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Determinants of digital technology development in sub-Saharan African countries: evidence from panel data analysis

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Abstract

The primary objective of this research is to explore the elements that shape the progression of digital technology in Sub-Saharan African nations. The study employs data obtained from 16 countries, covering the period between 2000 and 2020. Employing fixed effect panel regression analysis, our research indicates that various non-technological factors significantly impact digital technology development in the region. The results highlight that variables including general government final consumption expenditure, inflation rate, employment growth rate, financial development, ease of doing business index, logistics performance index, international migration, access to electricity, and access to safe drinking water have a positive impact on the development of digital technology. Conversely, international trade is identified as a negative influence, primarily due to insufficient infrastructural development. These findings underscore the significance of non-technological elements, encompassing aspects like globalization, economic conditions, favorable digital ecosystems, and the fulfillment of basic human needs, in shaping the landscape of digital technology in the region. The study, while acknowledging limitations in terms of selected indicators, years, and countries, emphasizes the need for broader investigations in future research. Practically, the study suggests that governments in the region should prioritize addressing these non-technological factors to fully leverage the potential of digital technology development. The originality and value of this research lies in its exploration of non-technological determinants, shedding light on their pivotal role in shaping the digital technology landscape in sub-Saharan Africa.

Keywords: Digital technology, Fixed effect, Panel data analysis, Principal component analysis, Sub-Saharan Africa

JEL Classification: O3, 031, 033

Introduction

While digital technology is experiencing rapid growth, particularly in developing countries, its definition remains inadequate and varies. As articulated by Hanna (2020); Obukhova et al. (2020); Koshinen (2018a); Koshinen (2018b); Bukht and Heeks (2018); Schelenz and Schopp (2018); Sutherland and Jarrahi (2018); and Domazet and Lazić (2017), digital technology refers to the application of Information and Communication

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Technologies (ICTs) across all economic domains. It represents a technological shift that fundamentally alters our daily lives, modes of communication and information dissemination, approaches to economic activities, social interactions, and interpersonal relationships. This definition encompasses the creation and utilization of this new technology on public and private institutions.

Digital technology is extensively infiltrating and reorganizing various facets of economic and social engagements. Its influence ranges from disruptive transformations of existing activities to more gradual and supportive impacts that complement on-going endeavours. There are instances where digital technology substitutes for established technologies and tasks, yet in other scenarios, it functions in harmony with existing practices. Moreover, on occasion, the integration of digital technology leads to the emergence of novel activities, services, innovations, and business prospects (Suroedova et al. 2021; Sutton et al. 2019).

Despite the widespread influence of digital technology, its adoption is not uniform across countries, resulting in growing disparities that particularly affect developing nations such as those in Africa (Malephane 2022; United Nations Conference on Trade and Development 2019). SSA (Sub-Saharan Africa) region, in particular, face challenges in advancing digital technology, impeding the exploration of new avenues for growth, and experiencing an uneven distribution of its overall impact in the region. Limited access to broadband networks persists in the area (Bayuo 2017; Kelly and Firestone 2016), and as noted by Velde (2018), there is a deficiency in digital skills compared to other regions.

As of the end of 2021, Sub-Saharan Africa had only 515 million mobile services subscribers, constituting 46% of the region's population, and 239 million people, equivalent to 26% of the population, regularly accessed mobile internet (The GSMA 2021). The contribution of digital technology, particularly in mobile services, amounted to approximately 8% of the region's GDP, generating 3.2 million jobs directly or indirectly. Notably, digital technology has played a role in supporting the public sector, contributing $16 billion through taxes (The GSMA 2022).

Various perspectives exist regarding the factors contributing to the low standing of Sub-Saharan Africa in digital technology development. For instance, Myovella et al. (2021) identified determinants such as digital infrastructure, GDP per capita, gross capital formation, political stability, regulatory efficiencies, access to electricity infrastructure, government consumption, and trade openness. Audi et al. (2022) pointed out that globalization plays a role in influencing digital technology development, particularly in the realm of information technology. Empirical studies have shown that the level of ICT infrastructure, digital competency, effectiveness of research and development, and innovation activities are also crucial in shaping digital technology development.

Researchers argue that previous studies on the determinants of digital technology development have been insufficient, citing issues with empirical methods, approaches, and geographical focus. Many existing empirical studies predominantly originate from developed countries, leaving a gap in understanding the dynamics specific to Sub-Saharan Africa (Rasskazova and Yurgenson 2021; Karieva et al. 2021). Even the few studies conducted in Sub-Saharan Africa use different measures of digital technology indicators or employ diverse estimation techniques, such as spatial Durbin analysis (Odusanya and Adetutu 2020; Murthy et al. 2015).

While some researchers have delved into the determinants of digital technology at the sectorial and firm levels (Rasskazova and Yurgenson 2021; Avenyo et al. 2022; Smidt and Jokonya 2022), this paper aims to comprehensively analyse factors that influence the digital technology development. It seeks to incorporate indicators of digital infrastructure and digital competence, employing principal component analysis and fixed-effect panel methods of estimation. Ultimately, the paper aims to address the question of what non-technological and technological factors influence digital technology in Sub-Saharan Africa.

The following sections of this paper are organized as follows. The following section provides a comprehensive review of relevant literature. Moving forward, the third section outlines the research methodology, encompassing a concise overview of the utilized data and considerations related to model specification. Section four delves into a detailed discussion of the research findings, while the concluding section incorporates summaries, policy implications, and recommendations.

Literature review

Concepts and definition of digital technology

Digital technology development describes the utilization and application of technology and digital tools in all economic activities. It refers to the use of advanced information and communication technology in collecting, storing, analyzing, and sharing physical information and market data at each link of the product value chain, providing technical support for innovation in various fields (Cangul et al. 2020; Berger and Roeglinger 2019).

It is a powerful tool to help unlock economic growth and create economic opportunities, tackle development challenges, ease access to services, and improve lives. In times of crises from natural disasters to global pandemics it have proven critical to support national resilience and keeping people, governments, and business connected (World Bank 2016).

Furthermore, digital technology development indicates the use of digital technology in most cross-cutting issues of climate change, by supporting the government to plan, build, procure, and operate climate-resilient infrastructure, helping governments to reduce greenhouse gas emissions and manage e-waste, gender, and inclusion; in which digital technology is used to reduce the gender gap and enhance the empowerment of marginalized social groups.

As mentioned by USAID (2021) digital technology development in context of Sub Saharan Africa includes the development of digital literacy, digital Gig economy, precision Agriculture, Research and Development, and digital ecosystem and in general it is revolutionizing industries, governments, economies and societies. Similarly Aker and Cariolle (2020) defines digital technology development as increase in number of internet users, mobile phone subscriptions, mobile broad band subscriptions and fixed broad band subscription that has spurred the deployment of a number of private and public-sector digital services, and therefore raised the prospected of growth, employment and poverty reduction in Sub Saharan Africa.

The term "Digital technology development" has gained widespread use globally, sparking numerous debates regarding its definition and measurement. Despite the diversity of interpretations, this article adopts the definitions provided by various sources, including Hanna (2020); Obukhova et al. (2020); Kari Koshinen (2018a), Kari Koshinen (2018b); Bukht and Heeks (2018); Schelenz and Schopp (2018); Sutherland and Jarrahi (2018), Domazet and Lazić (2017), and Unold (2003). According to these sources, digital technology development is characterized as a form of technological change that profoundly influences our daily lives, modes of communication and information dissemination, economic activities, social interactions, and relationships with others. It represents the 21st-century movement towards advanced technology in telecommunication, information, and innovations, contributing to overall development.

Essentially, digital technology entails the utilization of Information and Communication Technologies (ICTs) across various economic sectors, covering the creation and application of digital technologies in both public and private domains. It entails a set of digital affordances and potential actions for individuals or organizations within their environmental context. Furthermore, digital technology is distinguished by the digitalization of products and services, utilizing the Internet and other networks to support various economic activities.

A substantial body of literature explores the factors influencing digital technology development. For instance, Singh et al. (2020) employed descriptive research methods to investigate the impact of life expectancy on technological development, concluding that higher life expectancy contributes to technological advancement. Likewise, Owolabi et al. (2021) concentrated on investigating the correlation between enhanced electricity access and financial development facilitated by Information and Communication Technology (ICT) in 16 West African countries spanning the period from 2000 to 2017. Through panel data fixed effect instrumental variables estimation, their study unveiled that advancements in electricity access substantially boost the utilization of mobile and internet technologies, which are integral components of digital technology.

Rasskazova and Yurgenson (2021) conducted an analysis using analytics and econometrics to explore the determinants of digital technology in developed countries. They identified information and communication technology infrastructure, along with the availability of public services, as crucial factors influencing digital technology development. Similarly, Myovella et al. (2021) investigated the determinants of digital technology development and the digital divide in Sub-Saharan African economies, covering 41 countries. Utilizing spatial panel analysis with a spatial Durbin specification for data spanning from 2006 to 2016, their findings indicated that GDP per capita, gross capital formation, political stability, regulatory efficiency, electricity infrastructure, government consumption, and trade openness play pivotal roles as determinants of digital technology development in the region.

In Avenyo et al.'s (2022) study, which delved into the determinants of digital information and technology implementation for smart manufacturing using interpretive methods, they highlighted operations technology maturity and cybersecurity maturity as pivotal factors influencing the implementation of digital technology.

In the same way (Odusanya and Adetutu 2020) examining the determinants of internet usage in Nigeria by using micro-spatial approach. They found that the demographic, socio-economic and infrastructure factors t are predict internet usage in the area.

The working paper by Ghauran et al. (2023) on the Size and Distribution of Digital connectivity gap in Sub Saharan Africa by using household survey methods over 48 countries across the region found that access to electricity, mobile phone coverage, internet usage, computer and tablets are among the determinants of digital technology development in the region.

Researchers argue that existing empirical literatures on the determinants of digital technology development have been insufficient, citing issues with empirical methods, approaches, and geographical focus. Many existing empirical studies predominantly originate from developed countries, leaving a gap in understanding the dynamics specific to Sub-Saharan Africa and even the few studies conducted in Sub-Saharan Africa use different measures of digital technology indicators or employ diverse estimation technique. Furthermore, some researchers have delved into the determinants of digital technology at the sectorial and firm levels and. this paper aims to comprehensively analyse factors that influence the digital technology development. It seeks to incorporate indicators of digital infrastructure and digital competence, employing principal component analysis and fixed-effect panel methods of estimation. Ultimately, the paper aims to address the question of what non-technological and technological factors influence digital technology in Sub-Saharan Africa.

Methodology

To investigate the factors influencing the development of digital technology in specific Sub-Saharan African countries, a quantitative research method was employed. Fixed effect panel data analysis was utilized for the period between 2000 and 2020, considering data availability and the appropriateness of the model.

Data sources and description

A secondary data source was utilized to explore the determinants influencing the progress of digital technology in sub-Saharan African countries. The necessary components' standardized secondary data were obtained from the World Development Indicators (WDI), complemented by information from the International Telecommunication Union (ITU) and the African Development Bank.

To fulfil the study's objective, a sample of 16 countries was chosen from the sub-Saharan African region, spanning the years 2000 to 2020, based on the availability of data. Due to the relatively recent emergence of digital technology, there is a challenge with data accessibility in certain countries within the region. Consequently, researchers were compelled to select only those 16 countries that had adequate data on the necessary variables. The selected countries include Angola, Benin, Botswana, Burundi, Burkina Faso, Côte d'Ivoire, Ethiopia, Gabon, Ghana, Kenya, Mauritania, Mauritius, Mozambique, Rwanda, Senegal, and Zimbabwe.

Computing digital technology index

The digital technology index was computed using the principal component analysis (PCA) method, a multivariate technique that analyzes a data table with inter-correlated quantitative dependent variables. The principal component Analysis (PCA) is a powerful statistical techniques used for dimensionality reduction and data visualizations. However, like any statistical method, it comes with certain assumptions and limitations that should be considered when interpreting results. The assumption of PCA; Linearity, Independence, Normality, Homoscedasticity, Large Sample Size where as the model limitations are Loss of Interpretability Information Loss, Sensitive to Scaling, Assumption of Orthogonality and Nonlinear Relationships (Lever et al. 2017; Ali 2014; Karamizadeh et al. 2013; López del Val and Agreda 1993). Hence the researchers used different techniques, for instance KMO to test these assumptions and limitation to ensure the validity and reliability of the resulting digital technology index.

In constructing the digital technology index, data from technology infrastructure indicators, and technology usage were utilized. Technology usage indicators, as defined by Evangelista et al. (2014) and Solomon and van Klyton (2020), included fixed telephone subscriptions, fixed broadband subscriptions, the number of individuals using the internet, secured internet servers, and mobile users. Technology infrastructure indicators encompassed fixed telephone subscriptions per 100 inhabitants, secured internet servers per 100 people, mobile users per 100 inhabitants, and fixed broadband subscriptions per 100 inhabitants.

To construct the digital technology index, the researchers employed Principal Component Analysis (PCA) using the mentioned indicators. The validity of the PCA was evaluated through the Kaiser–Meyer–Olkin (KMO) test. The determination of the number of components was based on the Eigenvalue and Scree plot rule. The Scree plot, a commonly utilized method, assists in determining the number of principal components by examining a graphical plot. Following the eigenvalue rule outlined by Jeong et al. (2017), components with eigenvalues surpassing one were chosen for the computation of the digital technology index. In this investigation, four components with eigenvalues greater than one were selected, collectively explaining 79% of the shared variances in the dataset, as outlined in Table 1.

Aside from employing the eigenvalue rule, a scree plot displaying eigenvalues was utilized to choose four components for the construction of the digital technology index, as illustrated in Fig. 1.

Table 1 PCA and eigenvectors for digital technology index

Variables	Value					
	Kaiser–Meyer–Olkin (kmo)	PCA eigenvectors (highest)				Proportion explained
		Com1	Com2	Com3	Com4	
Digital technology index	0.6072	2.91	1.99	1.19	1.01	0.79

Source: Own Computation (2023)

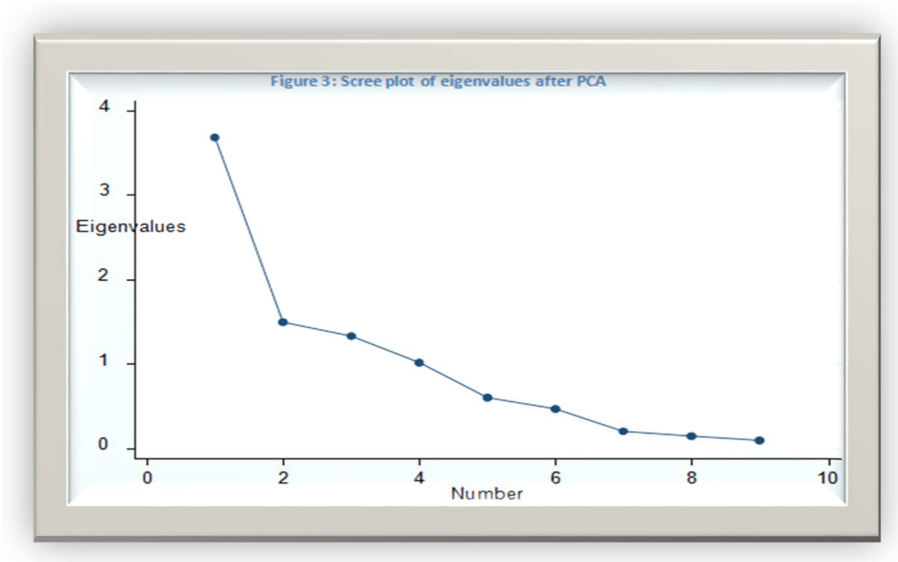

Fig. 1 Scree plot of eigenvalue after PCA. Source: Own Computation (2023)

Econometric model specification

To address omitted variable bias stemming from heterogeneity in the data, panel data analysis was employed. This approach controls for unobservable variables that may be correlated with predictors but are either inaccessible or immeasurable (Gujarati 1995).

Various scholars have employed different criteria to determine whether random effects or fixed effects should be utilized in panel data analysis. Beckett (1975) suggested that if individual effects arise from numerous non-observable stochastic variables, random effect specifications may be appropriate and for other the decision to use fixed or random effects ultimately rests with the investigator and whether the inference pertains to population characteristics or sample effects. Nevertheless, many scholars advocate basing the choice between fixed and random effects on statistical tests such as the Hausman test (Zulfikar 2018; Oscar 2010; Torres et al. 2007). According to the Hausman test, a fixed effect may be preferred when it yields a statistically significant result.

Therefore, the researchers conducted the Hausman and the result of Hausman test is significant, implies that there is evidence of systematic difference between the estimates obtained from fixed effects model and random effects model. The implication of choosing fixed effect over random effect when Hausman test significant: If the Hausman test suggests that the fixed effects model is preferred (i.e. the coefficient from fixed effects model are consistent and efficient), the using the fixed effects model is appropriate. It implies that the unobserved individual or group –specific effects are correlated with the explanatory variables. This suggests that there are individual or group-specific factors influencing the dependent variable that should be accounted for in the analysis. Here by using the fixed effect model, it is possible to control for these unobserved individual or group-specific effects, which can lead to more accurate and reliable estimates of the effects of explanatory variables on the dependent variables within each individual or group.

Hence, fixed effects are a method of controlling for all variables, whether they are observed or not, as long as they stay constant within some larger category. In a fixed effects model, the unobserved variables are allowed to have any associations whatsoever with the observed variables. The fixed effects model is a model that controls for, or partially out, the effects of time-invariant variables with time-invariant effects. This is true whether the variable is explicitly measured or not. Exactly how they do so vary by the statistical technique being used (Allison 2009).

Although fixed-effect panel regressions are now widely recognized as a powerful tools for longitudinal data analysis, the model has the limitation. For instance culture of omission, low statistical power, limited external validity, restricted time periods, measurement error, time invariance, undefined variables, unobserved heterogeneity are among some of them (Hill et al. 2020).

Furthermore the validity and reliability of the data from secondary sources were checked by using Hausman Test, Unit Root Tests to check for stationarity in data, the Breusch-Pagan LM test, and Goodness-of-fit Measures.

The fixed-effects model

Here the fixed effects (FE) model takes α_i to be a group-specific constant term in the regression equation:

$$y_{it} = \alpha_i + \beta_1 x_{it} + \beta_2 x_{2it} \ldots . + \beta_k x_{kit} + \varepsilon_{it} \tag{1}$$

Or in matrix notation,

$$y_{it} = \alpha_i + x\prime_{it}\beta + \varepsilon_{it} \tag{2}$$

where: $x_{it} = [x_{1it}, x_{2it}, \ldots x_{kit}]$ and

$$\beta\prime = [\beta_1, \beta_2, \ldots \beta_k]$$

The indices "i" denote cross-sectional units, where i = 1, 2, 3… N, and the indices "t" represent time-series occurrences, with t = 1, 2, 3… T. The individual effect α_i remains consistent over time (t) and is specific to each individual cross-sectional unit (i). The term α_i is presumed to encompass unobservable and immeasurable characteristics that distinguish individual units. This suggests that any variations in behaviour among individuals are constant over time and manifest as parametric shifts in the regression function. According to Beckett (1975) the intercept is allowed to differ from one individual to another, while the slope parameters are treated as constants in both the individual and time dimensions.

The fundamental assumptions of the fixed effects model are:

$$E\lfloor\varepsilon_{it} = 0\rfloor,\ \mathrm{cov}\left(\varepsilon_{it}\varepsilon_{jt} = 0\right),\ \mathrm{var}\varepsilon_{it} = \mathrm{E}\lfloor\varepsilon_{2it}\rfloor = \sigma^2 e,\ \mathrm{E}[\varepsilon_{it}, x_{it}] = \mathrm{E}[\varepsilon_{it} x_{it}] = 0$$

$E[\epsilon_{it}, x_{it}] = 0 \mathrm{and} x_{it}$ is not invariant. Under these assumptions, the ordinary least-squared estimator (OLS) can be used to obtain unbiased, consistent, and efficient (BLUE) parameter estimates.

Therefore, the following FE model was specified and estimated in the study:

$$
\begin{aligned}
DTind_{it} = \beta_0 &+ \hat{a}_1 GDppc_{it} + \beta_2 Ggfcxp_{it} \\
&+ \beta_3 VTrade_{it} + \beta_4 intour_{it} + \beta_5 Emp_{it} \\
&+ \beta_6 Lpi_{it} + \beta_7 Inf_{it} + \beta_8 Inv_{it} + \beta_9 Aw_{it} \\
&+ \beta_9 inmigr_{it} + \beta_{10} Edb_{it} + \beta_{11} Ae_{it} \\
&+ \beta_{12} Hci_{it} + \beta_{13} Lfe_{it} + \beta_{14} Dcp_{it} + \epsilon_{it}
\end{aligned}
\tag{3}
$$

where:

$GDppc_{it} =$ is the GDP per capita growth of a country (i)at a time (t).

$GgFcxp_{it} =$General government final consumption exp. of country (i) at a time (t).

$VTrade_{it} =$ Total amount of trade for a country (i) at a time (t).

$intour_{it} =$ International tourism for a country (i) at a time (t), measured as the sum of arrivals and departures of international tourists as share of the population.

Emp_n_{it}= number of employment for a country (i) at a time (t).

$Lpi_{it} =$ logistics performance index for a country (i) at a time (t).

$Inf_{it} =$ inflation rate for a country (i) at a time (t).

$Inv_{it} =$ level of investment for a country (i) at a time (t).

$Aw_{it} =$ percentage of Population Using Safe Drinking Water Services.

$Edb_{it} =$ Ease of Doing Business Index for a country (i) at a time (t).

$inmigr_{it} =$ International migrant stock for a country (i) at a time (t), measure in terms of the number of people born in a country other than in which they live, including refugees.

$Lfe_{it} =$ Life expectance for a country (i) at a time (t).

Ae_{it}= Access to electricity for county (i) at a time (t).

$Hci_{it} =$ Human capital; the index for a country (i) at a time (t).

Results and discussion

This section of the research focuses on presenting and discussing the outcomes derived from both descriptive statistics and the estimation of the econometric model.

Results of descriptive statistics

In this section of the paper, the quantitative data sourced from secondary data sets underwent analysis through descriptive statistical methods such as calculating mean and standard deviation. The GDP per capita is found to have a mean value of 1.99, with a standard deviation of 4.45, as presented in Table 2 below. Another explanatory variable in the model, international migration, exhibits a mean of 3.64 and a standard deviation of 3.96. The ease of doing business is characterized by mean and standard deviation values of 48.69 and 14.64, respectively. Foreign direct investment, a component of the model, demonstrates a mean of 3.33 and a standard deviation of 5.48. General government final consumption expenditures, with mean and standard deviation values of 13.94 and 5.98, respectively, are also noteworthy explanatory variables. Trade is represented with a mean of 67.89 and a standard deviation of 25.82. The numbers of employed individuals in the model exhibits mean and standard deviation values of 78.71 and 57.02, respectively. International tourism is characterized by mean and standard deviation values of 13.56 and 1.03. The logistic performance index has a mean of 2.328 and a standard deviation of 0.51. Inflation, with a mean of 2.33 and a

Table 2 Descriptive statistics for determinants of digital technology

Variable	Mean	SD	Min	Max
International migration	3.64	3.96	0.31	15.88
Easy of doing business	48.69	14.64	− 13.71	82.88
Foreign direct investment	3.33	5.48	− 11.20	39.46
GDP per capita*	1.99	4.45	− 18.49	18.07
Government expenditure	13.94	5.98	− 2.88	35.66
Trade	67.89	25.82	20.72	152.55
Number employment	78.71	57.02	1	196
Log of international tourism	13.56	1.03	9.95	15.87
Logistics performance index	2.33	0.51	− 0.28	4.15
Inflation rate	10.68	39.42	− 27.66	557.20
Investment	21.62	8.94	− 22.79	47.56
Access to safely managed water	63.66	7.64	18.08	99.87

Source, own computation (2023)

standard deviation of 39.42, is another variable considered. Investment, as part of the model, has a mean of 21.62 and a standard deviation of 8.94. Lastly, access to regulated drinking water is represented by mean and standard deviation values of 63.66 and 17.64, respectively.

Table 2: Descriptive statistics for determinants of digital technology.

Empirical findings and discussion

The model incorporated fifteen explanatory variables, and the overall findings from fixed effect estimation, as presented in Table 3, suggest that digital technology development is influenced by a combination of technological and non-technological factors, including economic factors, globalization factors, ease of doing business, fulfilment of human basic needs, and human capital.

Table 3 indicates that globalization is a significant factor affecting digital technology development in Sub-Saharan Africa. To examine the impact of globalization on digital technology, indicators such as international migrant stock, international tourism, foreign direct investment flow, and international trade were used as proxy variables. The results of fixed effect estimation highlight that two globalization indicators, specifically international migrant stock and international trade, exert a significant influence on digital technology development in Sub-Saharan Africa. As shown in Table 3, a one-person increase in the number of migrants corresponds to a 0.7 increase in the digital technology index at a 1% significance level, indicating a positive effect of international migration on digital technology development in the region.

International migrant stock positively affects digital technology development by fostering innovation in the migrants' home regions. It serves as a vital conduit for knowledge transfer. Despite concerns about brain drain in certain developing countries due to the departure of well-educated individuals, these countries benefit from the temporary migration of managers and engineers, the return of educated emigrants, and connections with a technologically sophisticated diaspora. Additionally, remittances sent by migrants play a role in promoting technology diffusion, thereby encouraging digital technology development. Furthermore, highly skilled migrants make substantial contributions to

Table 3 Fixed effect result

Digital Technology index	Coef	St.Err	t-value	Sig
International migration	0.6995	0.093	2.91	***
Foreign direct investment	0.019	0.02	1.08	
Easy of doing business index	0.038	0.02	3.59	**
GDP per capita	0.008	0.013	0.67	
Government final consumption expenditure	0.0527	0.012	2.06	***
International trade	− 0.01	0.00	− 2.71	*
Employment	0.03	0.00	4.34	***
Logistics performance index	0.31	0.16	2.15	**
Inflation	0.003	0.00	1.57	**
Investment	0.003	0.02	− 0.50	
Access to managed drinking water	0.06	0.01	4.69	***
Access to Electricity	0.02	0.01	3.22	***
Life expectancy rate	0.111	0.01	10.64	***
Human capital index	10.597	0.83	12.77	***
Financial development	0.019	0.004	4.54	***
Constant	− 7.637	1.863	− 5.29	***
Year dummies				Yes
Observations				243
R-squared				0.515
Number of countries	16			

Source, own computation (2023)

technology innovation, research, and development, particularly in destination countries with higher income levels. Overall, the positive impact of international migration on digital technology development is corroborated by studies such as Andersson et al. (2022), Foresti et al. (2018), and Burns and Mohapatra (2008).

The outcomes presented in Table 3 indicate a negative correlation between international trade and digital technology development in Sub-Saharan Africa. Specifically, a unit increase in international trade is associated with a 0.01 decrease in digital technology development at a 10% significance level. While this result contradicts prevailing theories, several explanations may elucidate this unexpected finding.

One plausible explanation is the region's inadequate and underdeveloped digital infrastructure, a notion supported by Dahlman et al. (2016) and UNCTAD (2022). These sources argue that underdeveloped digital infrastructure, limited digital skills among workers and consumers, insufficient financial support, a weak regulatory framework, and low levels of trust in digital transactions contribute to the adverse impact of international trade on digital technology development in low-income developing countries.

Moreover, the lack of access to digital technology for a substantial portion of the population in the region can hinder the positive effects of international trade on digital technology development. Economic disparities that result in unequal access to the benefits of international trade, concentrating those advantages in specific segments of the population, may also influence the relationship between international trade and digital technology development. Additionally, socioeconomic factors, government policies, and regulatory issues play a pivotal role in shaping the contribution of international trade to digital technology development. In alignment with the findings of this study, Serrano-Quintero (2022) also observed that an unfavorable digital environment and deficient logistics markets resulted in high trade costs, contributing to the negative impact of international trade on digital technology development in Sub-Saharan Africa.

The finding of this study and the reviewed empirical literature show that International trade negatively affects digital technology development in in Sub Saharan Africa. The reasons include gaps on connectivity, information and communication technology infrastructure and digital skills, as well as the lack of a predictable and transparent legal and regulatory environment.

To reverse the direction of the relationship between digital technology and international trade in Sub-Saharan Africa, policymakers should prioritize the development of digital infrastructure, invest in human digital skills, and establish a robust regulatory framework for digital technology.

In general, one can conclude that globalization significantly influences the development of digital technology in the region, with ample literature supporting the findings of this paper. For instance, Skare and Soriano (2021) and Hart (2000) have found a positive relationship between globalization and digital technology, suggesting that globalization positively affects technological penetration.

The second non-technological determinant impacting digital technology is macroeconomic factors, represented by GDP per capita, general government final consumption expenditure, employment growth, investment, inflation rate, and financial development. For instance, the findings indicate that a one percent increase in the employment growth rate corresponds to a 0.027 increase in the digital technology index, demonstrating a statistically significant relationship at the 1% significance level. This observation holds importance, particularly in the on-going discourse on the correlation between employment growth and digital technology. The positive connection identified in this study suggests that as employment opportunities expand, there is a concurrent rise in the adoption and development of digital technology within the region.

To provide additional context and insight into this result, it is essential to consider that employment growth often signifies economic expansion and heightened business activities. As more businesses flourish and generate jobs, there is an increasing demand for digital technology solutions to enhance productivity, streamline operations, and facilitate access to broader markets, both domestically and internationally.

This finding aligns with the viewpoints of Group (2020) and Schulte and Howard (2019), who similarly advocate for the interconnection between employment growth and digital technology development. They likely share the belief that as the workforce expands and industries evolve, there is a corresponding need for digital tools and infrastructure to meet the demands of a modern, competitive economy.

The study's outcomes in Table 3 reveal a significant positive relationship between general government final consumption expenditure and digital technology development. This result is consistent with prior research by Heitger (2001), which illustrated that government spending on public goods can stimulate overall economic growth, including technological progress. This positive association can be attributed to government investments in areas such as infrastructure, education, and research and development, creating an environment conducive to technological advancement. Government spending fosters the development of digital infrastructure, education systems producing a skilled workforce, and research initiatives driving innovation, ultimately leading to higher levels of digital technology adoption in the economy. Furthermore, investments in education and skills development contribute to a more knowledgeable and adaptable workforce, further enhancing technological progress.

The association between the inflation rate and digital technology is positive, with a one-unit increase in the inflation rate resulting in a 0.003 rise in digital technology at a 10% significance level. This suggests that higher inflation rates are linked to greater advancements in digital technology. This finding aligns with the research of Mallik et al. (2001), who observed that moderate levels of inflation can be conducive to overall sector growth. It is crucial to note, however, that their work also highlighted the potential negative impact of excessively high inflation on economic performance. Therefore, while some inflation appears to foster digital technology growth, there may be diminishing returns or adverse effects associated with very high inflation rates, emphasizing the need for a balanced approach to inflation management.

Financial development, as measured by domestic credit to the private sector, emerges as a significant factor influencing digital technology development in the region, with a coefficient of 0.02. This finding implies that an incremental increase in financial development results in a corresponding 0.02-point increase in digital technology. This association underscores the importance of a well-developed financial sector in promoting digital technology development. When domestic credit is readily available to the private sector, businesses and individuals have greater access to the capital needed for investments in digital infrastructure, innovation, and technology adoption. As a result, this fosters a more conducive environment for digital technology development in the region.

A conducive digital environment significantly influences digital technology development in the study area. Indicators such as the Ease of Doing Business Index and Logistics Performance Index (LPI) exhibit a positive effect on digital technology. These factors play a pivotal role in shaping the environment for digital technology growth. A favorable business environment, characterized by streamlined regulations and efficient logistics, facilitates innovation and investment in digital technology, thereby contributing to its development.

In summary, the study emphasizes the crucial role of a favorable digital environment, encompassing infrastructure and supportive policies, in driving digital technology in the region. This aligns with prior research by Scott and Minehane (2019) and Muller (2015), highlighting the importance of a conducive digital environment that includes quality infrastructure and digital skills. Furthermore, the study underscores that an enabling digital ecosystem, featuring affordable, high-quality digital services, incentives for digital infrastructure investment, strong cybersecurity, and a robust legislative framework, are crucial factors for fostering digital technology development.

To explore the impact of basic human needs on digital technology development, proxy variables such as the population with access to safe drinking water services, electricity access, and life expectancy were examined. The study reveals that an increase in the percentage of the population with access to safe drinking water services positively affects digital technology development. Similarly, electricity access, measured by the percentage of the population with access to electricity, significantly influences digital technology development. Life expectancy also demonstrates a positive influence on digital technology development in Sub-Saharan Africa, with a coefficient of 0.11. These findings underscore the significance of fulfilling basic human needs, such as safe drinking water and electricity, in facilitating the development of digital technology. The results of this paper, supported by Owolabi et al. (2021) and Rosenthal (2009), emphasize that the true value of technology and infrastructure can only be fully realized when a population's basic needs are met. Communities cannot fully benefit from digital technology without the fulfillment of these necessities.

This suggests that meeting basic human needs is a significant determinant of digital technology development in the region. Consequently, governments and policymakers in the region must prioritize investments in meeting these basic human needs to drive digital technology development.

The result in Table 3 also reveals that an increase in the human capital index is associated with a 10.597 increase in digital technology at a 1% significance level. This finding indicates that a skilled labor force is required to support digital innovation, build digital technology, and maintain its development in the region. This conclusion is reinforced by Novikov et al. (2020), who found that individuals with competence in the field of new technologies, capable of research, and able to introduce new technology are the main factors in digital technology development. To attain a leading position in digital technology, there should be intensive human capital development.

Besides non-technological factors, technology-related factors also play a crucial role in facilitating digital technology development. The result of this study indicates that technological indicators, such as fixed telephone subscriptions, fixed broadband subscriptions, the number of individuals using the internet, secured internet servers, and mobile users, fixed telephone subscriptions per 100 inhabitants, secured internet servers per 100 people, mobile users per 100 inhabitants, and fixed broadband subscriptions per 100 inhabitants are positively influence digital technology development in the region. Hence the government of the region should give attention to the development of these factors.

Conclusion and policy implications

The study's findings yield several policy implications and conclusions. It emphasizes the critical importance of fostering a conducive digital environment, which includes digital infrastructure, policies, and ecosystems, for the development of digital technology. This underscores the necessity for policymakers to prioritize and invest in digital technology infrastructure such as mobile infrastructure, access to the internet and secured internet servers, and access to electricity and, creating favorable digital conditions through investing in logistic performance index and ease of doing index to promote digital technology growth.

In summary, prioritizing the fulfillment of basic human needs is paramount for advancing digital technology in Sub-Saharan Africa. Governments and policymakers should concentrate on addressing these needs to propel digital development in the region.

Thirdly, macroeconomic factors have a significant impact on digital technology development in the area. Increased government spending on digital infrastructure, moderate inflation, and positive trends in financial development and employment growth contribute to fostering digital technology. Therefore, policymakers should carefully manage these economic factors to optimize digital development.

The growth of digital technology is influenced by globalization factors. Digital technology in Sub-Saharan Africa is positively affected by international migration; however, it is negatively influenced by international trade. This adverse consequence of international trade on technology development is attributed to high trade costs in the region, arising from inadequate hard infrastructure, an inhospitable digital environment, and deficient logistics markets. Therefore, the finding has policy implications for investing in the development of digital infrastructure, human digital skills, and establishing a robust regulatory environment for digital technologies. Finally, the study has limitations in terms of the number of indicators, years, and countries considered, and it underscores the importance of exploring a broader scope for future research.

Abbreviations

FDI	Foreign direct investment
GDP	Gross domestic product
KMO	The Kaiser–Meyer–Olkin
PCA	Principal component analysis
SSA	Sub-Saharan Africa

Author contributions

Conceptualization: EB; Data curation: EB, AB, and AG; Formal analysis: EB; Investigation: EB; Methodology: EB; Resources: EB; Software: EB; Supervision: AB and AG; Validation: EB, AB, and AG; Visualization: AB and AG; Writing – original draft: EB; Writing – review & editing: EB. Generally all authors are contributed for this paper.

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Data availability

The datasets used and/or analysed during current study are available from the corresponding author on reasonable request.

Declarations

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Not applicable.

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The authors declare no conflicts of interest.

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