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CAUSALITY BETWEEN ICT, FINANCIAL DEVELOPMENT AND ECONOMIC GROWTH IN KENYA

Mercy T. Musakwa[1] and Nicholas M. Odhiambo

Abstract

Research Background: *The growing importance of information and communication technology (ICT) in every facet of life motivated this study to examine the association between ICT, financial development and economic growth.*

Purpose*: The purpose of the study is to establish if there is a causal relationship among ICT, financial development and economic growth using annual data from 1990 to 2021.*

Research Methodology*: The study used ARDL bounds test for cointegration and the error correction model (ECM) – based Granger causality technique to examine the causal relationship between the three variables. Three proxies for ICT: the number of fixed telephone subscriptions per 100 people, the number of individuals using the internet as a percentage of the total population, and the number of cellular subscriptions per 100 people were used.*

Results: *The study found the causality between ICT, financial development and economic growth to vary depending on the ICT proxy used. A unidirectional causal flow from ICT to economic growth was found to predominate in the long run when two out of three ICT proxies were considered. The study also found bidirectional causality between ICT and financial development to dominate in the short run when two out of three ICT proxies were considered and a unidirectional causal flow from ICT to financial development in the long run when all three ICT proxies were considered.*

Novelty: *The study departs from the current literature on the causal relationship between ICT, financial development and economic growth by employing three proxies of ICT, namely the number of telephone subscriptions per 100 people, the number of cellular subscriptions per 100 people and the number of individuals using the internet as a percentage of the total population.*

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Keywords: I*nformation and communication technology (ICT); economic growth, financial development; Kenya; autoregressive distributed lag (ARDL)*

JEL: G21; F43; C22

1. Introduction

Although the COVID-19 pandemic brought so many challenges to economies and families through the loss of loved ones and livelihoods, it has also earned credit for fast-tracking the pace of technology used in every sector of the economy and at household level. The lockdown period was an eye-opener on the possibilities that technology can bring in social and economic transformation. Kenya was no exception in this development. Many nations embraced the fourth industrial revolution as a default survival mode for businesses, governments, and households. This development motivated this study to relook at the causal relationship between information and communication technology (ICT), financial development and economic growth in Kenya. This raises the question: which of the three macroeconomic variables should the Kenyan government prioritise in order to push the economy forward? There is evidence of government support for ICT and financial development as a springboard for achieving Vision 2030 in Kenya. The same effort has been displayed in the financial development in Kenya. Finding the direction of causality will help in refocusing government efforts to achieve prosperity for all.

Limited studies have examined the causality between economic growth, ICT and financial development (see Yeong-wha, Pang-ryong and JiYoung, 2021). A fair number of studies have explored the causality between economic growth and ICT (for example, Yeong-wha, Pang-ryong and JiYoung, 2021; Kaushal and Pathak, 2015) and economic growth and financial development (see Verma, Dandgawhal and Giri, 2023; Kumari and Singh, 2023; Aziz et al., 2022). The results from these studies are also inconclusive. Some found a bidirectional causal relationship between economic growth and financial development or economic growth and ICT, while others found a unidirectional causal relationship among the variables. There are some studies that found no causality between financial development, economic growth and

ICT. The direction of causality between the three variables adds invaluable contributions to policy makers' efforts to drive policies that result in achieving Vision 2030.

The study explores the causal relationship between economic growth, ICT and financial development using the autoregressive distributed lag approach, which has its known advantages. In an effort to capture ICT in its multidimensional form, the study used three proxies, namely, the number of individuals using the internet as a percentage of the population, the number of fixed telephone subscriptions per 100 people, and the number of mobile cellular subscriptions per 100 people. The three proxies will capture different ICT multidimensional aspects. Financial development is captured by the financial developed index developed by the International Monetary Fund (IMF). Kenya was selected for this study because of the progress the country has made in embracing technology and financial development initiatives, coupled with the country's economic blueprint – Vision 2030 goals. The causal relationship between economic growth, financial development, and ICT provides vital information in coming up with relevant and impactful policies to achieve the goals set out in the blueprint.

The study is organised as follows: Section 2 dwells on a review of related studies, and Section 3 outlines the estimation techniques. Section 4 discusses the empirical results, and section 5 concludes the study.

2.Literature review

2.1 ICT, Financial Development and Economic Growth in Kenya

ICT trends and dynamics

Information and Communication Technology has been an important element in Kenya in the last decade (Privacy Shield Framework, 2023). Kenya has managed to increase the number of people with access to ICT through technological innovation that has earned the country the name ‘Silicon Savannah’ (Privacy Shield Framework, 2023). Kenya is a regional leader in value-added services like money transfer services and mobile banking services. The Ministry of Information and Communication Technology plays a central role in managing, formulating and developing the information, and broadcasting and communication policy (Privacy Shield Framework, 2023). In 2016, the Ministry was split into the Department of ICT and Innovation and the Department of Broadcasting and Telecommunication. In the same year, the country launched the National Broadband Strategy (NBS) (Privacy Shield Framework, 2023). The strategy is implemented in 5-year intervals, and the current strategy is the National Broadband Strategy 2018-2023. The Communications Authority of Kenya (CA) is Kenya's regulatory authority in the communication sector. The authority was established in 1999 through the Kenya Information and Communication Act 1998 (CA, 2023). The Kenya Information and Communication Act 1998 was amended in 2013 to align with the promulgation of the Constitution in 2010 – Articles 33 and 34, where the regulatory authority was required to be independent of political or commercial influence (CA, 2023). Some of the responsibilities of the authority include licensing, and facilitating development in the sector (CA, 2023). Trends in ICT are reported below in Figure 1

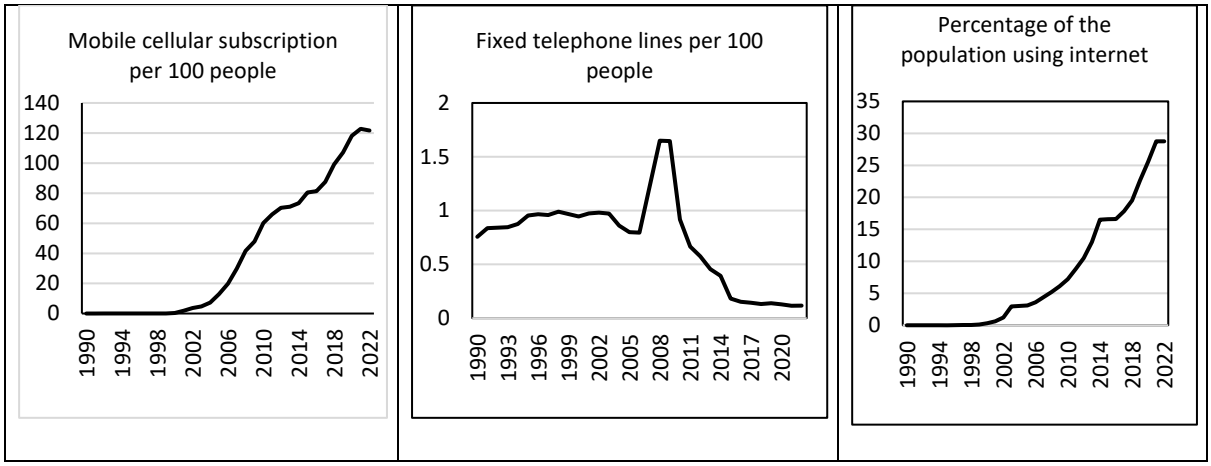


Figure 1. Trends in ICT – internet access, fixed telephone lines and cellular subscriptions 1990-2021

Source: Word Bank (2023)

Figure 1 reports an upward trend in mobile cellular subscriptions and the percentage of the population using the internet over the study period (World Bank, 2023). This suggests an increase in the use of ICT, with more people getting internet connectivity and access to cellular mobile phones. The presence of this trend prior to COVID-19 attests to the notion of a move to embrace the fourth industrial revolution, and COVID-19 only acted as a catalyst. However, this is the opposite with fixed telephone lines, which declined notably since 2008 (World Bank, 2023).

Financial development dynamics

The Kenyan financial system is relatively advanced in comparison to other African countries. The financial sector consists of commercial banks, a range of insurance companies, and non-bank financial institutions. Over the years, the financial sector has experienced tremendous growth across all financial service provisions. The Central Bank of Kenya plays a key role in regulating and supervising the financial sector. The Central Bank of Kenya was established by an act of Parliament of 24 March 1966. The creation of the central bank is rooted in Article

231 of the Constitution (Central Bank of Kenya, 2023). Before the creation of the central bank, the East African Currency Board was responsible for the issuance of currency for the East African Region. The performance of the Kenyan financial sector was under pressure in the 1980s and early 1990s, attributed to a number of weaknesses in the financial system (United Nations Economic and Social Council, 1997). Some of the factors include loose fiscal policy that led to excessive lending to the government, unequal incentives, excessive control of lending and borrowing rates, and lack of level playing fields and competition among financial sector participants (United Nations Economic and Social Council, 1997). These weaknesses resulted in an increase in inflation rate and monetary growth. This ushered in financial sector reforms to address the weaknesses in the financial sector and put the financial sector at the forefront of economic development. The reforms included reinforcement of the legal and regulatory system to redress the weakness in the financial sector and enhance the role of the central bank. The reform included the revision of the 1989 and 1991 Banking Acts and anchoring them with the Banking (Amended) Bill of 1994. The same applied to the Central Bank of Kenya of 1967 and 1984, which were strengthened by the Finance Bill of 1995.

The reforms taken by the Kenyan government have resulted in an increase in the number of participants in the financial sector, prudential regulation of financial service providers and a competitive financial sector that supports economic growth. Trends in financial development and economic growth are captured in Figure 2.

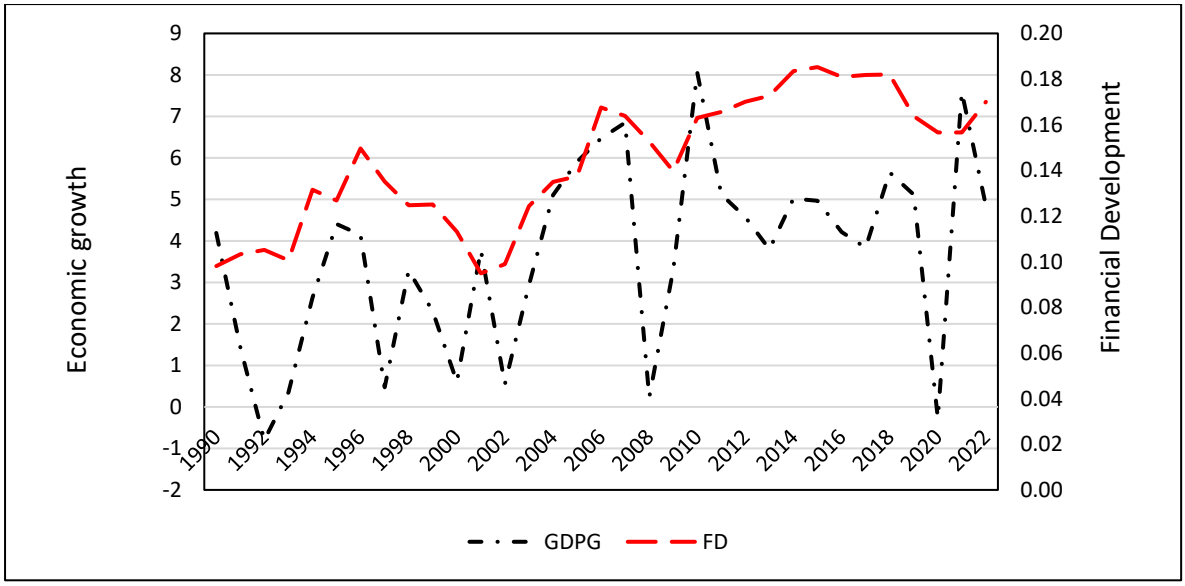


Figure 2. Trends in Economic Growth and Financial development 1990-2021

Source: World Bank, (2023) and IMF (2023)

Financial development and economic growth have fluctuated over the study period; however, a general upward trend can be observed. The general upward trend in the two variables brings the big question of which factor influences the other.

Economic growth dynamics

On the economic growth front, Kenya's Vision 2030 is a long-term blueprint for the country launched in 2008 and aims to transform the country into an industrialised middle-income country by 2030. Vision 2030 shapes the economic policies advanced in Kenya. The vision consists of the social pillar, economic and macro pillar, political pillar, and enablers (Kenya Vision 2030, 2023). The economic and macro pillar focuses on supporting key sectors, namely, Information and technology-enabled services, tourism, agriculture, wholesale and retail, manufacturing, financial services, and business process offshoring that will help boost

economic growth to around 10%. (Kenya Vision 2030, 2023). The social pillar aims to build an equitable society with improved living standards for all Kenyans. The targeted social sectors include water and sanitation, education and training, the environment, youth, sports and culture, gender and housing and urbanisation. The political pillar targets the creation of a democratic political system that is people-centred, results-oriented, and accountable to the public. Vision 2023 is implemented in Five-year medium-term plans, with the first plan covering 2008 to 2012 (Commonwealth Governance, 2023). A review of a precedent five-year medium-term plan informs the inputs into successive five-year medium-term plans.

Review of related studies

The Cobb-Douglas production function that was developed by Charles Cobb and Paul Douglas in 1928 expressed quantity of output as a function of capital (K) and labour (L), where an increase in labour and capital results in a proportionate increase in output. The production function is widely used as a basis for expressing the factors that affect output. However, some authors have modified the model to include technology that plays an important role in enhancing the productivity of labour and capital and financial development that provides funding for capital used in the production process. The production function suggests a direct relationship between labour and capital to output. Financial development enhances capital and the mobilisation of savings for investment. Thus, the development of the financial sector contributes to the scaling of capital in the production function. This brings a close connection between financial development, technology and economic growth.

Vast studies have examined the impact of ICT and financial development on economic growth, although the findings remain inconclusive. The literature on the causality between economic growth, financial development, and ICT is still scant, although it is growing. Among the few

studies that explored the causal relationship between the three variables, the results are inconclusive. Given the limited studies on the causality between economic growth, financial development and ICT, the studies that have investigated the impact of financial development on economic growth and the impact of ICT on economic growth are reviewed. Although impact studies cannot be equated to causality studies, the impact studies will shed some light on the relationship between the three variables.

ICT, Financial development, and economic growth

Verma, Dandgawhal and Giri (2023) studied the relationship between ICT, financial development and economic growth on a panel of 68 developing countries employing data from 2005 to 2019. The study used an index of ICT diffusion. Using Fully Modified Ordinary Least Squares (FMOLS) and Dynamics Ordinary Least Squares (DOLS), the study found a bidirectional causality between financial development and economic growth and another bidirectional causality between ICT and economic growth. The study also found a unidirectional causal flow from financial development to ICT growth in developing countries. Kumari and Singh (2023) examined the impact of ICT, financial development, and trade openness on economic growth for a sample of 27 low and 58 high-income countries using data from 2000 to 2019. Using Ordinary Least Squares (OLS) and Generalised Methods of Moments (GMM), the study found ICT to have a positive impact on economic growth across the majority of the ICT proxies used. Financial development complemented ICT, leading to a positive impact on economic growth. Aziz et al. (2022) traced the relationship between financial development, economic growth and ICT in 10 Asian developing countries using data from 2001 to 2017. Employing a Pooled Mean Group, FMOLS and DOLS estimation, the study found financial development to have a positive long-run impact on economic growth and ICT was found to have a negative impact on the economy; however, when combined with financial

development, the impact was found to be significant. In the same vein, Chatterjee (2020) investigated the relationship between financial inclusion, information and communication technologies and economic growth in 41 countries. Using the dynamic panel data model, the study found financial development and ICT to improve per capita growth. However, the role of financial inclusion and ICT on growth was found to be uncertain. Sassi and Goaied (2013) analysed the relationship between financial development, ICT and economic growth in the Middle East and Northern Africa (MENA) countries. The study found a negative impact of financial development on economic growth and a positive contribution of ICT to economic growth.

Economic growth and financial development

Fakudze, Tsegaye and Sibanda (2022) on a study on the causality between economic growth and financial development, found a bidirectional causality between money supply and economic growth. Wesiah and Onyekewre (2021) found the same results in a study on the United Kingdom using data from 1963 to 2015. Pinshi (2020) found unidirectional causality from economic growth to financial development in the Democratic Republic of Congo. Tadesse and Abafia (2019) examined the causal relationship between financial development and economic growth in Ethiopia using data from 1974 to 2016. Using an autoregressive distributed lag approach, the study found unidirectional causal flow from financial development to economic growth in the short and long run. Opoku, Ibrahim and Sare (2019) explored the causality between financial development and economic growth in 47 African countries using data points between 1980 and 2016. Using the frequency-domain spectral causality technique, the study found strong support for the neutrality hypothesis between financial development and economic growth.

Kaushal and Pathak (2015) studied the causality between trade openness, financial development, and economic growth in India using data from 1991 to 2013. Employing Vector auto-regression and Granger-causality, the study found no causal relationship between financial development and trade openness to economic growth. Instead, a unidirectional causal flow was confirmed from economic growth to financial development. Nyasha and Odhiambo (2015) found a unidirectional causal flow from stock market development to economic growth and no causality between bank-based financial development and economic growth in South Africa. Masih, Al-Elg and Madani (2009) assessed the causality between financial development and economic growth in Saudi Arabia. Using long-run structural modelling, the study confirmed the supply-led hypothesis in Saudi Arabia. Thus, a unidirectional causality from financial development to economic growth was confirmed. Calderon and Liu (2002) studied the causality between financial development and economic growth in 109 developing and industrial countries using data from 1960 to 1994. The study found financial development to lead to economic growth across all study countries. The study also found bidirectional causality between financial development and economic growth when the sample was split into developing and industrial countries.

On the impact studies, Guru and Yadav (2019), while examining the impact of financial development on economic growth in BRICS countries, found banking sector development and stock market development to be complementary in stimulating economic growth. Uddin et al. (2013) examined the relationship between financial development and economic growth in Kenya and found financial sector development to contribute positively to economic growth.

Economic growth and ICT

Yeong-wha, Pang-ryong and JiYoung (2021) examined the causal relationship between ICT and economic growth in South Korea using data from 1999 to 2016. Employing a vector error correction model, the study found a bidirectional causal relationship between the two. On the studies that analysed the impact of ICT on economic growth, Yeo, Hwang, and Lee (2023) investigated the impact of ICT software on production. Using a computable general equilibrium (CGE) model, the study found that the development of ICT software brings threats and opportunities to the economy. ICT can worsen inequality and advance higher economic growth. Jayaprakash and Pillai (2022) investigated the role of ICT on economic growth in 80 countries using panel data from 2000 to 2016. An ICT index consisting of fixed telephone lines subscriptions, mobile-cellular subscriptions, fixed broadband subscriptions and fixed internet subscriptions per 100 inhabitants was used. The study found ICT to have a significant positive effect on economic growth.

In the same spirit, Sarangi and Pradhan (2020) investigated the direct and indirect impact of ICT on economic growth. Manas and Kumar (2020) investigated the impact of ICT on economic growth in member countries of the South Asian Association for Regional Cooperation (SAARC) – India, Pakistan, Sri Lanka and Bangladesh - using annual data from 1990 to 2014. Using the number of fixed and mobile phones per 10,000 people as a proxy for ICT and employing the augments Cobb-Douglas production function and panel data techniques, the study found a positive impact of ICT on economic growth.

Financial development and ICT

Shahbaz et al. (2023), in a study on the relationship between financial development and ICT using data from Turkey from 1986 to 2018, found a unidirectional causal flow from ICT and economic growth to financial development. The study also found ICT to negatively affect financial development when a structural break was taken into consideration. Cheng, Chien and Lee (2021) examined the relationship between financial development, information and communication technology and economic growth in 72 countries using data from 2000 to 2015. Employing the GMM estimation, the study found financial development not to be desirable for economic growth across all the countries – high-income and low-income countries. The study also found ICT diffusion to affect economic growth positively in high-income countries, but the impact was found to be ambiguous in middle-and low-income countries. Alimi and Adediran (2020) traced the impact of ICT on finance and growth in ECOWAS countries using data from 2005 to 2016. Using an ICT diffusion index covering mobile cellular subscription, internet penetration, and fixed telephone lines, the study found financial development alone to negatively impact growth in the 15 ECOWAS countries. However, when financial development was used as an interaction variable with ICT, a positive impact on growth was confirmed.

3. Method

This study employs ARDL and ECM-Granger causality techniques to investigate the causal relationship between economic growth, financial development and ICT in Kenya. The ARDL approach was expanded by Pesaran, Shin and Smith (2001). The approach has a number of known advantages. Although the approach does not require variables to be integrated of the same order, the current study carried out a stationarity test to ensure that the variables included in the model do not have an order of integration greater than one. The approach falls away if any variable has an order of integration above one.

Variables

Variables of interest in this study are economic growth, measured by the rate of change of gross domestic product (GDPG); financial development (FD) captured by the financial development index- a composite index of bank-based and market-based financial development measures; and ICT measured by fixed telephone subscription per 100 people (FTL) captured in Model 1; mobile cellular subscription per 100 people (CELL) captured in Model 2; and individuals using the internet as a percentage of the population (INT) captured in Model 3. Education (EDU) - captured by gross primary school enrolment - was included as an intermittent variable that has a relationship with economic growth, financial development, and ICT.

ARDL model specification

The ARDL specification (GDPG, ICT, FD, EDU) for Model 1, 2, 3 is given in Equation 1 to 4

$$\Delta ICT_{mt} = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i}\, \Delta ICT_{mt-i} + \sum_{i=0}^{n} \alpha_{2i} \Delta\, GDPG_{t-i} + \sum_{i=0}^{n} \alpha_{3i}\, \Delta FD_{t-i} + \sum_{i=0}^{n} \alpha_{4i}\, \Delta EDU_{t-i} + \delta_1 ICT_{mt-1} + \delta_2 GDPG_{t-1} + \delta_3 FD_{t-1} + \delta_4 EDU + \gamma_{1t} \quad (1)$$

$$\Delta GDPG_t = \alpha_0 + \sum_{i=0}^{n} \alpha_{1i}\, \Delta ICT_{mt-i} + \sum_{i=1}^{n} \alpha_{2i} \Delta\, GDPG_{t-i} + \sum_{i=0}^{n} \alpha_{3i}\, \Delta FD_{t-i} + \sum_{i=0}^{n} \alpha_{4i}\, \Delta EDU_{t-i} + \delta_1 ICT_{mt-1} + \delta_2 GDPG_{t-1} + \delta_3 FD_{t-1} + \delta_4 EDU + \gamma_{2t} \quad (2)$$

$$\Delta FD_t = \alpha_0 + \sum_{i=0}^{n} \alpha_{1i}\, \Delta ICT_{mt-i} + \sum_{i=0}^{n} \alpha_{2i} \Delta\, GDPG_{t-i} + \sum_{i=1}^{n} \alpha_{3i}\, \Delta FD_{t-i} + \sum_{i=0}^{n} \alpha_{4i}\, \Delta EDU_{t-i} + \delta_1 ICT_{mt-1} + \delta_2 GDPG_{t-1} + \delta_3 FD_{t-1} + \delta_4 EDU + \gamma_{3t} \quad (3)$$

$$\Delta EDU_t = \alpha_0 + \sum_{i=0}^{n} \alpha_{1i}\, \Delta ICT_{mt-i} + \sum_{i=0}^{n} \alpha_{2i} \Delta\, GDPG_{t-i} + \sum_{i=0}^{n} \alpha_{3i}\, \Delta FD_{t-i} + \sum_{i=1}^{n} \alpha_{4i}\, \Delta EDU_{t-i} + \delta_1 ICT_{mt-1} + \delta_2 GDPG_{t-1} + \delta_3 FD_{t-1} + \delta_4 EDU + \gamma_{4t} \quad (4)$$

Where ICT_m = fixed telephone subscription per 100 people (FTL) for Model 1, mobile cellular subscription per 100 people (CELL) for Model 2 and individuals with access to the internet as a percentage of the population (INT) for Model 3. Each of the ICT proxies enters the equation one at a time and all the other variables remain unchanged.

FD= Financial Development Index

EDU= gross primary school enrolment

α_0 is a constant; $\alpha_1 - \alpha_4$; $\delta_1 - \delta_4$ are coefficients; and $\gamma_1 - \gamma_4$ are error terms.

The Granger causality tests for Equations 1-4 are given in Equation 5-8.

ECM- model specification

$$\Delta ICT_{mt} = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i}\, \Delta ICT_{mt-i} + \sum_{i=1}^{n} \alpha_{2i} \Delta\, GDPG_{t-i} + \sum_{i=1}^{n} \alpha_{3i}\, \Delta FD_{t-i} + \sum_{i=1}^{n} \alpha_{4i}\, \Delta EDU_{t-i} + \eta_1 ECM_{t-1} + \gamma_{1t} \quad (5)$$

$$\Delta GDPG_t = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i}\, \Delta ICT_{mt-i} + \sum_{i=1}^{n} \alpha_{2i} \Delta\, GDPG_{t-i} + \sum_{i=1}^{n} \alpha_{3i}\, \Delta FD_{t-i} + \sum_{i=1}^{n} \alpha_{4i}\, \Delta EDU_{t-i} + \eta_2 ECM_{t-1} + \gamma_{2t} \quad (6)$$

$$\Delta FD_t = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i}\, \Delta ICT_{mt-i} + \sum_{i=1}^{n} \alpha_{2i} \Delta\, GDPG_{t-i} + \sum_{i=1}^{n} \alpha_{3i}\, \Delta FD_{t-i} + \sum_{i=1}^{n} \alpha_{4i}\, \Delta EDU_{t-i} + \eta_3 ECM_{t-1} + \gamma_{3t} \quad (7)$$

$$\Delta EDU_t = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i}\, \Delta ICT_{mt-i} + \sum_{i=1}^{n} \alpha_{2i} \Delta\, GDPG_{t-i} + \sum_{i=1}^{n} \alpha_{3i}\, \Delta FD_{t-i} + \sum_{i=1}^{n} \alpha_{4i}\, \Delta EDU_{t-i} + \eta_4 ECM_{t-1} + \gamma_{4t} \quad (8)$$

Where $\gamma_1 - \gamma_4$ are error correction coefficients.

ECM= error correction model

The other variables remain the same as specified in Equation 1-4.

Data sources

The study analysed the causality between economic growth, financial development and ICT in Kenya using annual data from 1990 to 2021. Data on economic growth (GDPG), ICT measures - fixed telephone subscription per 100 people (FTL), mobile cellular subscription per 100 people (CELL), individuals using the internet as a percentage of the population (INT) and

education (EDU) were extracted from World Bank Development Indicators. The financial development index (FD) was obtained from the IMF financial statistics database.

4. Empirical results

This section is divided into three: the first section highlights the stationarity results, while section 4.2 presents the cointegration results. The last section, Section 4.3, dwells on the causality results.

4.1 Unit Root Test

The study used the Dickey-Fuller GLS unit root test and the Phillips-Perron test to investigate the stationarity of the variables in Models 1, 2 and 3. The Stationarity of variables is important to avoid spurious regression. It also assists in ensuring that all variables in the study are integrated at order zero or order 1. The unit root results are reported below in Table 1.

Table 1. Unit root Test Results

Dickey-Fuller-GLS Unit Root Test				
Variable	Variables in Levels		Variables in First Difference	
	No Trend	With Trend	No Trend	With Trend
FTL	-0.886	-1.693	-3.494***	-3.634***
CEL	-0.588	-1.880	-2.248**	-2.951**
INT	-0.013	-1.449	-2.701***	-3.945***
GDPG	-1.530	-1.411	6.680***	6.277***
FD	-1.686	-1.042	-7.485***	-7.488***
EDU	-1.292	-1.405	-6.147***	-6.321***
Phillips-Perron Test				
Variable	Variables in Levels		Variables in First Difference	
	No Trend	With Trend	No Trend	With Trend

FTL	-0.906	-2.771	-4.793***	-4.945***
CEL	-1.442	-1.872	-3.434**	-8.699***
INT	-1.056	-0.5138	-3.513**	-3.855**
GDPG	-1.490	-1.828	-6.226***	-6.438***
FD	-1.629	-1.874	-8.277***	-8.165***
EDU	-1.214	-1.128	-6.086***	-6.203***

Note: *, ** and *** denote stationarity at 10%, 5% and 1% significance levels, respectively.

The unit root results presented in Table 1 confirm that all the variables included in Models 1, 2 and 3 are stationary in the first difference. The next step is to test for the long-run relationship among the variables in each model. To confirm the long-run relationship, the calculated F-statistic is compared to the lower and upper bounds critical values provided by Pesaran et al. (2001). If the F-statistic is above the upper bound, cointegration is confirmed, while if the F-statistic is below the lower bound, no cointegration is confirmed. However, if the F-statistic falls between the upper and the lower bounds, the results are inconclusive. The results of the cointegration test are presented below in Table 2.

4.2 Cointegration Results

The results on the long-run relationship among the variables in the three models are presented in Table 2.

Table 2. Cointegration Results

Dependent Variable	Function	F-Statistic	Cointegration Status
Model 1. ICT proxied by fixed telephone lines (FTL)			
FTL	F (FTL|GDPG, FD, EDU)	1.075	Not Cointegrated
GDPG	F (GDPG|FTL, FD, EDU)	4.236*	Cointegrated
FD	F (FD|GDPG, FTL, EDU)	7.117***	Cointegrated
EDU	F(EDU|GDPG, FTL, FD)	5.883**	Cointegrated

Model 2. ICT proxied by cellular subscription (CELL)			
CELL	F (CELL|GDPG, FD, EDU)	1.724	Not Cointegrated
GDPG	F (GDPG|CELL, FD, EDU)	4.196*	Cointegrated
FD	F (FD|GDPG, CELL, EDU)	6.840***	Cointegrated
EDU	F(EDU|GDPG, CELL, FD)	5.267**	Cointegrated
Model 3. ICT proxied by access to the internet (INT)			
INT	F (INT|GDPG, FD, EDU)	2.368	Not Cointegrated
GDPG	F (GDPG|INT, FD, EDU)	5.420**	Cointegrated
FD	F (FD|GDPG, INT, EDU)	6.875***	Cointegrated
EDU	F(EDU|GDPG, INT, FD)	4.845**	Cointegrated
Critical values	10%	5%	1%
	I (0) I (1)	I (0) I (1)	I (0) I (1)
	2.676 3.586	3.272 4.306	4.614 6.966

Note: *, ** and *** denote stationarity at 10%, 5% and 1% significance levels, respectively.

The results reported in Table 2 confirmed the presence of cointegration in all the functions across all models, with the exception of the functions that capture ICT as the dependent variable - F (FTL|GDPG, FD, EDU), F (CELL|GDPG, FD, EDU) and F (INT|GDPG, FD, EDU). For these functions where no cointegration was confirmed, causality estimation is done in the short run only, while for the functions where cointegration was confirmed, causality estimation was done for the short run and long run time frames. Table 3 reports the causality results.

4.3 Causality Results

The results on the causal relationship between ICT and economic growth are presented in Table 3

Table 3. Causality Results

Panel 1		**Model 1: Fixed telephone lines as a proxy for ICT**			
	ECM t-statistics				**ECM (t-stat)**
	ΔFTL	ΔGDPG	ΔFD	ΔEDU	
ΔFTL	-	4.172* [0.076]	1.562 [0.227]	4.547* [0.044]	-
ΔGDPG	2.265 [0.129]	-	3.198** [0.034]	1.130 [0.300]	-0.709*** [-4.945]
ΔFD	3.279** [0.027]	0.079 [0.781]	-	1.484 [0.233]	-0.089*** [-6.311]
ΔEDU	4.053* [0.054]	0.349 [0.560]	0.590 [0.449]	-	-0.184* [-2.653]
Panel 2		**Model 2: Mobile cellular subscription as a proxy for ICT**			
	ΔCELL	ΔGDPG	ΔFD	ΔEDU	**ECM (t-stat)**
ΔCELL	-	2.240* [0.115]	3.772* [0.027]	1.064 [0.387]	-
ΔGDPG	5.498** [0.027]	-	0.000 [0.998]	3.222* [0.085]	-0.985*** [-5.559]
ΔFD	6.252*** [0.021]	0.371 [0.549]	-	2.992* [0.098]	-0.981*** [-5.648]
ΔEDU	1.431 [0.243]	1.587 [0.220]	9.362*** [0.000]	-	-0.114*** [-5.909]
Panel 3		**Model 3: Percentage of the population using the internet as a proxy for ICT**			
	ΔINT	**ΔGDPG**	**ΔFD**	**ΔEDU**	**ECM (t-stat)**
ΔINT	-	0.139 [0.713]	5.397** [0.030]	5.720 [0.026]	-
ΔGDPG	5.433** [0.028]	-	0.000 [0.998]	3.984* [0.057]	-0.964*** [-5.578]
ΔFD	3.288**	0.354	-	1.465	-0.987***

	[0.030]	[0.558]		[0.239]	[-6.293]
ΔEDU	3.005*	0.443	0.417	-	-0.197***
	[0.094]	[0.506]	[0.518]		[-4.398]

Note: *, ** and *** denote stationarity at 10%, 5% and 1% significance levels, respectively.

Results reported in Table 3, Panels 1, 2 and 3 confirmed a short-run unidirectional causal flow from economic growth to ICT captured by fixed telephone variable. A bidirectional causality between ICT and economic growth in the short run and a unidirectional causal flow from ICT to economic growth in the long run was also confirmed when ICT was captured by mobile cellular variable. When Internet variable was used as a proxy for ICT, a unidirectional causal flow from ICT to economic growth was confirmed in both the short and the long run. These results suggest that, on balance, ICT drives economic growth, given that two out of three proxies of ICT confirm a unidirectional causal flow from ICT to economic growth in the long run. Thus, ICT plays an important role in influencing economic growth in Kenya. The study also found a unidirectional causal flow from financial development to economic growth in the short and long run, but only when fixed telephone line variable was used as a measure of ICT. This finding confirms a supply-leading hypothesis in Kenya. Masih, Al-Elg and Madani (2009) also found the same results in Saudi Arabia. An increase in the supply of financial products and services leads to economic growth. The study also found a unidirectional causal flow from ICT to financial development in the short and long run, when ICT was captured by fixed telephone variable. Thus, ICT has a significant role in driving financial development in Kenya when it is measured by fixed telephone variable. However, when ICT was captured by Internet and mobile cellular variables, a bidirectional causal relationship was found to prevail between financial development and ICT in the short run and a unidirectional causal flow from ICT to financial development in the long run. These two

variables have a mutually reinforcing effect in the short run, while ICT plays a distinct role in influencing financial development in the long run.

Other results reported in Table 3, Panel 1, where ICT was captured by fixed telephone variable, confirmed that no causality existed between economic growth and education. The study also found bidirectional causality between ICT and education in the short run and unidirectional causal flow from ICT to education in the long run. These results suggest the importance of education in ICT consumption and in turn the positive influence of ICT in enhancing education in Kenya. No causality was confirmed between education and financial development, regardless of the time frame considered.

Results reported in Table 3, Panel 2, where ICT was measured by mobile cellular variable, confirmed a unidirectional causal flow from education to economic growth in the short and long run, suggesting the important role played by education in enhancing human capital, an important component to achieve economic growth. The study found no causality between ICT and education. A bidirectional causality between education and financial development in the short and long run was confirmed in this study. These results indicate a mutually reinforcing effect between the two variables. This suggests the importance of promoting education to realise financial advancement and in return advancement in financial development thus stimulating the acquisition of new knowledge in Kenya.

Results reported in Table 3, Panel 3, where Internet variable was used to measure ICT, confirmed a unidirectional causal flow from education to economic growth in the short and long run. The results suggest an important role played by education in stimulating economic growth. A bidirectional causality between ICT and education in the short run and unidirectional

causality from ICT to education in the long run was found. Thes two variables have a mutually reinforcing effect in the short run, while ICT plays a distinct role in influencing education in the long run. No causality was found between financial development and education in the short and long run.

5. Conclusion

The causal relationship between economic growth, financial development and ICT was examined in Kenya using data from 1990 to 2021. The study was motivated by the need to find out which variable can be influenced first to spur economic growth and fast-track the goals set in the country's blueprint - Vision 2030. The study used three measures of ICT, i.e., i) fixed telephone subscriptions per 100 people, ii) mobile cellular subscriptions per 100 people, and iii) individuals using the internet as a percentage of the total population. Using the ARDL approach to cointegration and ECM-based Granger causality techniques, the study found a unidirectional causal flow from economic growth to ICT in the short run when fixed telephone variable was used as a proxy for ICT. When mobile cellular and Internet variables were used as proxies, a distinct unidirectional causal flow from ICT to economic growth was found in the long run. The study also found a unidirectional causal flow from financial development to economic growth in the short and long run when fixed telephone variable was used as an ICT proxy. Thus, the results confirmed the supply-leading hypothesis in Kenya. The study also found unidirectional causal flow from ICT to financial development in the short and long run when fixed telephone variable was used as a proxy. However, when mobile cellular and Internet variables were used as proxies, bidirectional causality between ICT and financial development was found to prevail in the short run and a unidirectional causal flow from ICT to financial development was confirmed in the long run. It can be concluded that ICT plays an

important role in stimulating economic growth and financial development in Kenya. Based on the findings of this study, policy makers in Kenya are encouraged to continue buttressing policies that support ICT and financial development in the journey to achieve the goals set in the national blueprint – Vision 2030.

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