Indeed, a 1% increase in the latter significantly increases the former by by about 0.5%. This result suggests that the use of ICT might be a way to counter Prebisch's (1950) prediction that countries dependent on primary commodity exports would show a worsening in their terms of trade. Indeed, ICTs are a source of specialization (Renders & Sleuwaegen, 2012), factor endowment, transaction cost reduction, and quality improvements (Porter, 2009), and could therefore increase the terms of trade. According to Abeliansky et al. (2021), ICTs also make it possible to increase the profit margins on sales of products sold, which could also contribute to improving the terms of trade. Two other variables have significant but negative effects on the terms of trade, namely, natural resources rents and the export/import coverage coverage of imports by exports. Improvements in resource rents may simply result from higher terms of trade, a reverse causality. Similarly, higher terms of trade could lead to less exports as exporters would need to export less for a given income growth.

Figure 3 shows the response function of the terms of trade following shocks that are likely to increase the number of internet users as a percentage of mobile phone subscribers. These shocks can be the introduction or abolition of laws, regulations, and the construction of infrastructure to support the adoption, use, and integration of ICT.

Figure 3 shows that, following a shock that would increase the number of internet users as a percentage of the number of mobile subscribers, the terms-of-trade index reacts very positively, gaining more than 5% in value within a year. The effect of this shock however begins to fade after the first year and finally disappears at the beginning of the fifth year. Thus, this variable, the number of internet users as a percentage of the number of mobile phone subscribers, is not sufficient to produce long-term effects. However, it should be noted that a shock to the number of internet users as a percentage of mobile phone subscribers does not lead to a deterioration in the terms of trade below.

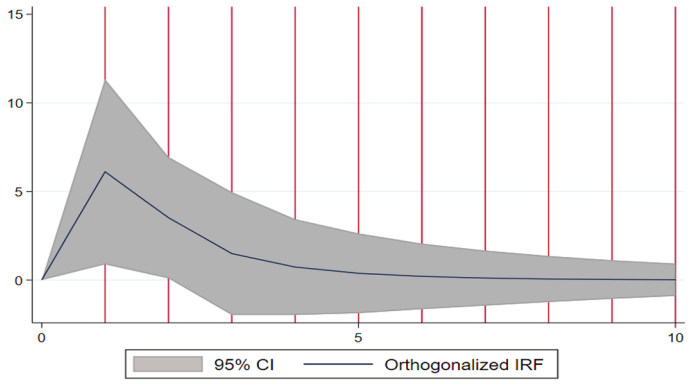

Fig. 3 Terms-of-trade reaction function following shocks, with number of internet users as a percentage of mobile subscribers in SSA. Sources: Authors with data from WDI and UNCTAD

5 Conclusion

The objective of this paper was to assess the effects of ICTs on the terms of trade of sub-Saharan economies. Based on new approaches to international trade, we have seen that ICTs are a source of productivity growth, cost reduction, human capital endowment, and specialization for firms and are therefore likely to affect the terms of trade. To test our point, we employed data from the WDI and UNCTAD over the period from 2005 to 2017. Using panel VAR modeling, we showed that the change in the terms-of-trade index is positively affected by the change in the number of internet users as a percentage of the number of mobile phone subscribers in SSA. The impulse response function further showed that a positive shock to this variable positively affects the terms-of-trade index, which gains more than 5% in value within a year. These results suggest that internet use is a channel through which ICTs can improve terms of trade in SSA. However, taking into account other aspects of ICTs, such as internet quality, computer programming, big data, 3D printing, and software, would allow us to explore new avenues and identify new channels through which ICTs improve the terms of trade in SSA.

Appendix

See Table 5.

Table 5 Countries included in the study. Sources: Authors with data from WDI and UNCTAD

Angola	Côte d'Ivoire	Madagascar	Rwanda
Botswana	Eswatini	Malawi	Seychelles
Burkina Faso	Gabon	Mali	Sierra Leone
Burundi	Gambia	Maurice	Senegal
Benin	Ghana	Mozambique	Tanzania
Cabo Verde	Guinea	Namibia	Togo
Cameroon	Guinea Equatorial	Niger	Uganda
Chad	Guinea-Bissau	Nigeria	Zambia
Comoros	Kenya	Central African Republic	Zimbabwe
Congo	Liberia	Democratic Republic of Congo	

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Availability of data and materials Not applicable.

Declarations

Competing interests It must either state that the authors declare that they have no competing interests or it must state the competing interests.

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