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ICT, Human Capital and Sustainable Development in Sub-Saharan Africa

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***Abstract*— The effects of ICT and human capital on sustainable development in sub-Saharan Africa (SSA) were examined in this study by employing a panel data set of 41 SSA countries for the period 2000-2021. The study employed several panel estimation techniques, including the pooled ordinary least squares (POLS), random effect and fixed effect estimators as baseline techniques, while the Generalised Method of Moments (GMM) was employed as the main estimation technique. Results indicated that ICT promotes sustainable development in SSA. The study also found that human capital stifles sustainable development in the region. The study, therefore, recommends that policymakers in SSA should ensure that there is sufficient access to quality education, vocational training and skill development programs to enhance human capital. The study also recommends that policymakers in SSA must address the disparities in access to education and training, otherwise human capital may not contribute to sustainable development.**

Keywords*— ICT, Human Capital, Sustainable Development, GMM, sub-Saharan African

I. INTRODUCTION

Promoting sustainable economic growth and development is a key macroeconomic objective of governments worldwide. Unfortunately, sub-Saharan Africa (hereafter, SSA) continues to face significant challenges that may prevent the realization of Sustainable Development. In particular, as revealed by the Africa Sustainable Development Goals Index and Dashboards Reports, Africa might be the least likely region to achieve Sustainable Development targets. The recent COVID-19 pandemic has further exacerbated the situation, pushing millions of Africans into poverty [1]. More particularly, SSA is characterized by a large population and predominantly low-income countries, where a larger proportion of the population lacks access to quality education and healthcare services. These might result in underdeveloped human capital that hinders productivity and thereby contributes to the region's relative poverty [2].

Available evidence shows that human capital development is critical in promoting economic growth and development [3], [4], [5] and [6]. Sadly, in SSA, education and healthcare, which are critical to human capital development, are typically underfunded, which might lead to poorly trained and underdeveloped human capital [7].

In the economic literature, Information and Communication Technology (ICT) has also emerged as a vital catalyst that promotes sustainable development. It reduces poverty, inequality and unemployment [8]. It also serves as a channel through which human capital can be developed. Unfortunately, the adoption of ICT in SSA remains low which may be due to high costs and inadequate ICT infrastructure.

Although several studies [9-12], have been done to provide a clear understanding of the effects of ICT and human capital on sustainable development in SSA, the empirical evidence presented so far suffers a major shortcoming. Existing studies relied on either GDP or carbon emissions as measures of sustainable development. Evidence from [13], has shown that these proxies wholly considered economic growth or ecological factors and do not account for the multifaceted disposition of sustainable development. It has been recognized that economic growth, social and ecological factors are the entire characteristics of sustainable development [14]. Therefore, relying on economic growth or ecological factors alone may prevent us from correctly understanding sustainable development in SSA.

This study hence adds to the literature in the following way: Unlike previous studies which have concentrated on either GDP or carbon emissions as measures of sustainable development, this study utilises an all-inclusive sustainable development index that accounts for the multifaceted nature of sustainable development in terms of economic growth, social and ecological factors.

This study found that ICT is an effective tool for promoting sustainable development in SSA. The study also found that human capital stifles sustainable development in the region. The literature review section examines previous research on the topic. The research method adopted in this study is explained in the methodology section. This is followed by the results section which presents the findings of the research. The discussion section presents the interpretation of the results, and finally, the concluding section summarizes the key findings, their implications, and conclusion.

II. A Brief Literature Review

An empirical review of the literature on information and communication technology, human capital, as well as sustainable development, is presented in this section. Information and communication technology serve as a powerful tool for reducing poverty, inequality, and unemployment in Africa [15]. Information and communication technology improve engagement and knowledge retention in the educational sector by providing the needed platform for E-learning. Information and communication technology also enhance collaboration among scholars both at the local and international levels by removing the barriers of distance and space while enhancing human capital development.

The disproportionate impact of internet access on economic growth in Sub-Saharan African countries was carefully studied by [16]. Information and communication technology were assessed through internet access, while economic growth was measured by the annual percentage growth rate of per capita gross domestic product. Using Hansen's threshold models, the study examined the existence of inflexion points in the relationship between internet access and economic growth in 42 sub-Saharan countries for 11 years. Some major findings were discovered in the study. The study established a significant internet threshold effect on economic growth. Internet access has been found to have a positive, favourable, and statistically significant influence on economic growth within countries situated in sub-Saharan Africa, but this is limited by the laws and import duty regimes practised by the governments of such countries.

Reference [17] underscored the significance of information and communication technology in conjunction with the financial sector for fostering economic growth. They identified three primary pathways through which information and communication technology catalyzes growth: ICT improves efficiency, creates new jobs, and bridges economic inequality. Exploring the immediate and long-run patterns of economic growth, financial inclusivity, and information and communication technology in India, a total of 20 states were tested in their study. An investigation into the presence of a cointegrating relationship among the economic variables was conducted through the application of the Johansen cointegration test. Furthermore, an analysis employing the fully modified ordinary least squares (FMOLS) method was employed, alongside a vector error correction mechanism (VECM) to gauge the speed at which the variables readjusted towards equilibrium.

The study by [18] examined both the direct and indirect relationship between ICT diffusion and financial development utilising panel data for the period 1980 to 2019 comprising 42 African countries. Using a dynamic system GMM, results from the study indicate that financial access is a component of financial development. If improved in tandem with the spread of ICT throughout Sub-Saharan Africa, this will result in greater availability of public goods and services, as well as enhanced access to knowledge and skills. Ultimately, this will contribute to fostering inclusive growth and development in the region.

Reference [19] recognised and identified the issues concerning sustainable development and the key barriers facing it, particularly the use of information and communication technology. Some of the difficulties stem from the lack of consensus on the precise impact of information and communication technology on economic growth and development. In their study, [20] examined the effect of information and communication technology on sustainable development. This was done by utilising a composite sustainable development index encompassing data from 140 countries. The collected data consists of the sustainable development index as the dependent variable. Information and communication technology is measured using metrics such as the number of mobile telephone subscribers per 100 people, the internet penetration rate, and the number of fixed telephone subscribers. From the findings, ICT has a positive and significant impact on sustainable development. According to the study, when developing measures for the 2030 agenda for socioeconomic development, policymakers should consider information and communication technology and the benefits it provides since ICT would enhance industrial productivity and economic activities, as well as increase access to foreign markets for their products.

In their research, [21] investigate if the proliferation of information and communication technology has a positive impact on inclusive human development in a dataset encompassing 49 African nations during the period spanning from 2000 to 2012. To account for the short set of dependent variables, they employed a Tobit model in their analysis. Using a double-censored Tobit regression estimate approach, the findings show that policies focused on promoting information and communication technology usage, if implemented, would lead to more inclusive development. Furthermore, the study revealed that non-oil exporting countries appear to be the driving force behind the observed synergy in mobile phone penetration.

Reference [10] examines the state of human capital development in Nigeria and its implications for sustainable development. The study highlights the significance of human resources in achieving the Sustainable Development Goals (SDGs) and identifies Nigeria's current challenges in this regard. Using available evidence and the SDG index, the study reveals

Nigeria's low ranking and inadequate progress in human-capital-related SDGs, specifically goals 3 and 4. The study concludes by recommending the implementation of appropriate policies, such as increased funding for education and healthcare, training and apprenticeship programs, migration policies, and special initiatives to enhance managerial capabilities. These measures are crucial for accelerating sustainable development in Nigeria by fostering the development of human capital.

III. METHOD

A. Data and Model Specification

Panel data from 41 sub-Saharan African countries are collected and tested in this study for a period from 2000 to 2021. The data used in this study are sourced from the World Development Indicators (WDI) of the World Bank [22] and [13] except otherwise stated. Principal component analysis (PCA) is used in this study to get a suitable composite index for ICT which has three proxies used in the study. The PCA is a typical statistical approach for reducing a larger collection of correlated variables into a smaller number of uncorrelated variables known as principal components, which account for the majority of the variance in the original data set [17], [23-24]. The PCA should be used if the Eigenvalue of the various components is equal to or greater than one.

The dependent variable is the sustainable development index (SDI) sourced from Hickel 2020.

The SDI is formulated as shown in (1):

$$SDI_{it} = \frac{HDI_{it}}{EII_{it}} \quad (1)$$

Where:

(SDI_{it})= Sustainable development index

(HDI_{it})= Human development index

(EII_{it})= Ecological impact index

The model specifies a direct function as shown in (2)

$$SDI = f(ICT, HC, X) \quad (2)$$

The model is further specified as:

$$SDI_{it} = \varphi_0 + \varphi_1 ICT_{it} + \varphi_2 HC_{it} + \varphi_n X'_{it} + \varepsilon_{it} \quad (3)$$

φ_0 is the constant term; φ_1- φ_n are the coefficient; i =1, 2, 3…, N and it represents the 41 countries (cross-sectional dimension); t =1, 2, 3, …, T. It represents the time dimension (22 years), ε represents the error term. The variables used in this study are presented in Table 1.

Table 1. Variable Measurement and *A priori* Expectations

S/N	Variables	Expected Sign	Source
1	Sustainable development index (SDI)	NA	(Hickel, 2020)
2	ICT adoption index (ICT)	+	Researcher's computation by using PCA
2.1	Mobile telephone subscribers (MTS)	+	WDI (2022)
2.2	Fixed telephone subscribers (FTS)	+	WDI (2022)
2.3	Internet access (INTACC)	+	WDI (2022)
3	Human Capital Index (HC)	+	Penn World Table 10.0
4	Foreign Direct Investment (FDI)	+/-	WDI (2022)
5	Population (POP)	+	WDI (2022)
6	Trade (TRD)	+	WDI (2022)

Source: Author's Compilation, 2024

B. Estimation Techniques

This study employs the Generalised Method of Moments (GMM) as the main estimation technique. Pooled ordinary least squares (POLS), the fixed effect, and the random effect are the baseline estimations. The POLS approach has gained popularity among researchers, and it has been widely employed in recent studies. Among the researchers who have recently employed its use include, [25], [26]. POLS estimation pools all data observation across different times and sections.

The generalised model is denoted in (4) as follows:

$$Y_{it} = \alpha_i + \beta Z'_{it} + \partial_t + (\eta_i + \varepsilon_{it}) \quad (4)$$

where, Y_{it} is represents the dependent variable, in this case, the sustainable development index, α_i is the constant, $\beta Z'_{it}$ is the vector of all regression coefficients, ε_{it} is the unobserved error term, ∂_t denotes the unobserved time-dependent error term while η_i representing the unobserved country-specific effects.

The POLS model is specified in (5) as:

$$SDI_{it} = \alpha_i + \beta_1 ICT_{it} + \beta_2 HC_{it} + \beta_3 X'_{it} + \partial_t + (\eta_i + \varepsilon_{it}) \quad (5)$$

The fixed effect is another estimation technique that shall be explored in the study. Intercepts in the fixed effect (FE) model are cross-section specific (in this case, they differ from country to country), although they may or may not change over time as a result of the model's assumptions. As a result of the possibility that every cross-sectional unit possesses some qualities or characteristics, the fixed-effect model helps account for the effect of country heterogeneity. The fixed effect method accounts for all of the time-constant, unobserved factors that have an impact on the dependent variable (sustainable development). η_i which is constant over time will have its effect differenced out to remove the country-specific effects η_i by transformation.

In cases where the number of counties exceeds the time period (N > T), as is the case with this research, the Generalized Method of Moment (GMM) estimator can be an appropriate estimation technique [27]. A Generalized Method of Moments (GMM) model is a statistical model that aims to estimate the parameters of a model by minimizing the difference between the sample moments and the corresponding population moments.

$$SDI_{it} = SDI_{it-1} + \varphi X'_{it} + \eta_i + \partial_t + \varepsilon_{it} \quad (6)$$

Where:

SDI_{it-1} is the lag of the dependent variable (sustainable development)

IV. Result and Discussion

This section presents and discusses the results from the various data analyses performed in this study.

A. ICT index using PCA

To measure ICT, a composite index for information and communication technology will be created using PCA and the eigenvalues are reported in Table 2.

Table 2: Principal Components Eigen Value Estimates

Component	PCM 1	PCM 2	PCM 3
Eigenvalue	2.11	0.72	0.17
Difference	1.40	0.55	-

Source: Author's Computation, 2024

In agreement with [28] and as postulated by [29], some criteria must be available before PCA can be used. Prominent among these criteria is that the value of the component must be greater than one. Only component one meets the requirement by [29] for retaining components and is retained in this study. The eigenvalue of component 1 is greater than one while component 2 and component 3 do not meet this requirement.

B. Baseline Estimation

Table 3 and Table 4 present the baseline estimation results for pooled ordinary least squares, the fixed effect and random effect estimations in SSA. The result indicates both positive and negative impacts on SDI contingent on the analysis used. However, this result is not discussed here as this estimation technique does not control for certain biases and is limited due to issues such as endogeneity, heteroscedasticity and serial correlation among others.

Table 3: Pooled OLS results for Full and Sub-Sample (Dependent Variable: SDI)

Variables	(1) CAC	(2) EAC	(3) SAC	(4) WAC	(5) SSA
ICT	0.054***	0.064***	0.030***	0.028***	0.035***
	(6.69)	(12.77)	(4.50)	(13.13)	(12.24)
HC	0.134***	-0.008	-0.172***	0.166***	0.073***
	(5.97)	(-0.68)	(-8.63)	(22.72)	(10.89)
FDI	-0.002***	-0.005***	0.008***	-0.000	-0.001***
	(-3.50)	(-7.11)	(03.50)	(-0.28)	(-2.95)
POP	0.012**	0.019***	0.029***	0.005***	0.009***
	(2.44)	(4.14)	(5.32)	(4.35)	(4.78)
TRADE	0.001***	0.002***	-0.001***	0.000***	0.000***
	(4.64)	(6.76)	(-5.96)	(2.66)	(4.40)
Constant	0.063	0.155*	0.602***	0.124***	0.215***
	(0.59)	(1.91)	(5.62)	(5.82)	(6.52)
Observations	132	230	102	262	726
R^2	0.76	0.63	0.64	0.86	0.48

***, **, * are statistically significant at 1%, 5% and 10% significance level respectively. T-statistics are in parentheses (). SSA is the full sample while the sub-region sample is divided into CAC, EAC, SAC and WAC. Source: Author's Computation, 2024

Table 4: Random Effect (RE) and Fixed Effect (FE) Results

RE	FE		Panel B (FE)			
Panel A(SSA)			CAC	EAC	SAC	WAC
0.016***	-0.002	ICT	0.001	-0.007	0.031***	0.0122***
(8.75)	(-0.85)		(0.003)	(0.005)	(0.008)	(0.002)
0.0854***	0.035***	HC	-0.076***	0.077	0.043*	0.0401*
(8.66)	(3.19)		(0.013)	(0.024)	(0.025)	(0.017)
0.0003	0.0004*	FDI	-0.0002	0.000	-0.001	0.001***
(1.42)	(1.92)		(0.000)	(0.000)	(0.002)	(0.000)
0.075***	0.229***	POP	0.264***	0.236	-.001***	0.151***
(13.3)	(22.61)		(.0010)	(0.021)	(0.000)	(0.0127)
1.21e-05	-0.0001*	TRADE	-0.0000	0.000	-.355***	0.000
(0.16)	(-1.74)		(.0000)	(0.000)	(.096)	(0.000)
-0.852***	-3.228***	Constant	-3.589***	-3.576	5.907***	-1.998***
(-9.37)	(-20.39)		(0.160)	0.333	(1.437)	(0.193)
726	726	Obs.	132	230	102	262
0.61	0.93	R^2	0.95	0.78	0.42	0.90

***, **, * are statistically significant at 1 per cent, 5 per cent and 10 per cent significance level respectively. T-statistics are in parentheses ( ). Source: Author's Computation, 2024

C. Generalized Method of Moments (GMM)

Estimating parameters from economic data is often a challenging task due to the complexity and heterogeneity of the underlying models. One widely used method for addressing these issues is the Generalized Method of Moments (GMM), which relies on instrumental variables and moment conditions to obtain consistent and efficient estimates. In this study, the GMM is applied to estimate the parameters of the economic model based on the sample data. The difference Generalized Method of moment developed by [30] is used to estimate the model while controlling for the problem of endogeneity

Table 5 presents the differences GMM result using the sustainable development index as the dependent variable. The result indicated that ICT has a positive and statistically significant impact on sustainable development at the 1 per cent level of significance in both the one-step and two-step estimators. The result shows that human capital is statistically significant at 1 per cent significance levels. Both the one-step and two-step difference GMM estimators show that it has a negative effect on sustainable development. This implies that a change in human capital by one unit will reduce sustainable development by 0.0945 and 0.105 using the one-step and two-step difference GMM estimates respectively.

For the control variable, FDI TRADE and POP were all statistically significant, but at different levels. FDI and POP are both highly significant at the 1% level, except for the one-step difference estimator, which found FDI to be insignificant. In contrast, TRADE was found to be statistically significant at the 10% level. FDI and POP have a positive influence on sustainable development, whereas trade has a negative association with the sustainable development index. The absence of second-order autocorrelation as indicated by the non-significance of the AR (2) coefficients in the specification diagnostics is a positive sign for the validity of the model. It implies that the errors in the model are not systematically related to their past values, which is an important assumption of the GMM. Furthermore, the outcome of the Hansen statistic suggests that the instrument sets are not over-identified, which is another crucial assumption of the GMM.

Table 5: Difference GMM

Variables	One-Step	Two-Step
L.SDI	0.387***	0.367***
	(3.32)	(5.26)
ICT	0.0159***	0.0140***
	(6.67)	(4.44)
HC	-0.0945***	-0.105***
	(-6.48)	(-3.31)
FDI	0.000103	0.000115***
	(1.60)	(5.95)
TRADE	-6.34e-05*	-3.20e-05*
	(-1.88)	(-1.74)
POP	0.142***	0.163***
	(5.05)	(5.61)
Observations	659	659
No. of Groups	34	34
No. of Instruments	23	23
AR(1)	0.611	0.750
AR(2)	0.070	0.128
Sargan Test	0.000	0.000
Hansen Test	-	0.309

****, **, * are statistically significant at 1 per cent, 5 per cent and 10 per cent significance level respectively. T-statistics are in parentheses ( ).*

Source: Author's Computation,2024.

D. Discussion of Results

The findings of the study suggest that ICT can be an effective tool for promoting sustainable development in Sub-Saharan Africa. The positive impact of ICT on sustainable development implies that countries in SSA should prioritize the adoption and use of ICT to enhance their competitiveness and economic growth. At the regional level, the study found that the ICT indicator was statistically significant and positively associated with sustainable development. This means that the more countries in the region adopt and utilize ICTs, the more likely they are to achieve sustainable development. However, it is important to note that the effectiveness of ICT in promoting sustainable development may vary across different sectors and sub-regions within SSA. Therefore, it is crucial to tailor ICT interventions to specific needs to achieve the desired impact. The findings are in line with the study of [20], [31].

The study also discovered that human capital exerts a negative but significant impact on sustainable development in SSA. This suggests that the development of human capital in SSA can undermine sustainable development. These findings imply that sustainable development efforts in SSA may be hampered due to a lack of adequate knowledge and skills required to address the environmental, social, and economic challenges of sustainable development. Furthermore, in developing countries, workers tend to have lower-quality education and health, which may limit the impact of human capital on economic growth. Therefore, these countries must invest in human capital development and allocate government funds towards improving human capital to foster sustainable development [32]. This finding is consistent with [33-35], who found human capital to have a negative impact on sustainable development.

Furthermore, the extent of this contribution varies by region. The study found that human capital in Central Africa (CAC) and West Africa (WAC) had a positive impact on sustainable development, while human capital in East Africa (EAS) and Southern Africa (SAC) had a negative impact. This suggests that the development of human capital alone may not be enough to ensure sustainable development, and other factors such as natural resources, governance, and social and economic policies may also play a role.

V. Conclusion and Policy Implication

The study investigates the effect of ICT and human capital on sustainable development in SSA. The findings indicate that ICT is an effective tool for promoting sustainable development in SSA. The study, however, found that human capital stifles sustainable development in the region which may be due to human capital voids, or the prevalence of very low levels of skills among individuals in SSA. The study therefore recommends the following: First, given that ICT (measured as mobile telephone subscribers, fixed telephone subscribers and Internet access) enhances sustainable development, governments in SSA should increase phone ownership (both

mobile and fixed) and expand broadband availability. Second, policymakers in SSA must see the development of human capital as an immediate policy priority. In particular, governments in SSA must increase investment to strengthen the quality of education and health which would enhance human capital in SSA. The government may then adopt the Private Public Partnership model to increase the pace of improving human capital.

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