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Effects of Digital Technology on Economic Growth of Selected Sub-Saharan African Countries: Evidence from Dynamic Panel Data Analysis

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Abstract

The purpose of this study is to investigate the influence of digital technology on the economic growth of Sub-Saharan African countries, utilizing data from 33 sample countries between 2010 and 2020. A two-step system GMM (Generalized Method of Moments) model was employed for data analysis, considering various factors including investment levels, inflation rates, government expenditures, unemployment, foreign direct investment, and the influence of digital technology on economic growth. Short-term analysis reveals a significant positive correlation between digital technology and economic growth. Additionally, investment levels, inflation rates, and government consumption expenditures were found to positively predict the short-term economic growth, while unemployment and foreign direct investment had adverse effects. Long-run model analyses also confirm the substantial positive influence of digital technology on economic growth in the region. The study underscores the necessity for investments in developing digital technology alongside clear policy frameworks. It suggests that augmenting human capital and infrastructure development will further amplify the positive effects of digital technology on economic growth in Sub-Saharan Africa. The findings highlight the pivotal role of digital technology in fostering economic growth in Sub-Saharan Africa, emphasizing the importance of strategic investments and policy initiatives to harness its potential.

Keywords: Digital technology, Economic growth, two-step system GMM

1. Introduction

A digital revolution, propelled by the rapid expansion of digital technology since the early 2000s (Imran et al., 2022; Wu, 2019; Netland, 2015), is transforming societies worldwide and becoming a dominant force. This revolution is marked by an unprecedented surge in global connections and data flows, underpinned by the swift pace of technological innovation and dissemination. Nyamadzawo (2011) defines 'digital technology' as the integration of data and the internet across various domains encompassing the production process, governance, household consumption, capital formation, cross-border flows, and finance. Its impact is fundamental, fostering increased productivity, expanded employment opportunities, and substantial improvements in living standards (Ayodele & Ahmed, 2017; Group, 2020). Moreover, this recent phenomenon significantly contributes to double-digit economic growth on a global scale, driven by economic, political, and technological advancements that fuel the growth of the digital economy (Yu et al., 2022; Bukht and Heeks, 2017).

Digital technology, founded on new developmental concepts and propelled by evolving technologies, relies on utilizing information networks and platforms to revitalize factors and resources. Its goal is to promote high-quality and sustainable development, serving as a critical cornerstone in shaping a modern economic system. This technology significantly influences various aspects of the production process and all other economic activities. As a result, it drives the transformation and modernization of society, playing a pivotal role in fostering sustainable development (Mottaeva et al., 2023). According to Obejko & Bartczak (2021) and Wermelinger et al. (2016), digital technology has brought substantial improvements to the global economy and society's way of life. Its applications are rapidly transforming extensive domains of human activity, outpacing previous waves of technological advancement. Consequently, the digital revolution can no longer be disregarded by any country.

The experience of developed countries demonstrates how digital technology can be transformative for development, creating social benefits for individuals, businesses, and governments. It offers opportunities for egalitarian and sustainable growth across various economic sectors (Magomedov et al., 2020).

Digital technology is increasingly crucial for expanding a country's productive capacity across all economic sectors, especially in developing nations like those in Africa. With its ability to connect a global network of people, businesses, and governments, these nations have the opportunity to overcome historical and geographical disadvantages by engaging in trade and economic activities as successfully as in the developed world (Zhao et al., 2022; Vogel et al., 2011).

The region of Sub-Saharan Africa has experienced both opportunities and challenges in leveraging digital technology for economic development. Research by Abri and Mahmoudzadeh (2014) and Chetley et al. (2006) highlights the potential impact of digital technology utilization on total factor productivity and manufacturing processes, which in turn can significantly influence economic growth. Reports from the Economy (2020) and Zhen-Wei Qiang et al. (2004) illustrate the substantial economic value created through digitalization, particularly in the mobile ecosystem, contributing 9% of GDP and over $155 billion in economic value added while supporting nearly 3.8 million jobs and contributing $17 billion in taxes collected in the region in 2019.

However, despite these opportunities, the region still grapples with a significant digital divide. Sub-Saharan Africa exhibited approximately 287 million internet subscribers in 2022, yet faced substantial disparities in mobile internet usage, highlighting barriers like affordability and limited digital skills. While countries like Mauritius, South Africa, and Seychelles boast mobile internet penetration exceeding 50%, others like Benin, Chad, and the Democratic Republic of Congo lag behind at below 15% (The GSMA, 2023).

The impact of digital technology in Sub-Saharan Africa remains underwhelming and unevenly distributed, as noted by Kelly & Firestone (2016) and Bayuo (2017). Carroll (2021) also highlights the region's low ICT penetration as a critical barrier hampering the diffusion of necessary digital technologies for holistic development. This inequality in access to digital technology is influenced by both demand-side factors shaped by population characteristics affecting technology adoption and supply-side challenges like limited internet infrastructure coverage. Alper & Miktus's (2019) empirical study further underscores the hurdles faced by digital technology in the region, including inconsistent internet and phone services, limited electricity access, and inadequate digital infrastructure.

The researchers posit that previous studies inadequately addressed the role of digital technology in influencing economic growth, lacking sufficient empirical methods, approaches, and representation across geographical locations. Many empirical studies originate from Europe, Asia, and OECD nations (Evangelista et al., 2014; Gomes et al., 2022). Even among the limited studies in sub-Saharan Africa, there are discrepancies in employed measures of digital technology indicators (Satrianto, 2023; Roger et al., 2022; Gbedjemaiho, 2020; Solomon & van Klyton, 2020). Most of these studies utilize digital infrastructure as a proxy variable for digital technology without considering the influence of digital usage and digital empowerment. Moreover, methodologies such as the Driscoll-Kraay strategy have been employed for estimation (Kouladoum, 2023). Consequently, the primary objective of this paper is to examine the effect of digital technology on economic growth by considering its three pillars: digital infrastructure, digital usage, and digital empowerment, utilizing Principal Component Analysis. The study employed an advanced and robust panel data model, specifically a two-step dynamic generalized method of moments for estimation. The remainder of the paper is structured as follows: The subsequent section comprises a review of related literature. The third section outlines the research methodology, encompassing a brief description of the data used and issues concerning model specification. Section four entails a discussion of the findings, and the final section includes conclusions and policy implications.

2. Review of Literature

2.1. Theoretical review

There exist economic theories that advocate the positive impact of technological advancement on economic growth. To investigate this phenomenon, existing theories are typically categorized into two main branches: modern (endogenous and evolutionary institutional) and traditional (neoclassical).

Neoclassical economists were among the first to extensively explore technological developments within growth theory. The integration of technology into economic growth theory is credited to the work of American economist Robert Solow (Solow, 1956, 1957). Solow introduced technological change as an exogenous factor of production. His concept of the residual or unanticipated share of growth proposes that technological advancement propels long-term economic growth (Sredojevi et al., 2016).

The endogenous growth theory encompasses models that extend beyond the Solow-Swan fr he framework of internalizing or endogenizing technological development gained traction through the pioneering work of Romer (1990), who played a pivotal role in constructing an explicit and rigorous growth model that incorporates endogenous technical advancement. This theory treats technology as an endogenous variable, outlining its function through a knowledge/technology production function that describes the evolution of knowledge creation (Goschin, 2010).

On the other hand, the evolutionary theory is rooted in Schumpeter's assertion that innovation is a fundamental driver of economic growth and acts as a catalyst for technological change. The neo-Schumpeterian theory posits that scientific progress, particularly in fields such as biotechnology, nanotechnology, material science, and information technology, is steering a global technological revolution. Notably, the information technology sector has superseded manufacturing as the primary driver of economic growth (Tuncel, 2015; Švarc, 2009).

2.2.Digital technology and economic growth: Empirical literature

Sizeable empirical studies agreed up on the contribution of digital technology on economic growth. For instance, Kouladoum (2023) evaluated the impact of digital infrastructural development on inclusive growth across 44 countries in Sub-Saharan Africa from 2000 to 2020. Employing the Driscoll-Kraay strategy, the study found that digital infrastructure played a significant role in fostering inclusive growth within the region, regardless of the income level of the countries. Similarly, Myovella et al. (2019) utilized the generalized method of moments (GMM) estimators to analyze the effects of digitalization on the economic growth of Sub-Saharan Africa in comparison to the Organization for Economic Cooperation and Development (OECD) countries from 2006 to 2016. The results revealed a positive impact of digitalization on economic growth in both sets of countries.

Solomon & van Klyton (2020) conducted an analysis of the influence of digital technology usage on economic growth across 39 African countries from 2012 to 2016. Employing a system GMM estimator and utilizing the network readiness index to measure digitalization, their study differentiated between the impact of individual, business, and government usage of digital technology on economic growth. The findings revealed that only individual usage of digital technology exhibited a positive impact on the economic growth of the region. In the same vein,, Evans (2019) investigated the correlation between internet usage as a representation of digital technology and the economic well-being of 45 Sub-Saharan African countries spanning from 1995 to 2015. Utilizing panel fully modified least squares (FMOLS) and panel dynamic ordinary least squares (DOLS), the study discovered a positive effect of internet usage on economic well-being.

A study conducted by Satrianto (2023) explores the impact of information and communication technology (ICT) and financial development on economic growth in high-income countries spanning from 2001 to 2020. Employing the panel data regression method with a random effects

(REM) approach, the study revealed that ICT subscriptions, internet usage, and fixed broadband subscriptions key indicators of digital technology significantly influence economic growth. In contrast, Adejumo et al. (2020) conducted a study assessing the extent to which digital technology has influenced activities in Africa and its impact on addressing development issues like poverty and unemployment. Utilizing the generalized method of moments, the study found that digital technology has a positive long-term impact on reshaping development outcomes.

A study by Roger et al. (2022) explored the influence of ICT and innovation on sustainable economic growth across 33 Sub-Saharan African countries from 2000 to 2020. Using DOLS and VECM methods, the study discovered a significant causal relationship among the variables in both the short and long run. Similarly, Mohamed et al. (2022) conducted a study to assess the impact of digital technology innovation on economic growth in developing countries from 1990 to 2018. Employing the error correction model (ECM) method, the study identified that an increase in technological innovation leads to economic growth in both the short and long term. It also revealed a two-way causal relationship between technological innovation and GDP growth over the long run.

Research conducted by Gomes et al. (2022) examined the impact of the digital economy on economic growth in OECD countries from 2000 to 2019. Utilizing the generalized method of moments (GMM), their findings suggest a positive correlation between the digital economy and the economic growth of member countries. Similarly, Sirait et al. (2023) investigated the impact of digital innovation on economic growth between 2015 and 2020. Their study revealed that digital innovation, encompassing digital infrastructure, digital lending, and digital payment, positively contributes to sustainable economic development.

Zhao et al. (2022) conducted a study on the dynamic influence of digital and technological advancements on sustainable economic growth across 21 Asian regions from 2004 to 2020. Employing the two-step dynamic generalized method of moments (GMM) for estimation, they concluded that digital advancements significantly and positively impact sustainable economic growth. Similarly, Gbedjemaiho (2020) examined the dynamic relationship between ICT infrastructure and economic growth across 28 Sub-Saharan African countries from 1990 to 2018. They employed panel Autoregressive Distributive Lag (ARDL) methods and Pedroni co-integration analysis to investigate the long-term relationship between three indicators of ICT infrastructure fixed broadband subscriptions per 100 inhabitants, mobile cellular subscriptions per 100 people, and the percentage of individuals using the internet and economic growth. Their findings indicated a long-run relationship between digitalization and economic growth.

The researchers argue that prior studies have inadequately addressed the influence of digital technology on economic growth, lacking comprehensive empirical methods, approaches, and representation across various geographical locations. While many empirical studies primarily originate from Europe, Asia, and OECD nations (Evangelista et al., 2014; Gomes et al., 2022), even among the limited studies in sub-Saharan Africa, discrepancies exist in the measures of digital technology indicators used (Satrianto, 2023; Roger et al., 2022; Gbedjemaiho, 2020; Solomon & van Klyton, 2020). Most of these studies utilize digital infrastructure as a proxy variable for digital technology without considering the influence of digital usage and digital empowerment. Moreover, methodologies such as the Driscoll-Kraay strategy have been employed (Kouladoum, 2023).

Based on the identified gaps, the following conceptual framework is developed to examine the effect of digital technology on economic growth with some controlled explanatory variables as shown in Figure 1 below

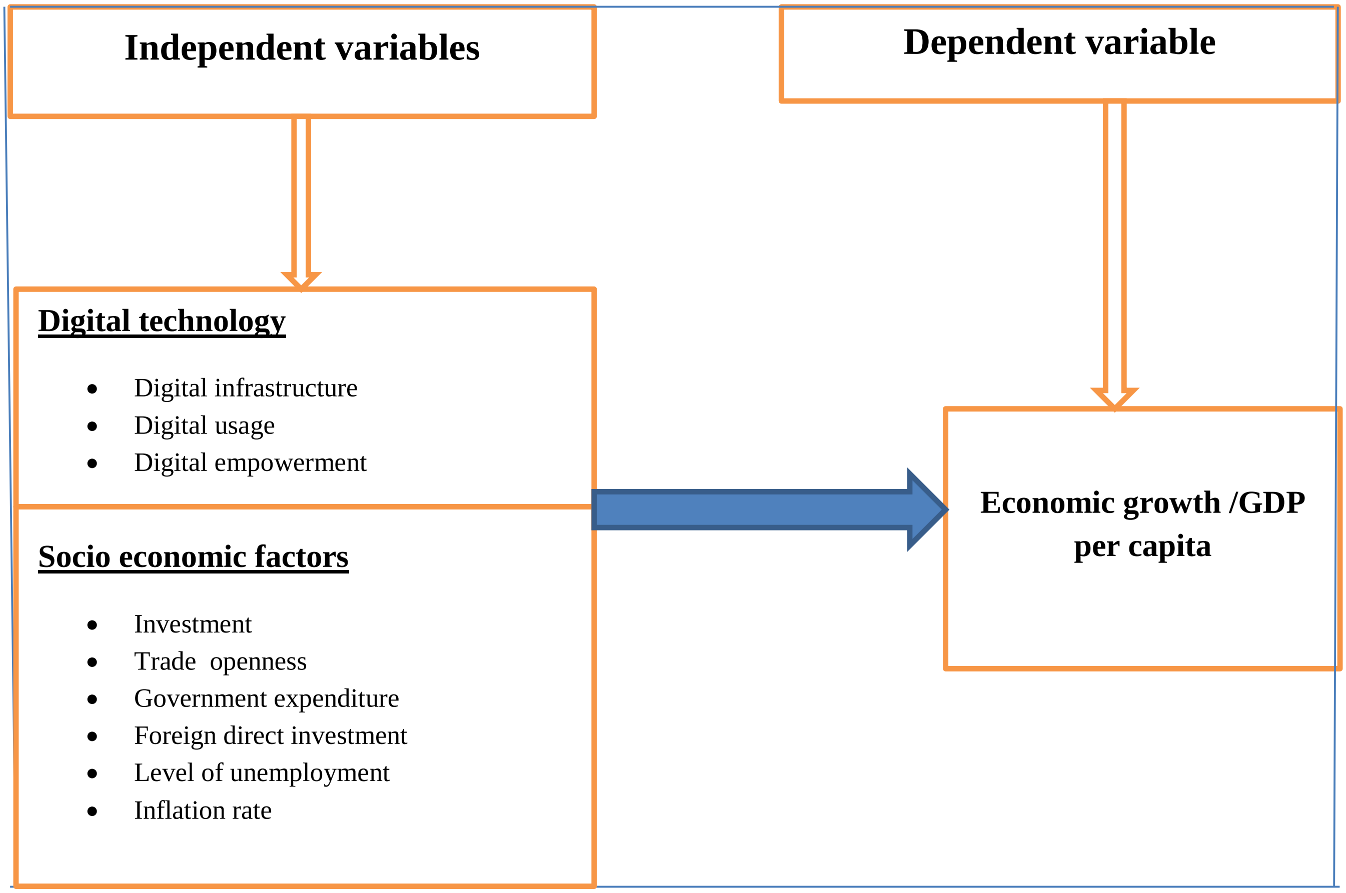

Figure 1: Conceptual frame work

Source, complied by the author (2023)

3. Materials and Methods

3.1. Data and data measurement

Data for this research were obtained from the World Bank database from 2010 to 2020 for 33 SSA countries (World Bank, 2022). However, due to incomplete data for all countries, the study opted for a sample of 33 Sub-Saharan African countries with a complete dataset. This comprehensive dataset encompasses the selected sample of the region.

The dependent variable, economic growth, is represented by GDP per capita. Owing to limited data availability on digital technologies in developing nations, the study considered the period from 2010 to 2020. However, due to incomplete data for several countries, missing years were estimated using linear interpolation techniques.

Independent variable of interest: The Digital technology indicators as provided by (Olo & Meliciani, 2014) are summarized as below .
Digital infrastructure- defined to capture fixed telephone subscriptions per 100 residents, secure internet servers per 100 users, mobile users per 100 residents, and fixed broadband subscriptions per 100 inhabitants, is the crucial pillar of the digital technology index(Kouladoum, 2023; Gbedjemaiho, 2020).

Digital usage measures the ability to use digital technology and it captures fixed telephone and fixed-line broadband subscriptions, as well as the number of internet users, secured internet servers, and mobile users and the third digital pillar is **digital Empowerment** measures the individual digital empowerment in key social and economic domains and Automated teller machines per 100,000 adults, ICT goods exports, and ICT service exports are taken as proxy variables (Olo & Meliciani, 2014).

Control variables: Besides digital technology indicators stated above, important policy variables (control variables) obtained from World Bank's Development Indicator dataset also included in the model. The control variables used in this study are; fixed gross capita formation(%GDP) as a proxy for investment and is expected to have a positive influence; trade openness(%GDP) is expected to a positive effect on growth because open trade policy of a country increases profitability and thus creates an incentive to invest and grow; Foreign direct investment(%GDP) is also included to capture the effect of foreign capital inflow on domestic economic growth which is generally considered to have positive influence on economic growth. We also include inflation as one policy variable (used as proxy for macroeconomic stability) because high inflation expected to harm economic growth as it distorts economic activities thereby reducing growth. Government expenditure and level of unemployment which have influence on economic growth are also included as policy variables in the model.

3.1.1. Computing Digital Technology Index

First, the PCA was used to generate a digital technology index. PCA is a dimensionality reduction method often used to reduce the dimension of larger data sets, by transforming them into a smaller dimensionality that still contains most of the information in the large set. In this particular case, the PCA method delivers the orthogonal linear transformation of high dimension digital technology indicators into low dimension digital composite index (Roger et al., 2022; Welo, 2019; Schelenz & Schopp, 2018; Karamizadeh et al., 2013).

The Kaiser-Meyer-Olkin (KMO) index was used to examine the reliability of the principal component analysis. The measure of sample adequacy test known as the Kaiser-Meyer-Olkin (KMO) index was used to evaluate the validity of the principal component analysis. A value greater than 0.50, in accordance with (Creel, Hubert, & Labondance, 2014), justifies the adoption of PCA. Hence as shown in Table 1 below, digital indices with KMO of 0.7348, 0.5913, 0.5520, and 0.6358 for the digital usage index, digital infrastructure index, digital empowerment index, and over digital technology index respectively, show that the use of PCA to construct digital index is valid.

Table 1: The KMO index and Eigenvectors

Variables		**value**		
	Digital Technology index	**Digital infrastructure index**	**Digital usage index**	**Digital empowerment index**
PCA eigenvectors (highest)	3.94	2.285	2.653	1.35
Proportion explained	0.737	0.57	0.53	0.45
Kaiser-Meyer-Olkin	0.6358	0.5913	0.7348	0.5520

Source: compiled by the author in 2023

The eigenvalue rule was used to determine number of components. Accordingly for digital usage index the first component with eigenvalue greater than one is selected and it has a standard deviation of 2.2850 and explains 53% of all model variation, as seen in Table 1 above. The result on Table 1 above also shows that the first component for digital infrastructure index captures more and explains 57% of the series' common variance whereas digital Empowerment Index has also one component that has an Eigen score greater than one which is 1.35, with 45% power to explain the overall variation.

3.2. Econometric model specification

The method of panel dynamic system GMM was employed to explore the effect of digital technology and other control variables on economic growth models performed during the specified time. The system GMM method is superior over fixed effect and random effect in that it could captures both country-specific unobserved heterogeneities as well as possible endogeneity in regressors. To introduce the effect of dynamism into the model, one year lagged value of GDP per capita was used as one explanatory variable which permits its partial adjustment to long run equilibrium (Adeleye, 2018 and Roodman, 2009).

The following is the simple specification of empirical model to be estimated

$$Gdppec_{it} = \beta_1 lab_{it} + \beta_2 GCFpgd_{it} + \beta_3 DTind_{it} + \beta_4 Gdppec_{it-1} + \beta_5 x_{it} + \varepsilon_{it} \qquad 1.1$$

Here $Gdppec_{it}$, the GDP per capita is used as an indicator of economic expansion, lab denotes labor that measure an economy's active workforce and $GCFpgd_{it}$ is growth capital formation per GDP taken as a proxy variable for physical capital stock. $DTind$, indicates digital technology index. The β coefficients used represent the factor inputs' respective factor input shares. By applying the first differencing it gives:

$$\Delta Gdppec_{it} = \beta_1 \Delta lab_{it} + \beta_2 \Delta GCFpgd_{it} + \beta_3 \Delta DTind_{it} + \Delta \delta_{it} \quad 1.2$$

It was believed that the country-specific efficiency parameter ($\Delta\delta_{it}$) is a function of past economic growth ($Gdppec_{it-1}$) in order to give conditional convergence between countries.

$$\Delta\delta_{it} = \partial_1 Gdppec_{it-1} + \varepsilon_{it} \quad 1.3.$$

The error term in equation 1.3, (ε_{it}), is made up of three components: a country-specific fixed effect σ_i that measures unobserved permanent differences in output across countries, a time-specific effect (θ_{it}) that captures disembodied technical change, and an idiosyncratic error term (μ_{it}) as follows:

$$\varepsilon_{it} = \sigma_i + \theta_{it} + \mu_{it} \quad 1.4$$

The Digital technology index can be approximated by using three pillars named as, Digital infrastructural index, digital usage index, and digital empowerment index. Taking the proxy variables of digital technology into account and combining equations written as follows:

$$\Delta Gdppec_{it} = \partial_1 Gdppec_{it-1} + \beta_1 \Delta lab_{it} + \beta_2 \Delta GCFpgd_{it} + \beta_3 \Delta INFi_{it} + \beta_4 \Delta USAi_{it} + \beta_5 \Delta Empi_{it} + \sigma_i + \theta_{it} + \mu_{it} \quad 1.5.$$

Lastly, additional control variables are included in the model to yield the following final equation:

$$\Delta Gdppec_{it} = \partial_1 Gdppec_{it-1} + \beta_1 \Delta lab_{it} + \beta_2 \Delta GCFpgd_{it} + \beta_3 \Delta INFI_{it} + \beta_4 \Delta USAi_{it} + \beta_5 \Delta Empi_{it} + \beta_6 \Delta Inv_{it} + \beta_7 Inf_{it} + \beta_8 \Delta Unem_{it} + \beta_9 \Delta To_{it} + \beta_{10} \Delta Fdi_{it} + \beta_{11} \Delta gfcepgd_{it} + \sigma_i + \theta_{it} + \mu_{it} \quad 1.6$$

However, in order to avoid weak instruments and increase the effectiveness of the estimator, Blundell and Bond (1998), referenced in (Youssef, El-Sheikh, and Abonazel, 2014), suggested a system GMM estimator that uses the moment requirements of DIF and LEV together. The model is given as:

$$Gdppec_{it} = \partial Gdppec_{it-1} + \beta x'_{it} + (\mu_{it} + \theta_{it}) \quad 1.7$$

Assume that equation (1.7) is a random walk and that Gdppec is persistent. The difference GMM estimator gives inaccurate and biased estimates of "∂" in finite samples and this is particularly acute when T (time) is short. Generally the two step system GMM was used as an econometric model based on Bond's (2001), Rule -of – thumb that says in equation (1.7) above:

The pooled OLS and fixed effects strategy should be used to estimate the autoregressive model first. The corresponding fixed effects estimate for ∂_1 should be regarded as a lower bound estimate, whilst the pooled OLS estimate should be regarded as an upper bound estimate. A system GMM estimator should be preferred if the obtained difference GMM estimate is downward biased due to weak instrumentation and is closer to or lower than the fixed effects estimate. Based on this rule, the final equation, a system GMM equation, is given as follows:

$$\Delta Gdppec_{it} = \partial_1 Gdppec_{it-1} + \beta_1 \Delta lab_{it} + \beta_2 \Delta GCFpgd_{it} + \beta_3 \Delta INFi_{it} + \beta_4 \Delta USAi_{it} + \beta_5 \Delta Empi_{it} + \beta_6 \Delta Inv_{it} + \beta_7 Inf_{it} + \beta_8 \Delta Unem_{it} + \beta_9 \Delta To_{it} + \beta_{10} \Delta Fdi_{it} + \beta_{11} \Delta gfcepgd_{it} + \sigma_i + \theta_{it} + \mu_{it} \quad 1.8$$

4. Results and Discussion

4.1. Descriptive Statistics

The quantitative data obtained from secondary sources were analyzed using descriptive statistical methods, encompassing measures such as mean, standard deviation, minimum, and maximum. The average Log GDP per capita across 11 years and among 33 sample countries is 8.174, with a standard deviation of 0.872. Its lag is recorded at 8.175, with a standard deviation of 0.878.

The overall digital technology index and its three sub-indices exist in the model. The digital usage index has a mean of -0.4972 and a standard deviation of 1.158. The digital empowerment index shows a mean and standard deviation of 1.030 and 0.556, respectively. Similarly, the digital infrastructure index has a mean value of 0.004527 and a standard deviation of 0.779. Finally, the overall digital technology index is represented in the model with a mean of 0.473 and a standard deviation of 0.617 across eleven years and 33 Sub-Saharan African countries.

Table 2: Descriptive Statistics

Name of variables	**Mean.**	**SD.**	**Min.**	**Max.**
GDP per capita*	8.174	.872	6.4966	10.533
Lag of GDP per capita*	8.175	.878	6.496	10.533
Foreign direct investment	3.657	4.93	-11.198	39.456
Number of labor*	15.229	1.499	12.076	17.946
Government expenditure.	84.243	15.011	31.717	134.55
Trade openness*	20.990	2.103	17.112	37.634
Number unemployment	7.902	7.204	.32	29.22
Digital infrastructure index*	.004527	.77940	-2.999	2.4030
Digital usage index*	-.4972	1.158	-6.234	2.464
Digital empowerment index*	1.030	.556	-2.83065	-2.830
Overall digital technology index*	.473	.617	-1.139-	2.445
Inflation rate	7.235	34.355	78.562	557.201
Investment	24.058	8.409	5.400	60.807

Source: Prepared by the authors, 2023

(*) refers variable is in natural logarithm

The findings of this study highlight variations in average GDP per capita among Sub-Saharan African countries. As depicted in Figure 1 below, Gabon has a GDP per capita of 10.173%, Mauritius has a GDP per capita of 9.868%, and Gambia has a GDP per capita of 9.622%. Consequently, the analysis suggests that Gabon, Mauritius, and Gambia exhibit the highest average

GDP per capita values, while Botswana, Nigeria, and Namibia showcase the lowest average GDP per capita values in the region (World Bank, 2022).

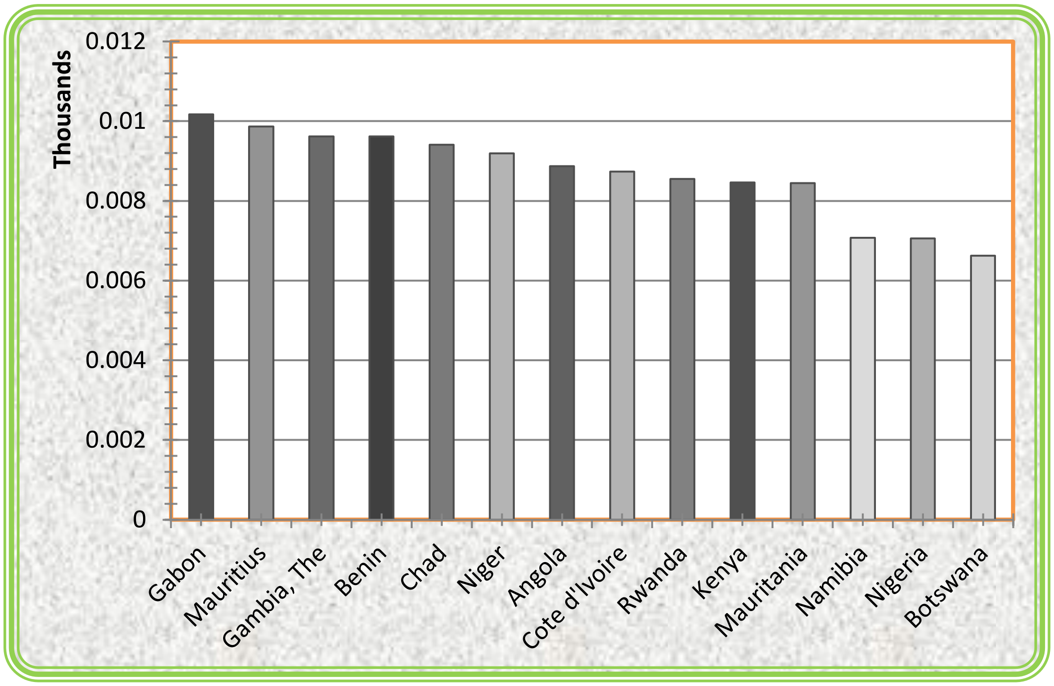

Fig 1, Average value of GDP per capita for some selected countries

The descriptive statistics from this investigation reveal an uneven distribution of digital technology among Sub-Saharan African countries. Figure 2 illustrates that Mauritius possesses the largest digital technology index. Cape Verde follows as the second country whereas South Africa stands as the third Sub-Saharan African country with a significant digital technology index. Conversely, Gabon, Gambia, and Mauritania are characterized by the lowest digital technology index in the region (World Bank, 2022).

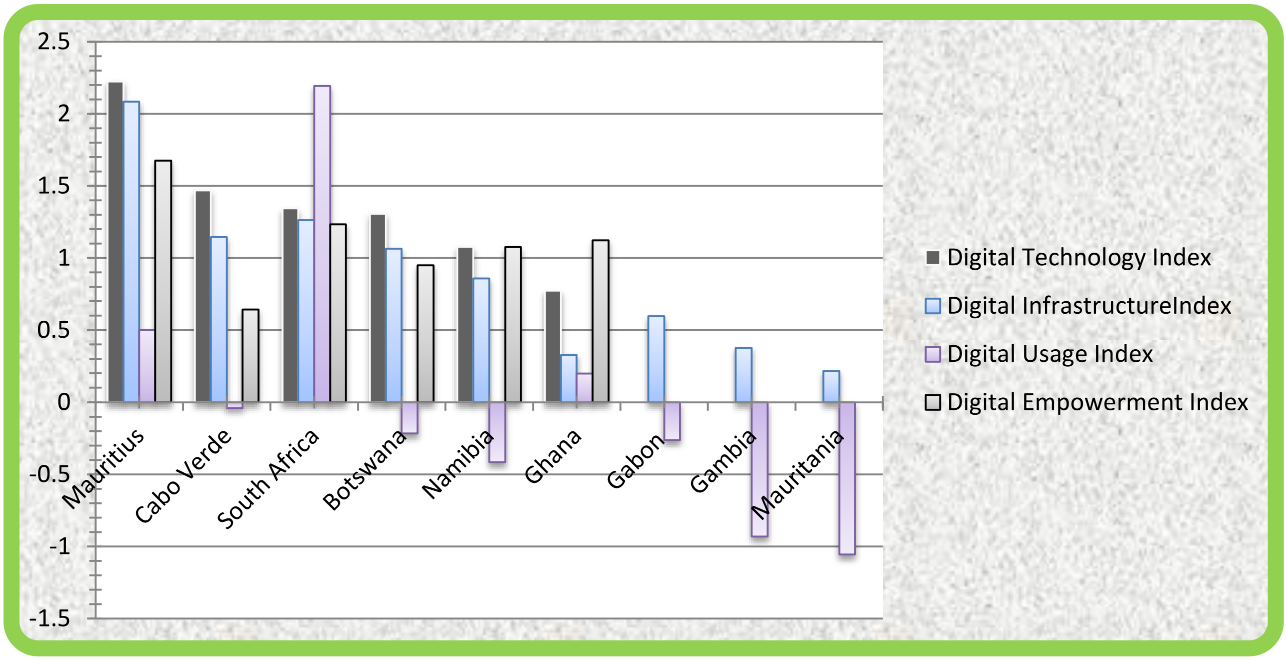

Fig 2, Average values of digital technology indices for some sample countries
Source: own computation (2023).

4.2. Econometric analysis

Regression analysis was performed twice to evaluate the influence of digital technology on regional economic growth. Initially, the analysis involved overall digital technology, followed by a separate regression focusing on the remaining digital technology pillars. This approach was adopted to address potential issues related to multicollinearity.

As seen in Table 3, there is instrumental validity as indicated by the values of Sargan's statistics (0.207) and Hansen's statistics (0.399). Using AR (2) statistics, second-order serial autocorrelation was examined; the result, which is equal to 0.465, shows that the model is free of second-order serial autocorrelation issues. The model's overall significance was further examined using F-statistics F (17, 28). Finally, the model has 25 instruments and 29 groups, showing that it is possible to run a two-step system GMM model because the number of instruments is smaller than the number of groups. The outcomes of the two-step system GMM are shown in the following manner following the model validity test:

The effects of the lag of GDP per capita on current years' economic growth (1.041) show that on average, ceteris paribus, in Sub-Saharan African countries, a percentage change in the lag of GDP per capita is associated with a 1.041% increase in current year GDP per capita in the short run at 1% significance level. This suggests that, in addition to other factors that may have an impact on GDP per capita, past realization has a role. The finding is corroborated by Behr (2003), who stated that in the dynamic panel model with short time and many individual units, the dependent variable on the left hand and its past realizations have a linear relationship, indicating that the dependent variable is dependent on its past realization.

The finding also indicated that Investment positively influence (0.004) economic growth which indicates percentage increase in investment leads to a 0.4 percent change in economic growth in the short run at a 5% significance level when other predictors remain constant. This indicates that level of investment positively influence GDP per capita growth in the study area. It is possible to justify this finding with many empirical studies. For instance, Suprapto *et al*.,(2022); Khang The & Nguyen (2021) founds that investment had positively predicted economic growth in their respective areas. Similarly Getachew (2019) also support the positive contribution of Investment on economic growth.

The government final consumption expenditure exists in the model with (.0057) meaning a percentage increase in this variable leads a 0.57 percent increase in GDP per capita growth in the short run at 5% level of significance in the region. This finding is supported by Heitger (2001) who found that general government final consumption expenditures on public goods have a positive effect on economic growth, but this growth effect tends to decline or even reverse when the government is overdoing it. Aluthge et al.(2021)also support this idea as they said general government expenditure on capital expenditure has a positive and significant impact on economic growth.

Table 3 also shows that a one percent increase in the inflation rate is associated with a 0.23 percentage change in economic growth when all other factors remain constant in the area. Moderate inflation aids growth, as argued by (Mallik et al., 2001), but rapid economic growth feeds back into inflation, putting these nations on a knife-edge and necessitating effective police follow-up.

When all other factors are held constant in the short term in the research region, foreign direct investment has a negative effect (-0.0043), which is a percentage increase in FDI results in a 0.43 percent decline in economic growth at a 1% significance level.

Theoretically, FDI is becoming an increasingly significant catalyst for GDP per capita growth through investment, employment, foreign exchange and, however, the finding of this study revealed the reverse. The finding is supported by Kamara (2013) who found that problems in human capital and infrastructure development lead to a negative relationship between FDI and economic growth in Sub-Saharan Africa. In a similar vein, Edrees (2015) likewise draws the conclusion that although FDI is anticipated to have favorable spill-over effects on economic growth theoretically, FDI hinders the economic growth of the region due to inadequate human capital and infrastructure in the area. Therefore, it is feasible to draw the conclusion that the degree of human capital and infrastructure development in the region affects the direction of the influence of FDI on economic growth.

Table 3: Two-step system GMM Regression output

GDP per capita*	Coef.	St.Err.	t-value	Sig
Lag of GDp per capita*	1.041	.032	32.38	***
Investment	.004	.007	2.34	**
Trade openness*	-.003	.013	-0.26	
Inflation rate	.002	.001	3.16	***
Unemployment	-.003	.003	-1.01	
Government final consumption expenditure	.006	.002	2.68	**
Foreign direct investment	-.004	.001	-3.24	***
Digital technology index	0.015	0.08	. 1.86	*
Constant	-.794	.51	-1.56	
Mean dependent var		8.108		
Year dummies		Yes		
Observations		198		
Number of groups		29		
AR(1)		0.025		
AR(2)		0.465		
Hansen		0.399		
Sargen		0.207		
Number of instruments		28		

Source: compiled by the author in 2023

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

As can be seen from the above table, when all other predictors are held constant, an increase in the overall digital technology index is associated with a 1.5 percent increase in economic growth in the short run. This conclusion was corroborated by Zhao et al. (2022); Zhang et al. (2022) who discovered that digital technology considerably boosts economic growth. According to their findings, digital technology influences economic growth by encouraging the upgrading of industrial structures, total employment, and employment restructuring. Additionally, this technique makes a beneficial contribution by reducing the global COVID-19 epidemic's detrimental economic effects.

The influence of digital technology on GDP per capita was also examined with three pillars of digital technology such as; the digital infrastructure index, digital usage index, and digital empowerment index.

To estimate the influence of the three pillars of digitalization on GDP per capita growth, all explanatory variables in Table 3 were used with three digital technology sub-indices. Hansen's statistics (0.564), as reported in Table 4, there is instrumental validity. AR (2) statistics were used to check for second-order serial autocorrelation; the result has a value of 0.582, shows that the model is free of second-order serial autocorrelation issues. The model's overall significance was further examined using the highly significant F-statistics F (17, 32). Finally, the model has 33 groups and 26 instruments, demonstrating that a two-step system GMM estimation model valid.

According to Table 4 below, the digital infrastructure index has a positive influence on Sub-Saharan Africa's economic growth (0.0389), showing that an increase in the index is associated with an increase in economic growth of 3.89 percent in the short run at a 1% significance level when other factors remain constant. Thus, the two-step system GMM's findings demonstrate that digital infrastructure predicts economic growth by affecting production variables, facilitating investment in human capital, and promoting inclusive growth and the decrease of poverty.

The digital empowerment index also has a positive significant effect on economic growth in the Sub-Saharan Africa. This conclusion is supported by Olo & Meliciani (2014) who found that digital empowerment exerts significant economic effects, especially on employment by favoring the inclusion of "disadvantaged" groups in the labor market. It may drive productivity and employment growth. Digital empowerment has the power to influence economic growth by addressing marginalized social groups such as women and periphery areas that are far from different infrastructures. The result also depicted that the level of unemployment has hurt economic growth in of the region

Table 4: Two-step system GMM regression output for digital indices

GDP per capita*	Coef.	St.Err.	t-value	Sig
Lag of GDp per capita*	0.830	0.054	15.54	***
Investment	0.013	0.004	4.43	***
Inflation rate	.001	0	3.87	***
Unemployment rate	-0.012	0.003	-5.27	***
Government final consumption expenditure	0.004	0.002	3.31	**
Foreign direct investment	-0.064	0.019	-3.24	***
Trade openness*	-0.003	0.013	-0.26	
Digital empowerment index	0.120	0.054	5.94	***
Digital usage index	-0.020	0.014	-1.44	
Digital infrastructural index	0.039	0.013	2.54	**
Constant	-0.794	0.510	-1.56	***
Mean dependent var	8.088			
Year dummies	yes			
Observations	330			
Number of groups	33			
AR(1)	0.047			
AR(2)	0.582			
Hansen	0.564			
Sargen	0.282			
Number of instruments	26			

Source: compiled by the author in 2023

*** p<0.01, ** p<0.05, * p<0.1

(*) refers variable is in natural logarithm

Besides the short-run effects of digital technology on the economic growth of the region, the long-run effect of this technology was also estimated in this paper. Long-run estimation was made for only significant variables in the short run as revealed in Table 5.

Table 5: Long-run effects of digital technology on economic growth

GDP per capita*	**Coef**	**Std. Err**	**z**	**Sig**
Digital infrastructure index	0.2300	0.0335	6.84	***
Digital empowerment index	0.2076	0.06763	3.07	***
Unemployment	-0.0685	0.0207	-3.31	***
Foreign direct investment	-0.3774	0.10893	-3.46	***
Level of investment	0.07583	0.10893	2.68	***

Source: compiled by the author in 2023

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

(*) refers variable is in natural logarithm

According to the long-run estimation result, a rise in the digital infrastructural index alters Sub-Saharan Africa's GDP growth by 22.95 percent at a 1% significance level. The outcome also showed that over the long term, at a 1% level of significance, an increase in the digital empowerment index is linked to a shift in economic growth of 20.76 percent. Thus, this suggests that digital technology has both short- and long-term effects on Sub-Saharan Africa's economic growth, with the long-term effects being bigger than the short-term effects as indicated by the short- and long-run coefficients.

According to Table 5, an investment also causes a significant rise in the region's economic growth. Investment has a greater long-run influence on economic growth (7.583%) than short-run (1.28%). Finally, over the long term, in sub-Saharan African countries, an increase in FDI is linked to a 37.74 percent decline in economic growth when other predictors stay constant.

5. Conclusion and Policy Implications

The findings yield several inferences and policy implications. Firstly, the study concludes that digital technology significantly and positively contributes to both short-run and long-run economic growth. Overall digital technology indicators, alongside digital infrastructure and digital empowerment indices, strongly predict economic growth in the region. Particularly, the digital infrastructure and digital empowerment indices emerge as the most influential factors. Consequently, the results suggest significant policy implications: There is a pressing need for investment in the region's digital technology development to amplify its contribution to economic growth.

Secondly, the results highlight that general government final consumption expenditure positively correlates with GDP growth in the region. This underscores the policy importance of directing government expenditure towards public goods like digital infrastructure. Additionally, inflation levels positively impact economic growth, indicating the advantage of low inflation for overall economic sectors. However, excessive inflation poses a threat, demanding vigilance from government and policymakers to maintain a delicate balance.

Moreover, Sub-Saharan Africa's economic growth is notably influenced by investment levels. Thirdly, the findings reveal that Foreign Direct Investment (FDI) negatively affects the region's GDP growth due to inadequate human capital and infrastructure development. This emphasizes the need for policymakers to invest in human capital and infrastructure to alter the impact of FDI on the region's GDP growth.

Lastly, unemployment exerts a negative influence on the region's GDP growth, prompting governments and policymakers to take proactive measures to reduce unemployment levels in the region.

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