The Potential of Information and Communication Technologies to Generate International Trade in Africa

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This article employs the dynamic panel two-step system generalised method of moments (GMM) approach to investigate the effects of information and communication technology (ICT) on trade and economic growth at a multisectoral level in 38 African countries from 1990 to 2019. The study reveals a significant and positive relationship between ICT and the export of agricultural raw materials and services. ICT shows a negative relationship with import in the agricultural sector, and a positive and significant relationship within the manufacturing sector. Additionally, there is no evidence of statistically significant relationships between ICT and service import. In relating ICT to growth, at the sectoral level, significant positive effects on growth were found with a varying magnitude in all sectors. The national ICT recommendation is that governments in African countries should increase investment in the ICT sector of the economy, which will have a remarkable effect on international trade and the economy.

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Introduction

The importance of technology as an instrument of economic growth and development has prompted different sensitive and important investigations, by visualising the causality from the explicit model of growth perspective, the neoclassical model of growth and its augmented version, the

endogenous factor-augmenting technology change model, and the structuralist perspective to economic growth (Pohjola 2000; Smulders and De Nooij 2003; Dittmar 2011; Mansfield 2019). Most of these studies have shown the strength of ICT in ensuring economic growth and development among nations of the world.

Unlike other forms of technology, however, the contribution of ICT to growth and development in countries, especially developing countries, is dependent on some factors which include externalities and spill-over, established policies supporting innovations, and human capital. ICT can therefore be said to be a general-purpose technology affecting different facets of the economy and gradually changing the approach of technology to development through many aspects and perspectives. Firstly, ICT serves as a means of applying technology to the various sectors of the economy, that is, the externalities or spill-over effect of ICT to the level of productivity or its contribution to GDP. Secondly, ICT has helped in the reformation of production processes and the creation of networks, and improves the exchange of information within the country and globally. Thirdly, ICT has helped poorer and disadvantaged people to support their livelihood. Fourthly, ICT has helped to transform the mode of supplying services in the form of e-finance, e-government, and e-commerce (United Nations Conference on Trade and Development 2007). Consequently, the importance of ICT to economic growth and development has attracted diverse research from economists, policymakers, and other researchers in Africa and other parts of the world (Langmia 2006; Nasab and Aghaei 2009; Stanley, Doucouliagos, and Steel 2018). The interaction between ICT and international trade has also attracted several empirical investigations ranging from individual countries to panel investigations connecting regions of the world (Freund and Weinhold 2002; Xing 2018; Gholami, Guo, and Lee 2009; Thiemann, Fleming, and Mueller 2012; Nath and Liu 2017; Liu and Nath 2013).

The investigations of ICT and economic growth and international trade in different countries and panel analysis of countries by employing various empirical techniques have not existed without disparities in their results. For example, a positive link between ICT and economic growth was established (Seo, Lee, and Oh 2009; Adeleye and Eboagu 2019; Sassi and Goaied 2013). Kurihara and Fukushima (2013) did not, however, find evidence of ICT stimulating economic recovery. Similarly, investigation of the impact of ICT on international trade by adopting different empirical methodologies to analyse individual countries, and the collection

of a spectrum of panel data also shows some disparities in their results (Thiemann, Fleming, and Mueller 2012). Fink, Mattoo, and Neagu (2002) found a positive link between ICT and international trade, while Freund and Weinhold (2004) and Mattes, Meinen, and Pavel (2012) found no evidence of the effect of ICT on international trade.

From the foregoing, the existing literature on the link between ICT, economic growth, and international trade in African countries are limited and their results exist with different disparities. The disparities will be a problem for policy makers on the directions to be followed in formulating policies concerning these matters. Additionally, to the best of the authors' knowledge there is no evidence of empirical investigations of the effect of ICT on economic growth and international trade in various sectors of the economy in Africa. It is against this background that this study has decided to answer the question 'What is the impact of ICT on different sectors of the economy in Africa?' Consequently, this study decided to conduct an empirical investigation to determine this impact by adopting a two-step system generalised method of moments (GMM). This study examines exclusively the impact of ICT on service sector import and export, manufacturing sector import and export, agricultural sector import and export, inflation, population growth, and gross capital formation.

This article is structured as follows. The second section reviews the existing literature. The third section describes the data used and sources, as well as the econometric model used. The fourth section analyses the empirical models and results, while the fifth section concludes the article.

Literature Review

As clearly stated earlier, the importance of ICT in achieving economic growth within different sectors of the economy and achieving economic development in the country can never be over-emphasized. Several authors have used different theories in the explanation and clarification of the importance of ICT in achieving organizational growth, sectoral improvement, economic growth, and economic development.

We begin from the Schumpeterian theory that viewed innovation which can be likened to technology as a form of new ideas to replace the old ways of doing things, thereby creating opportunities for growth in organizations and countries (Schumpeter 1934; Pyka and Andersen 2012; Bahrini and Qaffas 2019). The theory according to Solow (1956) views output (Y) as derived by the combination of technology (A), capi-

tal (K) and labour (L). The Solow model as imbedded in the combination of technology, labour and capital has different elements of ICT which will be contributory to its positive effect on the output of the firm (Fay 2012; Hallegatte et al. 2012; Biagi 2013). The Network Readiness Index, as proposed by Kirkman et al. (2002), viewed the internet and other forms of ICT as a game changer in the way the world works. The model is directed towards creating a better understanding of how ICT helps in the achievement of economic development, with emphasis on developing countries, by ranking 78 countries. The theories analysed above show a positive link between a firm's productivity and economic growth. The review of related literature was done from two different directions concerning ICT and economic growth and ICT and international trade.

ICT AND ECONOMIC GROWTH

Various studies reviewed the link between ICT and economic growth in individual countries and conducted panel studies. For example, Adeleye and Eboagu (2019) conducted an empirical investigation on the impact of ICT on economic growth in 54 African countries from 2005 to 2015 with empirical variables of individuals using the internet, fixed telephone subscribers, mobile subscribers, and trade openness and taking inflation as control variables by employing the system generalised pooled ordinary least square, and random and fixed effects. The authors established a direct and significant relationship between ICT and economic growth.

Sassi and Goaied (2013) adopted the system GMM estimators of a dynamic panel model to investigate the relationship between ICT and economic growth of 17 Middle Eastern and North African (MENA) countries from 1960 to 2009. The result shows a positive and significant relationship between ICT and economic growth. Seo, Lee, and Oh (2009) examined the link between ICT and economic growth of 29 countries in the 1990s by employing a model of cumulative growth. The authors found a positive relationship between ICT and economic growth. Adopting the gravity regression technique, Kurihara and Fukushima (2013) did not find evidence of ICT stimulating economic recovery among Asian countries.

Majeed and Ayub (2018) adopted an ordinary least square (OLS), the GMM, and the two-stage least square (SLS) to analyse the link between ICT and economic growth of 149 countries comprising developed, developing, and emerging economies from 1980 to 2015. The study confirmed a positive relationship between ICT and economic growth. Aghaei and Rezagholizadeh (2017) adopted a dynamic model method of growth,

GMM, to analyse dynamic and static data of selected countries from the Organisation of Islamic Conference (OIC) countries from 1990 to 2014. The study reveals a positive and significant relationship between ICT and economic growth among the countries considered. Stanley, Doucouliagos, and Steel (2018) adopted meta-regression analysis to investigate the impact of ICT on the economic growth of 58 developed and developing economies. The results show that the developed and developing countries benefit more from the usage of landline and cell technologies; however, developed countries benefit more from computing than developing countries do.

ICT AND INTERNATIONAL TRADE

Thiemann, Fleming, and Mueller (2012) employed a gravity model of international trade on importing and exporting countries between 1995 and 2009 to evaluate the hypothesis of the effect of ICT on the vegetable and fruit trade in general. The study found a significant impact of mobile penetration on vegetables and fruits by exporting countries. The study also found a negative impact of telephone usage on banana import, and internet usage also affects fruit and vegetables negatively for exporting countries. Freund and Weinhold (2004) adopted a gravity equation of trade among 56 countries and found no evidence of the impact of the internet on total trade flows for 1995, and established only weak evidence of the impact of the internet on total trade flows in 1996. On the other hand, they found a significant effect of ICT on trade at an increasing rate from 1997 to 1999 and found a stronger impact of the internet on trade for the poor countries compared to the rich countries. Fink, Mattoo, and Neagu (2002) showed a significant impact of communication cost on bilateral trade flows.

Yushkova (2014) examined the relationship between ICT and trade costs for export flows between 40 OECD countries and India, China, Indonesia, Brazil, Russia, and South Africa for the period 2010/2011. The result of the study shows that the level of internet use for business activities has a positive relationship with the export flows between the countries under review. Mattes, Meinen, and Pavel (2012) adopted the gravity equation in a different specification to find whether the use of ICT at the European Union national level enhances trade among EU countries. The study shows no evidence of the significant impact of ICT on EU trade or the trade diversion effect towards ICT in developed countries from less ICT-developed countries.

Nath and Liu (2017) employ the gravity model framework and the GMM to determine the effect of ICT on imports, exports, and the trade of ten services collected from 49 countries for the period 2000 to 2013. The authors found a positive and significant impact of ICT on international trade in seven out of ten selected service items. ICT was also found to have a significant impact only on import of insurance services, telecommunication services, royalties, travels, license fees, and export of transportation services.

Choi (2010) adopts pooled ordinary least squares regression, a panel GMM, and fixed effects to find the effect of ICT on service trade among 151 countries from 1990 and 2006. The study found a significant impact of ICT on service trade, and Vemuri and Siddiqi (2009) employed the extended gravity model of a panel study of 64 countries from 1985 to 2005 to find the relationship between ICT, internet services, and international trade. The article found the existence of significant and positive effects of ICT on international trade. Kurihara and Fukushima (2013) adopted the cross-country gravity regression technique to investigate the impact of ICT on international trade in developed countries and developing Asian countries. The investigation shows that ICT promotes international trade for the countries.

Econometric Methodology

In this section, we present the econometric model that is adopted for this study. The variables used, sources of data and their measurements are provided. Further, the empirical analysis is presented and results of the findings are discussed.

THE MODEL UTILISED

The current study employed the dynamic panel generalised method of moments technique (GMM) to examine the effects of ICT on international trade and growth at sectoral levels. Arellano and Bond (1991) developed the difference GMM in the panel data model to correct potential endogeneity problems. This procedure also generates estimates that are consistently free from heteroscedasticity and autocorrelation. The difference GMM produces instruments that are stationary at first difference series alone. The difference GMM used the lagged level of variables as instruments; in many cases, the difference GMM performs poorly due to weak instrumentation if the variables follow a random work process.

The system GMM, initially developed by Arellano and Bover (1995) and extended by Blundell and Bond (1998), can be used to estimate two equations (the level and first difference equation) simultaneously; therefore, it shows significant improvement on the difference GMM. The system GMM adopts the orthogonal deviations transformation as against the first difference of variables proposed by Arellano and Bond (1991). According to Blundell and Bond (1998), by considering the lagged levels and lagged first difference of variables, the instruments will improve the efficiency and consistency of the estimator. In addition, the system GMM procedure is used in dealing with the potential problem of endogeneity which may occur in simultaneous equations (Blundell and Bond 1998). The system GMM, therefore, produces a more reliable estimate than difference GMM. The Hansen (1982) test of overriding restrictions can be used to determine the validity of the instruments. The two categories of system GMM usually utilised in dynamic panel data estimation include one-step and two-step. Roodman (2009) states that the two-step system GMM is better than the one-step because it is more efficient asymptotically. The efficiency of the two-step GMM depends on its use of an optimal weighting matrix. Consequently, this study uses the two-step system GMM to analyse the empirical effect of ICT on international trade and economic growth at sectoral levels. The empirical models for this investigation are provided in three categories, namely export model, import model and service model, as follows:

Sector-Level Export Model

$$\begin{aligned} are = {} & \alpha_0 + \alpha_1 are_{t-1} + \alpha_2 fts + \alpha_3 intu + \alpha_4 mcs + \alpha_5 reer \\ & + \alpha_6 gdpg + \alpha_7 top + \alpha_8 pe + \alpha_9 se + \alpha_{10} olf + u_1 \end{aligned} \tag{1}$$

$$\begin{aligned} me = {} & \alpha_0 + \alpha_1 are_{t-1} + \alpha_2 fts + \alpha_3 intu + \alpha_4 mcs + \alpha_5 reer \\ & + \alpha_6 gdpg + \alpha_7 top + \alpha_8 pe + \alpha_9 se + \alpha_{10} olf + u_1 \end{aligned} \tag{2}$$

$$\begin{aligned} serve = {} & \alpha_0 + \alpha_1 are_{t-1} + \alpha_2 fts + \alpha_3 intu + \alpha_4 mcs + \alpha_5 reer \\ & + \alpha_6 gdpg + \alpha_7 top + \alpha_8 pe + \alpha_9 se + \alpha_{10} olf + u_1 \end{aligned} \tag{3}$$

Sector-Level Import Model

$$\begin{aligned} ari = {} & \beta_0 + \beta_1 ari_{t-1} + \beta_2 fts + \beta_3 intu + \beta_4 mcs + \beta_5 reer \\ & + \beta_6 top + \beta_7 inf + \beta_8 pg + \beta_9 lf + u_2 \end{aligned} \tag{4}$$

$$\begin{aligned} mi = {} & \beta_0 + \beta_1 ari_{t-1} + \beta_2 fts + \beta_3 intu + \beta_4 mcs + \beta_5 reer \\ & + \beta_6 top + \beta_7 inf + \beta_8 pg + \beta_9 lf + u_2 \end{aligned} \tag{5}$$

$$servi = \beta_0 + \beta_1 ari_{t-1} + \beta_2 fts + \beta_3 intu + \beta_4 mcs + \beta_5 reer + \beta_6 top + \beta_7 inf + \beta_8 pg + \beta_9 lf + u_2 \quad (6)$$

Sector-Level Growth Model

$$agric = \gamma_0 + \gamma_1 agric_{t-1} + \gamma_2 fts + \gamma_3 intu + \gamma_4 mcs + \gamma_5 gfcf + \gamma_6 gdpg + \gamma_7 top + \gamma_8 pg + \gamma_9 pe + \gamma_1 0se + \gamma_1 0lf + u_1 \quad (7)$$

$$manu = \gamma_0 + \gamma_1 agric_{t-1} + \gamma_2 fts + \gamma_3 intu + \gamma_4 mcs + \gamma_5 gfcf + \gamma_6 gdpg + \gamma_7 top + \gamma_8 pg + \gamma_9 pe + \gamma_1 0se + \gamma_1 0lf + u_1 \quad (8)$$

$$serv = \gamma_0 + \gamma_1 agric_{t-1} + \gamma_2 fts + \gamma_3 intu + \gamma_4 mcs + \gamma_5 gfcf + \gamma_6 gdpg + \gamma_7 top + \gamma_8 pg + \gamma_9 pe + \gamma_1 0se + \gamma_1 0lf + u_1 \quad (9)$$

Table 1 presents descriptions of variables and measurements.

DATA

The study uses panel data of 38 African countries from 1990 to 2019 (30 years). The selection of the countries was due to the availability of comprehensive data and considerable representation of various blocs in the continent. In most of the series, data were available from 2000, which makes the scope justifiable as most African countries have no record of ICT data before this period. Data for the analysis were gathered from the World Bank's World Development Indicator.

The countries considered are Algeria, Benin, Burkina Faso, Botswana, Burundi, Carbo Verde, Cameroon, Comoros, Republic of the Congo, Côte d'Ivoire, Ecuador, Egypt, Eswatini, Ethiopia, Gambia, Gabon, Ghana, Guinea, Kenya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Nigeria, Niger, Rwanda, Senegal, Seychelles, South Africa, Sudan, Tanzania, Togo, Tunisia, Zambia, and Zimbabwe.

Some of the limitations of the study are stated consequently. Only 38 out of 54 countries in sub-Saharan Africa were selected based on the data available at the time of the research. In the case of this study, the effect of telecommunication and ICT are examined for trade and output of 3 sectors, namely, agricultural, manufacturing and service.

Empirical Analysis

The summary statistics of variables utilised in this article are presented in table 2. The general focus is to examine the effects of ICT on trade and growth at sectoral levels. In this study, international trade is bifurcated

TABLE 1 Description of Variables and Measurements

Var.	Descriptions	Measurement
are	Agricultural export	Agricultural export as % of goods export
me	Manufacturing export	Manufactures export as % of goods export
serve	Service export	Service export in US$
ari	Agricultural import	Agricultural import as % of goods import
mi	Manufacturing import	Manufactures import as % of goods import
servi	Service import	Service import in US$
agric	Agricultural growth	Agricultural value added
manu	Manufacturing growth	Manufactures value added
serv	Service growth	Service value added
fts	Fixed telephone subscriptions	Fixed telephone subscriptions per 100 people
mcs	Mobile cellular subscriptions	Mobile cellular subscriptions per 100 people
intu	No. of internet users	Individuals using internet as % of population
reer	Real effective exchange rate	REER index (2010 = 100)
gdpg	Real GDP growth	% change in real GDP
top	Trade openness	Trade as % of GDP
pe	Primary school enrolment	School enrolment, primary % of gross
se	Secondary school enrolment	School enrolment, secondary % of gross
pg	Population growth	Population growth annual %
lf	Labour force	Labour force participation rate
inf	Inflation rate	Consumer prices annual %
gfcf	Gross fixed capital formation	Gross fixed capital formation as % of GDP

into export and import in various sectors. Among the commodity export, manufacturing goods have the highest mean, median and standard deviation, suggesting a relatively high contribution of the sector to aggregate export. The results of the skewness indicate that all the export variables are positively skewed. Manufacturing export's kurtosis value (3.14) is close to normal distribution, while the kurtosis' figures of other export variables deviate from normal distribution.

Similar to the statistics of the export, manufacturing import (*mi*) recorded the highest values of mean, median and standard deviation. Agricultural raw material import (*ari*) shows, however, a low mean median and standard deviation compared to other sectors. In addition, the values of manufacturing import are negatively skewed and positive in

TABLE 2 Summary Statistics

Variables	(1)	(2)	(3)	(4)	(5)	(6)
are	8.92	3.21	16.11	2.98	11.76	1.81
me	25.30	15.14	24.69	1.10	3.14	0.98
serve	7.70	4.83	9.64	3.33	16.03	1.25
ari	1.57	1.25	1.23	3.85	41.32	0.79
mi	62.40	62.83	11.37	−0.19	2.86	0.18
servi	10.71	8.41	7.74	2.63	13.23	0.72
fts	3.70	1.12	5.80	2.63	13.23	0.72
intu	8.74	1.80	14.13	2.03	6.49	1.62
mcs	35.60	9.78	44.43	1.07	3.04	1.25
reer	108.40	100.00	33.20	1.51	6.05	0.31
gdpg	1.57	1.71	4.23	−1.04	23.87	2.69
top	68.51	60.07	33.21	1.33	5.18	0.48
inf	9.64	5.72	15.42	5.18	41.84	1.60
pe	96.73	102.01	25.15	−58.00	3.31	0.26
se	45.61	40.77	26.59	0.48	2.32	0.58
pg	2.31	2.54	0.98	−1.91	18.27	0.42
lf	67.40	68.12	13.10	−0.09	1.85	0.19
gfcf	21.32	20.35	8.31	1.23	8.67	0.39
agric	20.27	20.17	12.23	0.37	2.34	0.60
manu	12.18	10.41	6.96	2.03	8.72	0.57
serv	47.58	47.87	9.84	0.05	3.17	0.21

NOTES Column headings are as follows: (1) mean, (2) median, (3) standard deviation, (4) skewness, (5) kurtosis, (6) coefficient of variation.

other sectors. Again, the value of kurtosis of the manufacturing sector is near normal distribution.

In line with the aim of these studies, growth is analysed on a sectoral basis. Variables used to proxy growth on a sectoral level include agricultural value added (*agric*), manufacturing value added (*manu*) and service value added (*serv*). The summary statistics of the variables in the last three rows of table 2 show that, on average, the service sector has the highest value added, next is the agricultural sector and the lowest is recorded in the manufacturing sector. The average (*mean*) values of sectors show the low contribution of the manufacturing sector in the value chain of the real sector. The skewness and kurtosis statistics indicate that

TABLE 3 IM Pesaran and Shin Panel Unit Root Test

S/N	Variables	At level		At first difference		Remarks
		(1)	(2)	(1)	(2)	
1	*are*	−1.9079	0.0000	−3.3340	0.0000	I(0)
2	*me*	−1.9645	0.0000	−3.3127	0.0000	I(0)
3	*serve*	−1.7814	0.0200	−3.5360	0.0000	I(0)
4	*ari*	−1.9330	0.0000	−3.4216	0.0000	I(0)
5	*mi*	−2.1372	0.0000	−3.5306	0.0000	I(0)
6	*servi*	−1.7933	0.0100	−3.5040	0.0000	I(0)
7	*agric*	−1.5224	0.2528	−3.8956	0.0000	I(1)
8	*manu*	−1.5707	0.1411	−3.6835	0.0000	I(1)
9	*serv*	−1.7061	0.0167	−3.7396	0.0000	I(0)
10	*fts*	−1.2624	0.9146	−3.1305	0.0000	I(1)
11	*intu*	1.4190	1.0000	−3.0085	0.0000	I(1)
12	*mcs*	1.1357	1.0000	−2.4781	0.0000	I(1)
13	*reer*	−2.0831	0.0016	−3.7234	0.0000	I(1)
14	*gdpg*	−3.3786	0.0000	−4.4026	0.0000	I(0)
15	*top*	−1.6950	0.0800	−3.7124	0.0000	I(1)
16	*pe*	−1.2254	0.9384	−2.7243	0.0000	I(1)
17	*lf*	−0.1716	1.0000	−2.1819	0.0000	I(1)
18	*inf*	−2.6643	0.0000	−3.8363	0.0000	I(0)
19	*pg*	−1.9653	0.0000	−1.9513	0.0000	I(0)
20	*gfcf*	−1.7304	0.0200	−3.6504	0.0000	I(0)

only service value added exhibits a normal distribution. The descriptive statistics of the variables used to proxy ICT are also discussed as follows. These variables include fixed telephone subscription (*fts*), mobile cellular subscriptions (*mcs*) and individuals using the internet as percentage of population (*intu*). Among these variables, mobile cellular subscriptions have the highest mean, median and deviation, while fixed telephone subscription shows the lowest computed average and standard deviation. All these ICT variables are positively skewed, and the kurtosis of mobile cellular subscription shows the trend is normally distributed. The summary statistics of other variables used in this study are provided in table 2.

Table 3 presents the IM Pesaran and Shin unit root test. The variables of interest are tested at level and first difference. The computed *t*-statistics

TABLE 4 Two-Step System GMM for ICT and Sectoral Export

Variables	Expect.	Agricult. Model 1		Manufact. Model 2		Service Model 3	
L.are		−0.210	(0.243)				
fts	+	7.112**	(3.610)	−4.913	(6.564)	0.388**	(0.166)
intu	+	−0.114	(0.290)	0.668*	(0.347)	0.074*	(0.040)
mcs	+	0.453***	(0.160)	−0.709	(0.537)	0.038**	(0.017)
reer	–	0.024	(0.491)	−0.220	(0.306)	0.033	(0.022)
gdpg	+	−0.514	(0.446)	0.293	(0.327)	0.050*	(0.028)
top	+	0.088	(0.115)	0.286***	(0.088)	0.049	(0.033)
pe	+	0.179	(0.299)	−0.486	(0.453)	−0.036	(0.027)
se	+	−1.845***	(0.555)	2.010	(1.674)	0.022	(0.038)
lf	+	−0.353	(1.184)	0.467	(0.481)	0.031	(0.055)
L.me				0.159	(0.312)		
L.serve						−0.098	(0.306)
Constant		55.82	(175.800)	−16.210	(59.470)	−1.219	(5.722)
AR(1)		0.42	(0.675)	−0.44	(0.661)	−1.03	(0.304)
AR(2)		−1.30	(0.195)	−0.28	(0.779)	−0.33	(0.738)
Sargan Test		1.01	(0.908)	5.79	(0.215)	5.56	(0.118)
Hansen Test		1.03	(0.906)	0.50	(0.974)	1.02	(0.314)
No. of instruments		8		8		8	
Observations		524		575		602	
Number of countries		38		38		38	

NOTES Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

(t-tilde-bar) of the variables are reported and the statistical significance of the variables are given. The results show that some variables are stationary at level while others are stationary at first difference. Specifically, agricultural sector export (*are*), manufacturing sector export (*me*), service sector export (*serve*), agricultural sector import (*ari*), manufacturing import (*mi*), service import (*servi*), service output (*serv*), real GDP growth (*gdpg*), inflation (*inf*), population growth (*pg*) and gross fixed capital formation (*gfcf*) are stationary at level. Other variables used in the study are only stationary after first difference. Since the results of the panel unit root test in table 3 shows that some variables are stationary at level while others are stationary after first difference, we can use a dynamic panel data regression.

Table 4 depicts the results of the two-step system GMM for ICT and export at sectoral level. Accordingly, the regressions of the three sectors, namely agriculture (*agric*), manufacturing and service are provided. The robustness of the results is determined by checking for autocorrelation in the first and second order. In addition, Hansen and Sargan tests were conducted to verify the appropriateness of instruments used. In all three models, there is no evidence of both first- and second-order autocorrelation. Furthermore, eight instruments were used for each of the export models; however, these instruments are supported by Hansen and Sargan tests.

Beginning with the agricultural sector, two ICT diffusion variables, namely, fixed telephone subscriptions and mobile telephone subscriptions, exert a statistically significant effect on agricultural export. Variables are significant at one and five per cent levels, respectively. A percentage increase in fixed telephone subscriptions would lead to a 7.1% increase in agricultural export. Similarly, a one percent rise in mobile telephone subscriptions causes agricultural export to increase by 0.4%. This result shows the importance of telecommunication in agricultural export in Africa. Hence, improvement in ICT can facilitate export of agricultural products. The findings are in line with the empirical results of Thiemann, Fleming, and Mueller (2012) as well as Fink, Mattoo, and Neagu (2002). Secondary school enrolment shows a negative effect on agricultural export. This suggests that as more people pursue formal education in secondary schools, less labour is available to support the agricultural value chain.

The results obtained for the manufacturing sector are presented in the second column of table 4. In the regression, fixed telephone subscriptions (*fts*) and mobile telephone subscriptions are statistically insignificant at conventional levels. The coefficient of individuals using the internet as a percentage of the population is, however, statistically significant only at the ten per cent level. This result suggests that in the manufacturing sector, ICT has a low effect on export of goods. A percentage increase in the number of individuals using the internet as a percentage of the population could lead to a 0.7% rise in manufacturing export, on average. Amidst other variables employed in the manufacturing sector regression, trade openness exhibits a positive and statistically significant effect on manufacturing export. Its coefficient shows that a one percent increase in trade openness could result in a 0.3% rise in manufacturing export. This finding conforms to the open economy theoretical predic-

tions that trade openness fosters the export of commodities. The last column of table 4 depicts the regression of the service sector. In this model, fixed telephone subscriptions and mobile telephone subscriptions exert a statistically significant effect on export at the five per cent level. Nonetheless, the number of individuals using the internet as a percentage of the population is significant only at the ten per cent level. These results indicate that a percentage rise in fixed telephone subscriptions and mobile telephones subscriptions would generate an increase in export of about 0.4% and 0.04%, respectively. This result is expected due to the significant growth of the service sector in Africa and its significant contribution to trade over the two decades. Available statistics have shown a remarkable performance of trade in services in recent years.

Table 5 depicts the results of the two-step system GMM for the effect of ICT on sectoral import. In this segment, agricultural, manufacturing and service sectors' models were analysed, and their results reported. The robustness of the results is confirmed by Arellano and Bond's AR (1) and AR (2). Based on Hasen and Sargen's tests for appropriate instruments, seven variables were utilised as instruments in each of the models estimated.

In the agricultural sector, a negative effect of both fixed telephone subscriptions and mobile telephone subscriptions on agricultural import was found. These two variables are statistically significant at a five per cent level. The results suggest that a percentage increase in fixed telephone subscriptions and mobile telephone subscriptions would lead to a decline in import of about 0.9% and 0.03%, respectively. These results suggest that an increase in ICT provision would discourage import in the agricultural sector. Also, this is in line with the findings of Thiemann, Fleming, and Mueller (2012). One plausible reason for this could be the inadequate coverage of telecommunication in Africa. Low ICT connectivity with the rest of the world could discourage the flow of imported goods. In addition, some government policies such as tariff and non-tariff barriers to import can be facilitated by ICT and telecommunication which could lead to a negative effect of ICT on import. Furthermore, the coefficient of the real effective exchange rate (*reer*) shows that, on average, domestic currencies' depreciation would increase agricultural import.

The result of the manufacturing sector of the import model is in contrast to the one obtained in the agricultural model. Here, fixed telephone subscriptions and mobile telephone subscriptions have a statistically significant effect on import in the manufacturing sector. A close look at the

TABLE 5 Two-Step System GMM for ICT and Sectoral Import

Variables	Expect.	Agricult. Model 1		Manufact. Model 2		Service Model 3	
L.ari		−0.154	(0.356)				
fts	+	−0.875**	(0.373)	10.58***	(3.463)	−0.054	(0.07)
intu	+	0.013	(0.018)	−0.343	(0.312)	0.016	(0.073)
mcs	+	−0.031**	(0.012)	0.240*	(0.140)	−0.009	(0.019)
reer	−	−0.035**	(0.016)	0.443***	(0.167)	−0.014***	(0.004)
gdpg	+	0.483	(0.344)	0.721	(2.445)	−0.07	(0.09)
top	+	−0.02	(0.02)	0.341	(0.250)	0.032***	(0.009)
inf	−	0.001	(0.025)	−0.1	(0.313)	−0.002	(0.012)
pg	+	−0.638	(0.656)	7.541	(8.964)	0.287	(0.233)
lf	+	−0.448**	(0.197)	3.934***	(1.431)	−0.012	(0.012)
L.mi				0.803***	(0.211)		
L.servi						0.818***	(0.065)
Constant		40.97***	(15.15)	−376.7***	(113.2)	1.355	(2.015)
AR(1)		−1.45	(0.148)	−2.81	(0.005)	−2.55	(0.011)
AR(2)		−1.03	(0.303)	0.59	(0.555)	−0.05	(0.964)
Sargan Test		1.92	(0.589)	3.06	(0.383)	1.32	(0.726)
Hansen Test		1.42	(0.700)	3.56	(0.313)	1.15	(0.764)
No. of instruments		7		7		7	
Observations		524		675		621	
Number of countries		38		38		38	

NOTES Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

regression shows that fixed telephone subscriptions exert a greater and more significant effect on import. This implies that, in the manufacturing sector, ICT expansion would increase the rate of import. Further evidence reveals that, in the sector, real effective exchange rate appreciation would lead to a significant increase in import. Additionally, evidence was found that an increase in the labour force generates more increase in import in the sector.

Consequently, the parameter estimates of the service sector model indicate that the three ICT variables considered in our study, namely fixed telephone subscriptions, mobile telephone subscriptions and individuals using the internet as a percentage of the population are not statistically significant at the required levels. This implies that ICT does not have a

TABLE 6 Two-Step System GMM for ICT and Sectoral Growth

Variables	Expect.	Agricult. Model 1		Manufact. Model 2		Service Model 3	
L.agric		0.073	(0.270)				
fts	+	1.048	(0.897)	0.368**	(0.149)	0.165***	(0.056)
intu	+	−0.866*	(0.518)	0.699**	(0.277)	−0.016	(0.028)
mcs	+	0.404***	(0.148)	0.272**	(0.108)	0.016*	(0.008)
gfcf	+	−0.196**	(0.094)	−0.038	(0.047)	−0.007	(0.021)
gdpg	+	−0.072	(0.124)	0.295	(0.236)	−0.242	(0.245)
top	+	−0.138***	(0.049)	0.045**	(0.022)	−0.004	(0.008)
pg	+	−2.444	(2.005)	−0.151	(0.625)	−0.664	(0.444)
pe	+	0.084	(0.144)	−0.013	(0.019)	0.019*	(0.01)
se	+	−0.716*	(0.424)	0.105**	(0.051)	−0.009	(0.018)
lf	+	−0.104	(0.302)	−0.052	(0.066)	0.001	(0.0216)
L.manu				0.375	(0.281)		
L.serv						0.719***	(0.088)
Constant		56.59***	(21.02)	10.99	(8.504)	13.20***	(4.439)
AR(1)		0.18	(0.861)	−0.54	(0.589)	−2.90	(0.004)
AR(2)		0.86	(0.392)	1.25	(0.212)	−1.58	(0.115)
Sargan Test		5.97	(0.113)	9.19	(0.027)	1.82	(0.768)
Hansen Test		5.44	(0.143)	2.79	(0.425)	2.53	(0.640)
No. of instruments		8		8		8	
Observations		624		565		616	
Number of countries		38		38		38	

NOTES Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

significant effect on the volume of imported goods. Again, this could be a result of the poor state of telecommunication and less coverage in Africa. Most of the countries in Africa are still facing challenges with telecommunication networks. The significance of the coefficient of the real effective exchange rate suggests that real exchange rate depreciation could increase service import. As expected, the coefficient of trade openness indicates that trade liberalisation promotes service import in Africa.

The next line of discussion is the results of the two-step system GMM for ICT and growth at sectoral level. The estimations as provided in table 6 show diverse evidence. In the model, eight instruments were used. The choice of the instruments adopted is consistent with Hansen and Sargan's

tests. Similarly, the statistics obtained for Arellano and Bond AR (1) and AR (2) show that the models are free from autocorrelation.

Empirical evidence from the results of the agricultural sector indicates that ICT variables, especially mobile telephone subscriptions, exhibit a positive and statistically significant effect on agricultural output. A one percent increase in mobile telephone subscriptions would lead to about 0.4% growth in the agricultural sector. This result suggests that efficient mobile communication enhances the growth of the agricultural sector. Similar results were obtained by Adeleye and Eboagu (2019) for SSA countries as well as Sassi and Goaied (2013) for 17 MENA countries. Other variables employed in the model show interesting results. For instance, coefficients of gross fixed capital formation and trade openness harm agricultural output. These results are contrary to theoretical expectation. A possible reason for the negative coefficient of gross fixed capital formation could be the poor state of infrastructure and capital investment in the agricultural sector. The agricultural sector in Africa depends on a peasant system with little capital investment.

In the manufacturing sector model, fixed telephone subscriptions (*fts*), numbers of individuals using the internet as a percentage of the population (*intu*) and mobile telephone subscription (*mcs*) exert a positive and statistically significant effect on the sector's performance and growth. In other words, all the ICT variables employed in this study promote manufacturing growth. The results suggest that a percentage increase in fixed telephone subscriptions, internet users and mobile telephone subscriptions would enhance manufacturing sector performance by 0.4%, 0.7% and 0.3%, respectively. These results suggest that, on average, the manufacturing sector's growth in Africa is positively affected by ICT. Further evidence from the model indicates that trade openness and secondary school enrolment facilitate manufacturing sector performance.

The last column of table 6 shows the results of the two-step system GMM for ICT and service sector output. Among the ICT variables employed, fixed telephone subscriptions (*fts*) show a positive and statistically significant impact on the service sector. This implies that a percentage increase in fixed telephone subscriptions would generate about a 0.2% increase in the service sector's growth. Similarly, mobile telephone subscriptions have a positive effect on service sector growth; however, this is only statistically significant at the 10% level. Overall, the results of the empirical investigation on the effect of ICT on growth show that ICT contributed to sectoral growth in African economies.

Conclusion

Information and communication technology (ICT) plays a significant role in the growth and international trade transactions of developed countries. However, the development and coverage of ICT in Africa have yet to reach the level of developed countries. This study empirically investigated the effect of ICT on international trade and growth in Africa. It was seen that earlier studies on either ICT and trade or ICT and growth generally considered it at the aggregate level; therefore, our study examined these relationships at multisectoral levels. For this study, a panel of 38 African countries was analysed using a dynamic two-step system GMM.

The findings of this study show that ICT positively and significantly enhances the export of agricultural raw materials and services; this result is in line with the theories reviewed in the earlier part of this study as they viewed ICT as a form of technology having a positive link with a firm's performance and economic growth. The effect of ICT on the manufacturing sector's export is, however, negligible. Furthermore, the effect of ICT on import shows diverse findings. In the agricultural sector, ICT variables show a negative effect on import. In the manufacturing sector, however, a positive and significant effect of ICT on import was found. The effect of ICT on service import is not statistically significant. A plausible explanation for the statistically insignificant effect of ICT on service import could be as a result of the poor state of telecommunication and less coverage in Africa.

Concerning the effect of ICT on growth at sectoral levels, a positive and statistically significant effect of ICT on the growth of all the sectors was found. The magnitude of the effect varies across the sectors, however. While only one out of three of the variables used to proxy ICT is significant in the agricultural and service sectors, all three ICT proxies show significant contributions to the manufacturing sector's growth.

Several policy implications can be drawn from this study. Firstly, given the low contribution of ICT to export in the manufacturing sector, African governments should provide an enabling environment to attract investment in the ICT sector of the economy. Secondly, ICT support systems should be made available by various industries to enhance the positive effect of ICT in productive processes.

Future studies in this area might look at more countries in Africa. Similarly developing countries in general can be explored. Only three sectors

were considered in this study; hence, a future study could look at the mining or raw materials extraction sector.

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