ICT Adoption and Trade Nexus on Economic Growth in Africa: Evidence from Static and Dynamic Simulations

ADELEYE Ngozi[♦a,b,c], **ADEDOYIN** Festus[♠d], **NATHANIEL** Solomon[♣e]
[a]Department of Economics and Development Studies, Covenant University, Nigeria
[b]Regional Centre of Expertise (RCE) Ogun, Nigeria
[c]Centre for Economic Policy and Development Research (CEPDeR), Covenant University, Nigeria
[d]Department of Accounting, Finance and Economics, Bournemouth University, UK
[e]Department of Economics, University of Lagos, Nigeria

Abstract

This paper contributes to the ICT-growth and trade-growth literature by investigating the ICT-trade nexus on economic growth. That is, does ICT adoption enhance or distort the impact of trade on economic growth? With data on 54 African countries from 2005 to 2015 and using mobile phones and fixed telephone subscriptions as the indicators of ICT, the study engages the static (pooled OLS) and dynamic (difference GMM) approaches to proffer answers among others. Findings provide evidence that (1) trade is a significant and positive predictor of economic growth, (2) that the impact of trade on growth differs significantly across Africa's five sub-regions, (3) that the effect of ICT adoption also differs significantly across the sub-regions, (4) that ICT innovation enhances the impact of trade on growth, and (5) the ICT-trade nexus differ significantly across the sub-regions. The study submits that these variables are key drivers of economic growth in Africa. However, the lack of consistency of the results across the sub-regions suggests that the level of ICT is still undeveloped relative to other regions of the world and the benefits of international trade is yet to be properly harnessed. Policy implications are discussed.

Keywords: economic growth; trade openness; mobile phones; fixed telephone; SSA, pooled OLS; difference GMM
JEL Codes: C32, E13, E22, F14, F43, J24, O3, O11, O43, O47

♦Corresponding Author ngozi.adeleye@covenantuniversity.edu.ng; ORCID: 0000-0002-1274-714X; website: https://cruncheconometrix.com.ng; https://www.youtube.com/c/CrunchEconometrix
♠fadedoyin@bournemouth.ac.uk; ORCID: 0000-0002-3586-2570
♣nathaniel_solomon21@yahoo.com; ORCID: 0000-0001-7623-9526

1 Introduction

Trade openness is a catalyst for productivity and growth therefore its impact is conditional on its weight in economic activity. Significant findings from the literature (Chang et al, 2009; Calderon et al, 2004; Fetahi-Vehapi et al, 2015) reveal that open economies are more productive than countries which only produce for the domestic market. The theoretical literature is inundated with studies that emphasize the benefits of trade openness on economic growth, but its impact is still an open discourse among researchers. A range of empirical studies (see Sachs and Warner, 1995; Frankel and Romer, 1999; Dollar and Kraay, 2004) have documented that trade and economic growth exhibit positive relationship. For instance, from a sample of 122 countries, Sachs and Warner (1995) assess the impact of trade on growth and conclude that open economies exhibit higher growth patterns than protectionist economies. Similarly, Frankel and Romer (1999) from a sample of 63 countries show that trade openness generate higher income levels. Likewise, Dollar and Kraay (2004) reveal that greater trade openness which is measured by trade volume yields increased growth rates. Besides, international trade encourages the efficient distribution of resources which precipitates higher growth that may be transformed into greater productivity, most especially to those countries associated with technology diffusion and knowledge spillovers.

On the nexus of information and communication technology (ICT) and economic growth, the literature is awash with studies that allude to the fact that the development of telecommunication propels economic growth (see Myovella, Karacuka & Haucap 2020; Donou-Adonsou 2019; Lau 2010; Vu 2011). Economic growth in developing countries, Sub-Saharan African (SSA) countries inclusive, is actually contingent of many factors; information technology and foreign direct investment (FDI) are chief among these factors (Adom, Opoku & Yan 2019; Fanta & Makina 2017; Boamah 2017; Dunne & Masiyandima 2017; Gui-Diby 2014). However, ICT is a more contemporary driver of growth compared to foreign direct investment. Recent literature (Adeleye & Eboagu 2019; Minkoua Nzie, Bidogeza, & Azinwi Ngum 2018) support the growth-enhancing function of ICT in Africa hinges on the fact that information technology can lead to macroeconomic gains in the form of positive externalities (Issahaku, Abu & Nkegbe 2018; Gosavi 2018).

Given the documented evidence on the impact of trade and ICT on economic growth, there is an observed lacuna in the literature, which to the best of knowledge, has not been addressed: does ICT adoption enhance or distort the impact of trade on growth? This investigation become

germane in understanding the *total* or overall impact of trade on growth. With ICT innovations sprouting across the globe, international trade is now facilitated from several hi-tech channels which has made it easy to initiate and execute business deals across borders within the comforts of homes and offices. To address this apparent gap in the trade-growth literature, a sample of 54 African countries from 2005 to 2015 is used. The variables of interest are gross domestic product (measure of economic growth), trade openness, mobile phone and fixed telephone subscriptions (as ICT indicators). This study attempts to answer four questions: (1) does trade and ICT adoption significantly promote economic growth? (2) Is the interaction of trade and ICT adoption significant to promote economic growth? (3) Does the effect of trade and ICT adoption significantly differ across the Africa's sub-regions? (4) Does the moderating impact of ICT adoption on trade significantly differ across the sub-regions? The empirical investigation employs static (pooled ordinary least squares) and dynamic (difference generalised method of moments) techniques proposed by Arellano and Bond (1991). Our findings, for the most part, aligns with previous studies but the novel contribution is that ICT enhances the impact of trade on economic growth in Africa. Other results suggest that across the five sub-regions, the ICT-trade nexus on economic growth significantly differs. The rest of the paper is structured as follows: Section 2 reviews the extant literature; Section 3 presents the data and empirical approach; Section 4 discusses the results; and Section 5 concludes with policy recommendations.

2 Brief Literature Review

This section undertakes a brief review of related studies from two empirical standpoints: trade-growth and ICT-growth relations. Extensive work on the impact of trade and ICT on economic growth have been covered in the literature howbeit with mixed results which are not unconnected to scope of study, indicators of ICT used, measures of trade openness, empirical technique(s) and so on.

Trade-Growth Relation

Hypothetically, the literature on growth and international trade reveals that the latter stimulates long-term growth. That is, trade is an essential ingredient in the development path of many countries with increasingly significant impact to economic growth. Some strand of the literature finds that openness has a positive impact on economic growth (Kong, Peng, Ni, Jiang & Wang 2020; Kpomblekou & Wonyra 2020; Manwa, Wijeweera & Kortt 2019; Keho 2017; Salahuddin & Gow 2016; Zahonogo 2016; Fetahi-Vehapi, Sadiku & Petkovski 2015). For

instance, Kong et al. (2020) investigate the role of trade on economic growth in China for the period 1994 to 2018 using the ARDL estimator. Trade openness exerts a positive impact on the country's growth, while an "*N*-type" relation was discovered between growth and trade openness. Similarly, Chang et al. (2009) posit that the positive association between growth and trade may be significantly improved if complementary policies are undertaken. Also, Manwa et al. (2019) examine the influence of trade liberalization on economic growth in five Southern Africa countries adopting four trade liberalization indicators (tariff, trade ratio, real interest rate, and adjusted trade ratios). This is actually a novel attempt compared to other similar studies for African countries. Their findings suggest that trade liberalization has very little influence on the economic growth of Swaziland, South Africa, Namibia, Lesotho, and Botswana over the last thirty years.

Calderon et al. (2004) find that trade has positive impact on growth in high income countries but does not exhibit similar growth effect in countries with low per capita income. Similarly, Salahuddin & Gow (2016) discovere that openness to trade has been instrumental in the growth trajectory of South Africa from 1991 to 2013. The study further alluded to the fact that, apart from trade openness; financial development and internet usage are key to the economic expansion in South Africa. The country may need to expand internet infrastructure and trade in order to sustain its growth. Also, Freund and Bolaky (2008) using a sample of 126 countries submits that openness exerts a positive impact on per capita GDP. Their outcomes show that trade leads to higher standards of living in flexible economies, but not in rigid economies. In tandem, Malefane and Odhiambo (2018) employed time series data for the period 1975 to 2014 and found that an increase in total trade to GDP ratio leads to an increase in the GDP per capita. Therefore, suggesting that trade openness has a positive impact on economic growth in South Africa. Likewise, Zamango (2018) uses the pooled mean group (PMG) estimator to explore the effect of trade on economic growth in 42 SSA countries from 1980 to 2012 and reported that trade openness has a positive impact on growth on the first group of countries. The second group finds a negative relationship between trade and growth (Zahonongo 2017; Adhikary 2011), while the third established that openness to trade has no impact on growth (Were 2015; Eris and Ulasan, 2013; Musila & Yiheyis 2015; Babatunde, 2011).

ICT-Growth Relation

Donou-Adonsou (2019) explores the influence of telecommunication infrastructure on economic growth in 45 SSA countries. The study divided SSA countries into two groups: those that have access to better education and those who do not. The findings suggest that internet drives economic growth in the former, but there is no strong evidence that the same could be true for the latter. The study concludes that education is necessary for internet usage, but may not be relevant for mobile phone usage. In the same vein, Myovella et al. (2020) use the GMM estimator to examine the effect of digitalization on economic growth in 74 countries encompassing SSA and Organisation for Economic Cooperation and Development (OECD) countries. The findings from the study revealed that digitalization is the fulcrum of growth in both SSA and OECD countries. However, the impact of mobile telecommunication on economic growth was high in SSA compared to OECD countries, while the influence of broadband internet was minimal in SSA than OECD countries.

Similarly, Adeleye and Eboagu (2019) using a sample of 54 countries from 2005 to 2015 estimate the relationship between ICT and economic growth. Employing a pooled ordinary least squares, random and fixed effects and system generalised method of moments models and further dividing the sample across five regions, the study showed a positive relationship between the ICT variables and economic growth. In particular, mobile subscriptions had a higher output elasticity than fixed telephone subscriptions across all estimated models. The study concluded that mobile telecommunication has the ability to enable Africa to skip the traditional development phases. Equally, Ejemeyovwi & Osabuohien (2018) apply the GMM technique to investigate the effect of mobile technology on economic growth in 15 Africa countries from 2004 to 2014. Surprisingly, the outcomes indicate that mobile technology has no meaningful impact on economic growth in Africa. This finding contradicts previous results. However, the authors believed that the slow adoption of ICT in most African countries could be responsible for the insignificant impact of ICT on economic growth in the region. They call for an improvement in mobile technology so as to enhance economic growth in Africa.

Furthermore, Koutroupis (2011) using annual data from 192 countries covering the period 1990–2007 found that mobile telecommunications stimulate economic growth. Going further, the study shows that the contribution of telecommunication to GDP growth differed according to country income level as telecom contribution to annual GDP growth was 0.11% for low-income countries and 0.20% for high-income countries. Likewise, Ward and Zeng (2015) from a panel of 31 regions in China for the period 1991 to 2010 find that telecommunication is an

important contributor to economic growth in China. The study which employs a system GMM, apart from showing that mobile telecommunication had a greater impact on growth than fixed telecommunication also reported regional variations in the impact of telecommunication on economic growth across the country.

3 Data and Model

The study engages a panel data on 54 African countries from 2005 to 2015. On the need to allow more countries for a considerable representation of the continent, the scope is restricted to the start date of 2005 which becomes justifiable as most African countries shows substantial loss of ICT data in pre-2005 years. Also, in evaluating the ICT-trade nexus on economic growth it becomes intrinsic to appraise this relationship alongside each sub-region. Hence, the full sample is split into five sub-samples across regional delineations[1] – Central Africa, East Africa, North Africa, Southern Africa and West Africa.

3.1 The Variables

In line with similar studies, the indicator of economic growth is gross domestic product (constant 2010 US$) (*GDP*); trade openness (*TRADE*) captures a country's trading activities in the global market; two indicators of ICT adoption used are: mobile cellular subscription (*MOBILE*) and fixed telephone subscription (*TEL*). Individuals using the internet (% of population) (*INTERNET*) is included as a control variable (and not as an indicator of interest) because internet is an enabler particularly for mobile phone users engaging in foreign trade. Other control variables are gross fixed capital formation (*GFCF*); and labour participation rate (*LABOUR*). Inflation rate (*INFL*) is included for robustness checks. Lastly, interaction terms of trade and mobile phone usage *(TRADE*MOBILE)* and trade and fixed telephone subscription *(TRADE*TEL)* are included to address the study questions. All variables are obtained from World Bank (2019) World Development Indicators (WDI).

The indicators of economic growth, trade openness, and ICT have been broadly expounded in the introduction and literature review sections, and in line with *a priori*, positive coefficients are expected. Other variables are explained in brief. *Gross fixed capital formation* measures the stock of fixed investment which comprises net increase in physical assets within the measurement period. From Romer (1986) and Solow (1956) physical capital accumulation is

[1]See Appendix Table 1A for the list of countries and their respective regions.

an important determinant of growth and firms accumulate know-how through capital accumulation which can produce growing returns and promote economic growth. Also, this variable is included because a country that is open to international trade will require some level of absorptive capacity to produce, which in turns affects economic growth. Therefore, in line with expectation, a positive coefficient is envisaged.

Labor force participation rate is the proportion of the population age 15 and older that is economically active. Skilled labour is required for production and it is an essential ingredient for growth (Hotchkiss, 2009). More skilled labour engaged to handle machineries for production is an impetus for growth, but unskilled and untrained will be a drag on growth (Fetahi-Vehapi et al, 2015). Hence, the expected sign in indeterminate. *Internet usage* is an enabler of global connectivity. This variable is included because to enhance trade across borders, persons require to have internet connection on their mobile phone. Internet access can be via computers, internet-enabled mobile phones, digital television, and game machines such that business can be initiated and concluded with ease and within the comforts homes and offices without having to travel to conclude such deals. A positive coefficient is expected upon estimation. The study hypothesizes that trade, mobile phone and fixed telephone subscription is expected to positively impact economic growth, therefore, the interaction of trade and mobile phone usage *(TRADE*MOBILE)* and trade and fixed telephone subscription *(TRADE*TEL)* are also expected to be positive to enhance the *total* impact of trade openness on economic growth. Lastly, rising price level, *inflation*, may have adverse consequences on the economy. Hence, a negative coefficient is expected.

3.2 Summary Statistics and Correlation Analysis

Table 1 shows the statistics for the full and sub-regions. With emphasis on the indicators of interest, the average GDP for the continent is US$34.9billion. Sao Tome and Principe shows the lowest in 2011 with US$126million while Nigeria has the highest at US$547billion in 2014. Across the sub-regions, mean GDP value ranges between US$13.7billion (East Africa) and US$93.9billion (North Africa). The mean trade value is 79.27. Data reveals that Southern Africa has the highest average trade openness (% of GDP) with 89.874 and Central Africa recorded the lowest with 73.84. The continent's average for mobile phone usage is 10.3million. Across the sub-regions, West Africa records the highest average mobile subscribers at 23.9million followed by North Africa with 23.6m users. Southern Africa has the highest average fixed telephone subscription while the highest average for internet users is from North

Africa. On average, gross fixed capital formation (% of GDP) which is highest in North Africa at 26.65 which is higher than the continent's average of 22.26. The lowest average value is recorded for West Africa at 20.67. The continent's average labour participation rate is 67.35. North Africa indicates the lowest with 48.15 while the highest is Central Africa with 72.45.

Table 1 Summary Statistics

Variables	***Full Sample***		***Central Africa***		***East Africa***	
	Mean	SD	Mean	SD	Mean	SD
GDP	3.49E+10	7.52E+10	2.19E+10	2.84E+10	1.37E+10	1.39E+10
TRADE	79.272	38.104	73.584	32.804	78.816	44.069
MOBILE	1.03E+07	1.88E+07	4269375	7057565	7137922	9593327
TEL	541844.1	1480251	193723.5	306248.6	106074	132000.7
INTERNET	10.16592	12.3186	6.31319	7.085187	9.508218	12.29396
GFCF	22.26532	8.904629	22.37035	9.994872	21.76518	8.42603
LABOUR	67.34951	12.85585	72.45199	10.73972	71.94571	12.18461
INFLATION	53.12296	1030.434	8.324217	8.864306	199.1539	2101.628

Notes: For example: 1.03E+7 = 10,300,000.00; GDP: Gross domestic product; GFCF: Gross fixed capital formation; TEL: Fixed telephone subscription

Source: Authors' Computations

Table 1 Summary Statistics (Contd.)

Variables	***North Africa***		***South Africa***		***West Africa***	
	Mean	SD	Mean	SD	Mean	SD
GDP	9.39E+10	7.79E+10	4.40E+10	1.03E+11	2.96E+10	8.97E+10
TRADE	76.119	28.08	89.874	23.82	78.098	44.105
MOBILE	2.36E+07	2.38E+07	9156587	1.85E+07	1.13E+07	2.39E+07
TEL	2485757	3039276	639786.1	1419525	167437.7	269320.5
INTERNET	21.06728	15.54834	11.70773	12.8682	7.173768	9.668342
GFCF	26.6503	9.419201	22.37391	7.238429	20.6741	8.794349
LABOUR	48.14523	3.186839	68.50589	13.10669	68.87922	8.456939
INFLATION	7.170792	7.217981	7.585632	4.53417	5.745547	6.846131

Notes: For example: 2.36E+7 = 23,600,000.00; GDP: Gross domestic product; GFCF: Gross fixed capital formation; TEL: Fixed telephone subscription

Source: Authors' Computations

Table 2 details the pairwise correlation which measures the relative association among the regressors and the dependent variable. Overall, the variables with the exception of inflation have statistically significant relationships with economic growth howbeit with varying signs. Similarly, a cursory look at the Table indicates no presence of multicollinearity among the covariates.

Table 2 Correlation Matrix

Variables	*GDP*	*GFCF*	*LAB*	*TR*	*INFL*	*INT*	*MOB*	*TEL*
GDP	1.00							
GFCF	0.1247***	1.00						
LABOUR	-0.2637***	-0.11	1.00					
TRADE	-0.1637***	0.2540***	-0.1796***	1.00				
INFLATION	-0.02	-0.1549***	0.06	0.02	1.00			
INTERNET	0.3222***	0.2572***	-0.4230***	0.1916***	-0.02	1.00		
MOBILE	0.8559***	0.09	-0.1410***	-0.2574***	-0.02	0.3235***	1.00	
TEL	0.7658***	0.08	-0.3301***	-0.1586***	0.03	0.3806***	0.6816***	1.00

Notes: GDP: Gross domestic product; GFCF: Gross fixed capital formation; LAB: Labour; TR: Trade; INF: Inflation; INT: Internet usage; MOB: Mobile subscription; TEL: Fixed telephone subscription

Source: Authors' Computations

3.3 The Model

To investigate whether trade openness has a significant impact on economic growth and if its impact is influenced or hampered by ICT adoption, this paper adapts the empirical approach of Adeleye and Eboagu (2019) and Adeleye and Jamal (2020) and specifies economic growth as a linear function of trade openness, ICT indicators (*MOBILE* and *TEL*) and other control variables. The ICT-trade nexus is represented by the interaction of trade with each ICT indicator and the explicit form of the models are specified as:

$$\ln GDP_{it} = \xi_0 + \xi_1 \ln TRADE_{it} + \xi_2 \ln MOBILE_{it} + \xi_3 \ln TEL_{it} + \xi_4 \ln (TRADE * MOBILE)_{it} + \xi_5 \ln (TRADE * TEL)_{it} + \xi_6 \boldsymbol{Z'}_{it} + \omega_i + \lambda_t + e_{it} \quad [1]$$

$$\ln GDP_{it} = a_0 + a_1 \ln TRADE_{it} + a_2 \ln MOBILE_{it} + a_3 \ln TEL_{it} + a_4 \ln (TRADE * TEL)_{it} + a_5 \boldsymbol{X'}_{it} + \eta_i + \delta_t + v_{it} \quad [2]$$

Where $\ln GDP_{it}$ is the natural logarithm of GDP; $\ln MOBILE_{it}, \ln TEL_{it}$ are the natural logarithms of ICT innovation (mobile subscription and fixed telephone subscribers); $\boldsymbol{Z'}_{it}$ and $\boldsymbol{X'}_{it}$ are the vector of control variables (internet usage, gross fixed capital formation, labour participation) in natural logarithms; ω_i and η_i indicate country dummies; λ_t and δ_t represent year dummies (which controls for common shocks such as the global financial crises of 2008-2009), and e_{it} and v_{it} are the general error terms.

Note, the signs of the coefficients of the interaction terms, ξ_4 and a_4 evaluate if the interaction of ICT adoption (mobile phone usage and fixed telephone subscription) on trade enhances or distorts the impact of trade on economic growth. A positive sign indicates that ICT boosts trade performance on growth and vice versa. The total effect of trade on economic growth given mobile phone usage is computed as:

$$\frac{\partial \ln GDP}{\partial \ln TRADE} = \xi_1 + \xi_4 \ln MOBILE \quad [3]$$

Similarly, the total effect of trade on economic growth given telephone users is expressed as:

$$\frac{\partial \ln GDP}{\partial \ln TRADE} = a_1 + a_4 \ln TEL \quad [4]$$

So, if $\xi_4, a_4 > 0$ it implies that ICT innovation is an enhancer of trade on growth. But if $\xi_4, a_4 < 0$, the overall impact of trade on growth depends on the magnitude of the negative. If the negative signs of ξ_4, a_4 outweighs the positive sign of ξ_1, a_1 then ICT innovation distorts the impact of trade on economic growth. On the contrary, if the negative sign of ξ_4, a_4 is less than the positive sign of ξ_1, a_1 it implies that the distortionary influence of ICT is not sufficient to inhibit the positive effect of trade on economic growth. Finally, if $\xi_4, a_4 = 0$ it is an indication that the interaction of ICT innovation with trade has no significant impact on growth.

To methodically draw the significance of trade and ICT innovation on economic growth, the study adopts the use of static and dynamic models. These estimation approaches are used by similar studies (Niebel, 2014; Adeleye, Osabuohien, & Bowale, 2017; Adeleye & Eboagu, 2019; Adeleye & Jamal, 2020). Similarly, the adoption of these techniques serve as robustness for one another in order to observe the consistency of the impact of trade and ICT on economic growth. The static technique is the pooled ordinary least squares (*POLS*) which does not allow for heterogeneities across the panels while the dynamic model is the Arellano-Bond (1991) difference generalized method of moments (*difference-GMM*) estimator technique[2] which corrects for endogeneity, cross-sectional dependence, serial correlation and heteroscedasticity by including instruments that are uncorrelated with the regressors in the underlying routine during estimation. Another argument for engaging dynamic panel data modelling is due to the

[2]Perhaps, due to the fact that regressors and instruments outnumber the cross-sections, our model is not robust to the use of the system generalized method of moments (GMM) approach. Several simulations yielded statistically insignificant results and in most cases the diagnostics are returned by dotted (.) signs.

potentially endogenous estimators the results of the OLS technique which may be biased upwards. For the difference-GMM, the validity of instruments used determines the consistency of the parameters that emanates from such estimator. Two specification tests put forward by Arellano and Bond (1991) to examine the validity of the instruments is the Hansen statistic and second-order serial correlation *AR*(2). Failure to reject the null hypotheses of *over-identifying restrictions are valid* and no second-order serial correlation gives credence to the results.

4 Results and Discussions

This section presents empirical findings which fill important gaps in the trade-growth and ICT-growth literature on Africa by showcasing findings on whether trade openness individually promotes economic growth and/or if its interaction with ICT innovation enhances or alters its impact on growth significantly. Estimations begin with alternate analysis of models with *MOBILE* and *TEL* and their interactions with *TRADE* as shown in Table 3. The composite result incorporates the robustness checks for estimations consistency. Columns [1], [2], [5], and [6] relate to the results of the main regressions from the pooled OLS and difference-GMM techniques while columns [3], [4], [7], and [8] are the corresponding robustness checks with *INFLATION* as additional control variable. Interpretation of the results from the two estimation techniques are taken in turns.

4.1 Full Sample Results

Starting with the pooled OLS analysis, as expected, the coefficient of trade openness is positive and statistically significant at the 1% level. This outcome is consistent with Fetahi-Vehapi et al (2015) and implies that trade openness is an important contributor to growth in Africa and that an increase in trade leads to an increase in growth across the continent. *MOBILE* has a positive and 1% statistically significant effect on growth which aligns with previous studies (Roeller & Waverman, 2001; Torero, Chowdhury, & Bedi, 2006: Chavula, 2013; Adeleye and Eboagu, 2019). This infers that mobile telecom induces economic growth across Africa and that a 1 percent increase in mobile telecommunication subscription will lead to between 1.43 and 1.65 percent increase in growth, on average, *ceteris paribus*. Ditto for *TEL* with significant positive impact ranging between 1.62 and 1.65, on average, *ceteris paribus*. The impact of *GFCF* is not statistically significant and *LABOUR* on the other hand has a negative impact on economic growth with a statistically significant relationship ranging from 1% to 10%. Specifically, a 1 percent increase in *LABOUR* will cause a decrease of 0.59 to 0.77 percent in

economic growth, on average, *ceteris paribus*. This outcome shows that unskilled labour is a drag on growth (Adeleye and Eboagu, 2019)

On the contribution of ICT innovation to the trade-growth nexus, the coefficients of the interaction terms which indicate whether ICT innovation enhances or distorts trade openness are negative across all model specifications. However, the magnitude of the negatives determines the influence of ICT innovation. For instance, in column [1], the differential[3] of 1.9816 (that is, 2.1188 – 01372) gives the *total* effect of trade on growth given *MOBILE* which shows that the negative interaction is not sufficient to dampen the positive impact of trade on economic growth. Considering the interactions of both *MOBILE* and *TEL*, the *total* impact of trade on growth amounts to 1.9816, 2.7262, 2.2668 and 2.1083, respectively. This is an important finding and contributions to the literature as it corroborates to the growth-enhancing impact of trade openness. The respective intercepts of the sub-regions show similar patterns across the four models. All have higher intercepts than the base sub-region (West Africa) whose intercept is represented by the coefficient of the constant term which is 367.76.

[3]The differential is obtained by deducting the coefficient of the interaction term from that of trade openness.

Table 3 Pooled OLS Results - Full Sample (Dep. Variable: GDP, log)

Variables	Pooled OLS				Difference GMM			
	Main Regressions		*Robustness Checks*		*Main Regressions*		*Robustness Checks*	
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
Constant	367.7564***	-108.8363***	374.2422***	-142.2249***				
	(13.19)	(-2.67)	(12.87)	(-3.41)				
GDP_1, log					0.1501	0.5384***	0.2706*	0.5620***
					(1.08)	(2.92)	(1.95)	(3.51)
GFCF, log	0.0561	0.0238	0.0671	-0.1428	0.1431	0.1255**	-0.1413	0.1102**
	(1.11)	(0.24)	(1.21)	(-1.35)	(0.50)	(2.63)	(-0.34)	(2.34)
LABOUR, log	-0.7419***	-0.6409**	-0.7672***	-0.5925*	-0.3135	-0.2672	-0.8879	-0.3037
	(-3.88)	(-2.01)	(-3.72)	(-1.75)	(-0.46)	(-0.89)	(-1.24)	(-1.07)
INFLATION, log			0.0000	-0.0001***			0.0000	0.0000
			(1.12)	(-5.93)			(0.04)	(0.15)
TRADE, log	2.1188***	2.4998***	2.9117***	2.3274***	1.4001**	0.4035	1.9820*	0.4782
	(2.62)	(4.45)	(3.44)	(4.35)	(2.57)	(1.43)	(1.87)	(1.59)
INTERNET, log	0.2011***	0.0515	0.1974***	-0.0020	0.2040	0.0590*	0.1439	0.0620**
	(6.35)	(0.84)	(5.74)	(-0.03)	(1.22)	(1.79)	(1.06)	(2.04)
MOBILE, log	1.4294***		1.6511***		0.6720***		0.8678***	
	(6.69)		(7.47)		(4.25)		(3.61)	
TRADE*MOBILE, log	-0.1372***		-0.1855***		-0.1158***		-0.1443**	
	(-2.68)		(-3.50)		(-3.59)		(-2.53)	
FIXED TEL, log		1.6525***		1.6163***		0.2320**		0.2515**
		(7.57)		(7.65)		(2.17)		(2.23)
TRADE*TEL, log		-0.2330***		-0.2191***		-0.0557**		-0.0605**
		(-4.60)		(-4.45)		(-2.25)		(-2.30)
Central Africa	1.3914***	1.2022***	1.3263***	1.3774***				
	(13.39)	(8.47)	(13.02)	(10.01)				
East Africa	0.3230***	0.3691**	0.3374***	0.4459***				
	(5.70)	(2.47)	(5.54)	(2.79)				

North Africa	0.3153***	0.0556	0.2716**	0.1384				
	(2.86)	(0.34)	(2.47)	(0.86)				
Southern Africa	0.6494***	0.0990	0.6294***	0.1307				
	(9.67)	(0.95)	(9.29)	(1.30)				
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of Obs.	492	479	480	469	393	384	387	377
R-Squared	0.884	0.696	0.888	0.715				
F Statistic	196.789	82.667	251.151	91.280	62.614	243.667	91.803	230.420
Instruments/Groups					30/48	37/50	30/47	37/48
AR(2)/Hansen Stat.					0.068/0.127	0.598/0.498	0.084/0.498	0.514/0.457

Notes: ***, **, *are statistical significance at the 1%, 5% and 10% levels respectively; *t*-statistics in ( ) are based on White heteroscedasticity-consistent std. errors;
GFCF = Gross fixed capital formation
Source: Authors' Computations

From the GMM estimations represented in columns [5] to [8], evidence show that growth is persistent in the data in three out of four models. That is, a percentage increase in previous year's economic growth contributes between 0.27 to 0.56 percent to current growths, on average, *ceteris paribus*. The coefficient of *TRADE* is positive and statistically significant at the 5% as well as 10% levels, respectively but only for the *MOBILE* models with similar interpretation as given earlier. The coefficients of *MOBILE* and its interaction with *TRADE* is statistically significant though with asymmetric effects. Previous interpretation holds. That is, the negative interaction impact of mobile phone on trade openness is not sufficient to dampen the total effect of trade on economic growth as the differential is positive. Ditto for *TEL*. Lastly, while controlling for year dummies, the goodness-of-fit of the models shows that the proportion of variation in the dependent variable explained by the regressors ranges from 71.5% to 88.8%, and across all model specifications, the *F*-statistics indicate that the regressors are jointly significant in explaining economic growth. For the *difference-GMM*, there is no evidence of second-order serial correlation given the indicated *p*-values while the null hypothesis of instruments validity cannot be rejected at the 5% significance level. Hence, the results obtained from these augmented regressions can be used for inferences.

4.2 Sub-Sample(s) Results

For the five sub-sample analysis, a total of ten models are estimated using only the pooled OLS technique to enable comparative discussions. Results shown in columns [9] to [18] of Table 4 indicate each sub-region having two columns each. The odd-numbered columns relate to *MOBILE* models while the even-numbered columns are for *TEL* models. Emphasis will centre mainly on the individual and interactive effects of *TRADE*, *MOBILE*, and *TEL* on growth. Starting with *TRADE*, its coefficient is statistically significant in eight out of ten models. Except for columns [9] and [17], the results show that trade openness has statistically significant mixed impact on growth. Positive coefficients are consistent for both models in East Africa and Southern Africa, consistent negatives for North Africa while only negative for the *TEL* models in Central and West Africa. These outcomes imply that at the sub-regional levels, trade openness facilitates and inhibits growth. Given the relative historic characteristics of these sub-regions, this outcome is not unexpected.

Table 4 Pooled OLS Results for Sub-regions (Dep. Variable: GDP, log)

Variables	*Central Africa*		*East Africa*		*North Africa*		*South Africa*		*West Africa*	
	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]
Constant	4.7939	26.5940***	1.2527	-35.9522***	61.1690***	32.6475***	-0.4645	-53.5656***	13.6469***	-1.8084
	(0.86)	(8.11)	(0.21)	(-3.46)	(7.37)	(7.07)	(-0.04)	(-4.84)	(3.00)	(-0.37)
GFCF, log	-0.0100	0.3379**	0.0158	0.4254**	-0.8968***	0.2386	1.0846***	0.3147	0.0093	-0.5539***
	(-0.03)	(2.04)	(0.16)	(2.27)	(-3.82)	(1.46)	(4.94)	(1.34)	(0.09)	(-4.22)
LABOUR, log	1.1787***	0.7988***	0.2830	2.7482***	1.4902	-0.6202	-1.9773***	1.5442***	-2.0853***	-1.5911***
	(4.56)	(3.02)	(0.67)	(3.80)	(1.18)	(-0.57)	(-3.97)	(3.63)	(-6.08)	(-2.98)
TRADE, log	1.2466	-3.3891***	2.3905*	9.4058***	-13.3974***	-3.5480***	4.6622*	14.0973***	1.3010	5.3077***
	(0.76)	(-3.77)	(1.98)	(4.43)	(-7.46)	(-3.59)	(1.81)	(6.37)	(1.28)	(5.58)
INTERNET, log	0.0540	0.3168***	-0.0491	0.0745	-0.3803***	0.1137	0.1141	0.3517***	-0.0640	0.0715
	(0.78)	(5.23)	(-1.13)	(0.61)	(-4.14)	(1.64)	(1.56)	(4.53)	(-1.18)	(0.98)
MOBILE, log	0.4768		1.2853***		-2.3642***		2.4038***		1.3623***	
	(0.99)		(3.84)		(-5.22)		(3.21)		(5.03)	
TRADE*MOBILE, log	0.0222		-0.1421*		0.8262***		-0.4234**		-0.1294*	
	(0.19)		(-1.80)		(7.53)		(-2.42)		(-1.96)	
FIXED TEL, log		-1.2767***		4.0006***		-0.2252		5.9977***		3.1829***
		(-3.86)		(4.88)		(-0.72)		(8.28)		(7.45)
TRADE*TEL, log		0.4422***		-0.8235***		0.1972**		-1.2401***		-0.5395***
		(5.29)		(-4.20)		(2.61)		(-7.62)		(-5.49)
No. of Obs.	74	71	109	106	66	66	87	87	156	149
R-Squared	0.839	0.901	0.873	0.561	0.902	0.929	0.903	0.915	0.830	0.756
F Statistic	75.555	119.358	122.393	15.532	87.602	178.555	170.611	187.980	121.494	75.908

Notes: ***, **, *are statistical significance at the 1%, 5% and 10% levels respectively; *t*-statistics in ( ) are based on White heteroscedasticity-consistent std. errors; GFCF = Gross fixed capital formation

Source: Authors' Computations

Still on *TRADE*, Southern Africa indicates the largest output elasticities of 4.6622 and 14.0973 while North Africa shows the lowest with -13.3974 and -3.5480. In other words, the impact of trade on economic growth in the former will be more profound than on the latter. To capture the effect of trade openness succinctly, it means that at the regional level, trade facilitates growth in East and Southern Africa, reduces growth in North Africa and has no significant impact on growth in the Central and West African regions (in the *MOBILE* models).

The ICT indicators of mobile phone usage and fixed telephone subscription indicate 1% statistically significant asymmetric effects on economic growth. Positive coefficients support previous studies on the growth-enhancing impact of ICT. For instance, a percentage increase in *MOBILE* is expected to contribute between 1.28 to 2.40 percent increase in growth, on average, *ceteris paribus* ditto for *TEL* which will range between 3.18 and 5.99. The magnitude of these coefficients may suggest that increase in ICT adoption leads to increased investments in the telecommunications sector equipment which contributes directly to the GDP. In part, the availability of mobile phones leads to faster economic transactions and revenue generation. The demand for mobile telecommunication also contributes to the establishment of telecommunication services companies, and the creation of jobs which all contribute to boosting overall economic activities in Africa. Needless to say that the presence of mobile telecom boosts economic activities thereby increasing economic benefits to the citizens.

The interactions between *TRADE* and the ICT indicators vary across the sub-regions. Depending on the form of ICT variable, the moderating effect of ICT either stimulates the impact of trade on growth or act as a slug in the trade-growth wheel. From the *TRADE*MOBILE* nexus, the differentials are 0 (Central Africa), 2.2484 (East Africa), -12.5712 (North Africa), 4.2388 (Southern Africa), and -0.1294 (West Africa). These outcomes which are significant findings and contributions to the literature imply that mobile phone usage enhances the impact of trade openness in Southern Africa relative to other sub-regions. Analysis from the *TRADE*TEL* nexus indicate that the differentials are -2.9469 (Central Africa), 8.5823 (East Africa), -3.3508 (North Africa), 12.8572 (Southern Africa), and 4.7682 (West Africa). Again, fixed telephone subscriptions boost the impact of trade openness in Southern Africa relative to other sub-regions. Comparatively, the enhancing impact of ICT adoption in North Africa is not large enough to revert the distortionary

impact of trade on economic growth relative to other sub-regions. For the control variables, the signs and statistical significance of their coefficients are not consistent across all model specifications. Within the sub-regions, *GFCF* and *INTERNET* indicate varying impacts while for *LABOUR* some consistencies can be observed from Central (West) Africa with positive (negative) and statistically significant coefficients at the 1% level. This shows that while the labour force in Central Africa contributes to economic growth, the contrary occurs in West Africa. On the goodness-of-fit of the models, the R-squared show that the variables in the model explain the variation in economic growth between the range of 56.1% to 96.9% and the F-statistics demonstrate that the variables are jointly significant in explaining economic growth. For robustness, *INFLATION* is added to the models and the outcomes (see Appendix Table 1B) are not significantly different from the main results.

5 Summary and Policy Recommendations

With data on 54 African countries from 2005 to 2015 and using mobile phones and fixed telephone subscriptions as the indicators of ICT, the study engages the static (pooled OLS) and dynamic (difference GMM) approaches to examine the ICT-trade nexus on economic growth. In broader terms, this paper addresses five research questions among which is whether trade openness significantly impact growth and if the adoption of ICT influences or hinders the impact of trade on economic growth?

Findings, amongst others, provide evidence that (1) economic growth is persistent in Africa; (2) trade is a significant and positive predictor of economic growth, (3) that the impact of trade on growth differs significantly across Africa's five sub-regions, (4) that the effect of ICT adoption also differs significantly across the sub-regions, (6) that ICT innovation enhances the impact of trade on growth, and (7) the ICT-trade nexus differ significantly across the sub-regions. Given the consistency of the full sample results in relation to the three indicators of interest (trade, mobile phones and fixed telephone subscription), the study submits that these variables are key drivers of economic growth in Africa. However, the lack of consistency of the results across the sub-regions suggests that the level of ICT is still undeveloped relative to other regions of the world and the benefits of international trade is yet to be properly harnessed. Furthermore, that ICT enables trade

in some sub-regions while inhibiting trade (though minimally) in others also indicates the relative development of the ICT sector across the sub-regions.

In conclusion, some suggested policy measures are as follows: (1) to harness the gains from trade African goods must be competitive at the global markets, (2) there is the need to relax trade restrictions and remove barriers, (3) the effective take off and implementation of the Africa Continental Free Trade Agreement (AfCFTA) will go a long way in synergizing trade relations within the African continent, and (4) the rising use of ICT innovation particularly mobile phones calls for the need to regulate the sector with the aim of easing accessibility and at reduced cost. Overall, policymakers, regulators and governments must cooperate to initiate and implement policies that will engender increased trading so as to boost economic growth. With available data, the monotonic impact of trade on economic growth may be taken up in future.

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Appendix

Table 1A List of Countries

S/No.	Country	Region	S/No.	Country	Region
1	Algeria	NA	28	Libya	NA
2	Angola	CA	29	Madagascar	SA
3	Benin	WA	30	Malawi	SA
4	Botswana	SA	31	Mali	WA
5	Burkina Faso	WA	32	Mauritania	NA
6	Burundi	EA	33	Mauritius	SA
7	Cabo Verde	WA	34	Morocco	NA
8	Cameroon	CA	35	Mozambique	SA
9	Central African Republic	CA	36	Namibia	SA
10	Chad	CA	37	Niger	WA
11	Comoros	EA	38	Nigeria	WA
12	Congo, Dem. Rep.	EA	39	Rwanda	EA
13	Congo, Rep.	EA	40	Sao Tome and Principe	CA
14	Cote d'Ivoire	WA	41	Senegal	WA
15	Djibouti	EA	42	Seychelles	EA
16	Egypt, Arab Rep.	NA	43	Sierra Leone	WA
17	Equatorial Guinea	CA	44	Somalia	EA
18	Eritrea	CA	45	South Africa	SA
19	Ethiopia	CA	46	South Sudan	EA
20	Gabon	CA	47	Sudan	NA
21	Gambia, The	WA	48	Swaziland	SA
22	Ghana	WA	49	Tanzania	EA
23	Guinea	WA	50	Togo	WA
24	Guinea-Bissau	WA	51	Tunisia	NA
25	Kenya	EA	52	Uganda	EA
26	Lesotho	SA	53	Zambia	EA
27	Liberia	WA	54	Zimbabwe	EA

Source: Authors' Compilation

Table 1B Pooled OLS Results for Sub-regions (Robustness)

Variables	*Central Africa*		*East Africa*		*North Africa*		*South Africa*		*West Africa*	
	[19]	[20]	[21]	[22]	[23]	[24]	[25]	[26]	[27]	[28]
Constant	-8.9448	23.7002***	5.8595	-38.8369***	59.7348***	33.8561***	-1.2004	-54.3764***	16.9023***	0.7858
	(-1.20)	(7.28)	(0.97)	(-3.56)	(7.18)	(7.54)	(-0.09)	(-5.11)	(3.64)	(0.17)
GFCF, log	-0.2319	0.1608	-0.1260	0.3970*	-0.8860***	0.2069	1.0346***	0.3490	0.0317	-0.5019***
	(-0.86)	(0.91)	(-1.24)	(1.92)	(-3.87)	(1.21)	(4.51)	(1.41)	(0.29)	(-3.82)
LABOUR, log	0.8663***	0.7270**	-0.3385	3.4509***	1.4263	-0.5983	-1.8895***	1.5147***	-2.1673***	-1.6389***
	(2.66)	(2.64)	(-0.79)	(4.81)	(1.07)	(-0.52)	(-3.55)	(3.48)	(-6.34)	(-3.20)
INFLATION, log	-0.0134	0.0014	0.0000	-0.0000***	-0.0106	-0.0136	-0.0102	0.0097	0.0210***	0.0336***
	(-0.99)	(0.21)	(0.27)	(-3.08)	(-0.95)	(-1.52)	(-0.90)	(0.64)	(2.66)	(3.86)
TRADE, log	4.7308**	-2.4147**	1.8549	9.3872***	-12.8768***	-3.7296***	4.8098*	14.2445***	0.6194	4.6586***
	(2.31)	(-2.60)	(1.50)	(4.16)	(-6.59)	(-4.23)	(1.78)	(6.70)	(0.61)	(5.20)
INTERNET, log	0.0149	0.2599***	-0.0905**	0.0909	-0.3620***	0.1130	0.1093	0.3551***	-0.0451	0.0807
	(0.20)	(4.47)	(-2.27)	(0.72)	(-3.69)	(1.60)	(1.50)	(4.66)	(-0.82)	(1.14)
MOBILE, log	1.5130**		1.1987***		-2.2220***		2.4454***		1.1745***	
	(2.51)		(3.54)		(-4.54)		(3.12)		(4.36)	
TRADE*MOBILE, log	-0.2054		-0.1082		0.7849***		-0.4335**		-0.0886	
	(-1.46)		(-1.35)		(6.37)		(-2.36)		(-1.37)	
FIXED TEL, log		-0.8648**		3.9511***		-0.2528		6.0467***		2.9502***
		(-2.51)		(4.51)		(-0.91)		(8.67)		(7.32)
TRADE*TEL, log		0.3386***		-0.8117***		0.1984***		-1.2495***		-0.4845***
		(3.86)		(-3.85)		(2.84)		(-7.94)		(-5.25)
No. of Obs.	69	66	102	101	66	66	87	87	156	149
R-Squared	0.841	0.895	0.885	0.590	0.904	0.931	0.904	0.916	0.838	0.779
F Statistic	40.836	93.688	183.684	30.814	78.377	175.667	145.334	171.942	128.925	70.701

Notes: ***, **, *are statistical significance at the 1%, 5% and 10% levels respectively; *t*-statistics in ( ) are based on White heteroscedasticity-consistent std. errors; GFCF = Gross fixed capital formation

Source: Authors' Computations