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Poverty, ICT and Economic Growth in SADC Region: A Panel Cointegration Evaluation

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Abstract: Although there is a wealth of evidence on the relationship between economic growth and poverty or poverty and information and communication technology (ICT), there are few studies on the interaction between the three factors. The triangle relationship between poverty, information and communication technology, and economic growth in SADC were investigated in this study from 2005 to 2019. The research looked at how ICT and economic growth impact poverty in SADC countries, using the instruments of the Mean-Group FMOLS, Mean-Group DOLS, and Robustness Mean-Group Estimators in achieving its major objective. The principal component analysis was employed in generating a single index value for ICT and the data were subjected to relevant econometric tests to achieve robust results. Findings showed that all the variables exhibited poverty-reducing effects in SADC except inflation. Results confirm the existence of the "leapfrogging" hypothesis for the region. It is necessary to strengthen existing bilateral links among member nations of the area to maintain the benefits of ICT's poverty-reducing impacts, economic growth, financial development, and trade openness. As applicable in other advanced and some emerging economies, the digital competence of the region needs to be synchronized for effective ICT service delivery.

Keywords: SADC; ICT; poverty; economic growth

1. Introduction

In recent years past, Information and Communication Technology (ICT) has taken the center stage of global economic activities. Contesting the fact that it has turned the world into a global village is, to say the least. Apart from employment generation, its contributions to the GDP of countries in both the regional and country-specific terms had been quite overwhelming. Although the social and economic situations of countries within the SADC differ marginally, it is also important to state that the degree of ICT services usage depends on member states' economic power. While the argument on the relationship between poverty, ICT, and economic growth rates continues, we consider it sacrosanct to provide a deeper understanding of the extent to which ICT has contributed to economic growth and alleviate poverty with the SADC as an economic bloc

The idea of today's SADC was mooted at a summit in Windhoek, Namibia in 1992 when the heads of the frontline states (Angola, Botswana, Mozambique, Tanzania, and Zambia) (the original members) met to sign the Southern Africa Development Community (SADC) Declaration and Treaty to replace the Southern African Development Coordination Conference (SADCC). The driving spirit of the region was based on what they referred to as "Towards a Common Future" with their secretariat located at Gaborone in Botswana. As of today, there are sixteen-member countries (Angola, Botswana, Comoros, Democratic Republic of Congo, Eswatini, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, United Republic of Tanzania, Zambia, and Zimbabwe) following the admission of Comoros in 2017. The objectives of this economic bloc as contained in its article of formation are:

i. Development and economic progress; poverty reduction; raising the standard of living of Southern Africans and providing support to the socially disadvantaged through regional integration.
ii. to develop a set of shared political principles, systems, and institutions
iii. Peace and security promotion and defense
iv. promotion of self-sustaining development based on member states' interdependence and collective self-reliance
v. Complementarity between national and regional strategies and programs is achieved.
vi. Promotion and maximizing of productive employment and resources, effective environmental preservation, and building and consolidating the region's long-standing historical, social, and cultural affinities and links.

However, one method to achieve these lofty goals, particularly the first, is through ICT investment. As a result, member nations signed the Information and Communications Technology Declaration in 2001 to promote regional ICT policy and strategy. The treaty intends to promote sustainable economic development, technology, and the closing of the digital divide between the area and the rest of the world, among other things. and between as of 2018, the total GDP of the region accounted for 25.6% of Africa's GDP with an estimated value of US$721.3bn at an annual growth rate of 1.8%; with services (ICT inclusive) contributing 59.4%. The region occupies a land space of 556,781 km^2 with an average life span of 61 years. Since the global financial crisis of 2007–2009, the GDP growth rate of the region has been on a downward trend. For instance, the GDP reduced from 6.8% in 2007 to 0.2% in 2009 and went up to 4.5% in 2012, down again to 2.1% in 2017 and 1.2% in 2018 [1]. Accounting for the slow growth rate is a rising inflation rate, increasing government debts as well as low commodity prices. A close review of mobile phone users within the region shows that South Africa constitutes the highest number of usages. Within ten years, the number of mobile telephone users in South Africa increased from 33.96 m in 2005 to 87.99 as of 2015. Although with a smaller population, countries such as Eswatini, Comoros, and Seychelles have mobile phone users of 941,000; 424,786; and 148,244 respectively as of 2015. In terms of internet users and surprisingly, Seychelles recorded the highest percentage with 58.12 percent against South Africa's 51.91 percent as of 2015. At the lowest level of the ladder are the Democratic Republic of Congo (3.79%) and Madagascar (4.17%) during the same period [2]. Another challenge facing the region just as in other regions in sub-Sahara Africa is poverty. As reported in the [3], almost half of the population of the region survives on less than 1 US$ per day. To tackle poverty which has become an overarching priority in the region, the Regional Poverty Reduction Framework was to take effect in 2013. Other economic issues facing the region, like in other parts of Africa, include the creation of a climate conducive to regional integration, economic growth, poverty eradication, and the channeling of resources toward sustainable development. Another aspect of this study is to investigate the causal relationship between ICT and poverty reduction within the SADC region. However, there are two opposing views about this relationship. At the extreme are those who shared the view that ICT does not reduce poverty if it cannot provide for the basic needs of the poor [4]. Furthermore, it has been argued that only the rich people can afford the cost of procuring ICT and then enjoy the services while the downtrodden masses who can hardly afford a square meal per day cannot. Unfortunately, the low-income countries within the SADC account for over 60% of the total population of that region. Similarly, the study on whether there is any correlation between access to ICT and poverty in South Africa by [5] produced mixed results. It was observed in the study that areas with a high level of poverty are expected to experience low access to ICT services than those areas with a low poverty rate which are likely to enjoy more access to ICT.

In a textual analysis of policymakers in selected African countries appraising the nexus between ICT and poverty reduction, ref. [6] concluded that policies on ICT in Africa are being tailored toward empowering the poor. Furthermore, ref. [7] appraise the link between ICT and poverty reduction in Romania and confirmed the role of ICT in reducing

the poverty level of that country. On the proliferation of mobile phones, ref. [8] asserted that ICT innovation has become a major force to reckon with in the developmental process of any economy. On the other hand, ref. [9] submitted that despite the technological innovation from the socioeconomic context, opinions differ on the ICT-economic growth hypothesis. Further, studies such as [10,11] revealed a bidirectional relationship between ICT and economic growth while a unidirectional causality was established in the study by [12]. Regarding an Afrobarometer survey of 34 African countries, ref. [13] said that the much-celebrated achievements in the growth rate of Africa's economy have not reduced the continent's poverty rate nor improved the people's living standard. This opinion was corroborated by [14] in his submission that the potential for ICT explosion in sub-Saharan Africa might not be realized because of the dominance of foreign nationality at the expense of the rich cultural values and traditional institutions. Evidence abounds to show the relationship between economic growth and poverty or poverty and Information and Communication Technology (ICT) but studies on the nexus between these three variables are still scanty in development economic literature. Not only that, but different opinions also permeate the triangular relationships of these variables. Ref. [15] opined that ICTs' relevance transcends the creation of sources of income for the most disadvantaged people in society, the improvement in health and educational services, and the reduction in poverty level. Other researchers have also alluded to the benefits of ICT, especially in the areas of global integration, economic growth enhancement, provision of new opportunities for the people, and as an antidote to poverty alleviation [15–21] As pointed out [22], one key benefit of ICT in Africa is the ability to reduce and eradicate poverty.

In 2020 ICT accounted for half of the total GDP of the countries of the world. However, despite the appreciable and impressive achievements in terms of economic growth in the SADC region, poverty remains an issue in the region. Our pertinent research question centers on the ambivalence regarding the triangular relationship between ICT, economic growth, and poverty in the SADC region. Nonetheless, the dearth of strong empirical evidence about the triangular association between poverty, ICT, and economic growth, especially in the regional context remains unresolved by previous studies, necessitating further research interests. Furthermore, whether there is an existence of a "leapfrogging hypothesis" in the SADC is also an issue of debate amongst policymakers. Thus, our research questions were:

(i) What is the direction of causality among these variables [poverty, ICT, and economic growth]?
(ii) Is there a long-run effect of ICT and economic variables [economic growth, financial development, and trade openness] have poverty-reducing effects? and
(iii) Does the leapfrogging hypothesis exist in the SADC region?

2. Related Review of Literature: [Poverty, ICT, and Economic Growth]

The relationship between ICT and economic growth, on the one hand, and ICT and poverty reduction, on the other hand, has been verified by empirical investigations. Others in the economic literature have looked into the relationship between economic growth and poverty eradication. The nexus between poverty and economic growth, on the other hand, is the core of the relationship between poverty and ICT. The understanding here is that ICT evolution impacts poverty positively through economic growth [23–25]. As early as 2003 when researchers predicted that ICT was fast becoming a vital engine for global economic advancement, its link with economic development and poverty reduction was described as an extraordinary venture [26,27]. Other frontline apostles of the nexus between ICT and poverty alleviation include [28,29]. According to [28], if the Millennium Development Goals are to be taken seriously, the contribution of ICT to poverty reduction should be a major issue in the international debate. However, other leftists believe that ICT constitutes additional expenses to the poor and therefore, adds to their level of poverty [30]. They found a direct relationship between a low level of poverty and higher usage of ICT and vice versa [16,31]. Ref. [15] employed Eurostat data from 2014–2017 and applied the

Partial-Least Square for European Union countries on the relationship between investment in ICT and sustainable economic development. One of the study's primary findings is that ICT has a positive link with GDP in the European countries studied. Ref. [18] investigated the relationship between ICT, foreign direct investment, and economic growth for the BRICS economies using OLS with fixed effects, the FMOLS, the DOLS, and the group-mean estimator techniques on data from 2000 to 2014. They discovered that ICT positively aided economic growth for the BRICS economies. However, depending on their level of ICT usage, this link differs from country to country. Ref. [17] used the Autoregressive Distributed Lag approach to examine the relationship between ICT and economic growth in India. They found that ICT had a beneficial impact on the country's economic growth.

Although [32]'s submission on the effects of ICT on economic growth in European Union countries supported theoretical and empirical findings that ICT infrastructure is a major driver of economic growth in EU countries, it was concluded that the degree of the effects varies among member countries depending on the technology under consideration. In a previous study by [10] on the causal link between ICT (telecom) and economic growth in EU nations, it was discovered that these variables have a bidirectional relationship in countries with high incomes but a unidirectional association in those with lower incomes. They concluded that ICT is not a significant determinant of economic growth in developing countries. This implies that opinions on the impact of ICT on economic growth are still divided. Ref. [33] found that improvements in ICT had a statistically favorable link with economic growth in their investigation of the impacts of ICT on economic growth in 54 African countries. The results of the estimated pooled OLS and GMM models backed up the "leapfrogging" hypothesis, indicating that Africa can use ICT to skip developmental phases at both the regional and continental levels. Similarly, [34] found that ICT increases growth at both the global and regional levels in their study of the influence of ICT on economic growth. Statistically, the leapfrog hypothesis concerning the relationship between ICT and economic growth was equally verified by the study, which used the OLS, Pooled OLS, Two-Staged Least Squares (2SLS), and GMM approaches. The above viewpoints differ from [35] findings, which disproved the leapfrogging hypothesis. Further investigation into the relationship between ICT and economic growth in Sub-Saharan Africa has yielded varied results [32,36,37]. In their study, Ref. [37] found that ICT proxies such as fixed telephone lines, mobile phones, and internet usage have a positive and statistically linear effect on economic growth in SSA, but the effect of nonlinear statistical analysis shows that these proxies slow down the economic growth of the region. Ref. [38] looked at population growth, GDP per capita, ICT (internet users), and inflation as economic drivers in Nigeria, and found that increases in inflation, GDP per capita, and population negatively affect ICT, and so negatively affect Nigeria's economic growth. Ref. [19] study of the influence of ICT diffusion on economic growth in 45 developing Middle East, North Africa (NEMA) and SSA nations found that mobile phones, internet usage, and broadband adoption were the region's key economic drivers. Only the fixed telephone element of the examined ICT variables demonstrated a negative link with economic growth within the research regions when using a two-step General Moment Method for data from 2007 to 2016. As a result, many low-income earners in the tested nations do not profit from the benefits of ICT. The interchangeability of fixed and mobile telephones could be one cause for this. This is a mixed result that requires further investigation to see how it applies to SADC member countries. While ref. [39] showed that ICT does not contribute much to economic growth in Japan, Ref. [40] revealed a low contribution from ICT to growth in Latin America. Examining the causal relationship between ICT and economic growth in ten Latin American countries, Ref. [11] revealed that a two-way causality exists in eight out of the ten countries under review. However, it was acknowledged that differences in the measurement of ICT could be the cause of the different results. Development in ICT cum financial inclusion goes hand in hand as the relationship between these variables is a symbiotic one [41]. This suggests ICT as a requirement for financial inclusion that enhances sophisticated products that will ultimately support the expansion of the ICT sector. Another dimension to the

ICT-economic growth nexus tagged "ICT-finance-growth" relationship is the argument supporting the influence of financial development. The panel analysis of [42] latest study on ICT spread and the finance-growth nexus in ECOWAS demonstrates that only the coupling of financial development with ICT has a major impact on economic growth. Financial development almost always has an indirect impact on economic growth through interactions with ICT. This was in contrast to a previous study by [43], which found a granger causality between ICT penetration, financial development, and economic growth in both the short and long run. Overall, governments in the regions should increase their ICT investment if and only if the desired influence of financial development on economic growth is to be felt in the regions. In continuation with the ICT-growth-poverty paradox is the relevance of human and infrastructural development in SADC. Ref. [44] emphasized that economic growth in SADC requires investment in infrastructural facilities such as ICT and human capital development. As against the use of the static panel technique, the study employed dynamic panel data and shows that infrastructural development affects economic growth positively. As revealed in the study, the region has challenges in the areas of power supply, good roads network, inadequate supply of clean water, and high cost of ICT acquisition; all of which have been eroding the economic growth aspiration of the region and thereby reducing the standard of living of the people and contributing to their poverty level. In the same spirit, Ref. [45] applied regression analysis to examine the link between ICT: mobile, internet, telephone, and human development in SADC and revealed that the usage of these components exerts positively on human development.

Further, Refs. [46,47] confirmed the leapfrogging hypothesis in their various studies in that ICT affects economic growth positively in developed and developing economies while [35] arrived at a contrary conclusion. This is an indication that opinions differ on the effects of ICT on economic growth. Other studies such as [34]) also showed that the effects of ICT on economic growth in developing economies are stronger than in developed countries. This was in tandem with the findings of [21],) where financial inclusion was seen as an instrument of economic growth and poverty alleviation.

The above review shows that research into the causality between poverty, ICT, and economic growth has not received much attention in the literature and hence the need to bring the relationship to the fore. The integration between these three concepts is expected to result in a new paradigm and create opportunities for sustainable growth and recovery from the current economic challenges facing the SADC region.

3. Data and Methodology

To achieve our research aim, this study employed the instruments of the Mean-Group FMOLS, Mean-Group DOLS, and Robustness Mean-Group Estimators in addressing these identified research areas in 16 SADC countries from the period 2005-to 2018. This period coincides with the evolution of ICT and the fourth economic revolution that was characterized by the digital explosion.

3.1. Description of Variables and Data

The analysis is the link between poverty, ICT, and economic growth in 16 SADC countries from 2005 to 2019. We sourced data mainly from the World Bank-World Development Indicator (WDI) and SADC statistical yearbook. It is a panel data study with financial deepening, trade openness, and inflation as additional explanatory variables.

3.1.1. Measurement and Definitions of Variables

1. Poverty (POV_{it}): We measure poverty using the household final consumption expenditure per capita growth (annual percentage). This measurement is preferred especially against the popular headcount ratio because of data availability (See [25,48]). Apart from the fact that this method of measurement had been used extensively in the literature [23,33], it is often favored in the sense that required information on the

poverty gap and incidence of poverty, among others, may not be readily available since we are dealing with Less Developed and Developing countries.

2. ICT (ICT$_{it}$): Our measurement of ICT for this study consists of multiple indexes of the following three variables: fixed telephone (measured as fixed telephone subscription per 100 users), mobile line telephone subscribers (measured as mobile cellular subscription per 100 inhabitants), and internet users (measured as secured internet server per 1,000,000 inhabitants). This had been extensively used in the literature. (For instance, see [19,42]). However, the study adopts the Principal Component Analysis (PCA) in arriving at a single composite index value for sub-variables of the ICT (see [18,42,43]). This approach has the benefits of harmonizing ICT components into a single linear form [46,47].

3. Economic growth (GDPgr$_{it}$): Economic growth is represented by the growth rate of GDP per capita, and it is measured at (constant 2010 US$) by the United Nations and the World Bank's measurement of economic growth [49–52].

We also include some variables as a control for the study. These are: (i). Financial development, (measured by domestic credit to the private sector); (ii) Trade Openness (measured as trade percentage of the GDP) and (iii) Inflation (measured by consumer price index-2010 = 100). The countries in SADC are very interconnected, interdependent, and interrelated and this informed our decision to include trade openness as an additional control variable. Ref. [53] demonstrated that the effect of financial development on economic growth at a lower level of inflation is greater than at a higher level of inflation. This suggests that financial development and inflation jointly affect growth even though at different frequencies.

Table 1 presents the summary of the variables and their measurement.

Table 1. Summary of the measurement of variables and sources of data.

Variables	Description/Measurement	Sources of Data
Poverty	Household final consumption expenditure per capita growth (annual %)	WD Indicators
Information and Communication Technology (ICT Index Value): Mobile Cellular Subscription (MCS). Fixed Telephone Subscription (FTS). Secured Internet Services (SIS)	This is the index value generated through PCA from MCS, FTS, and SIS. This is mobile cellular subscribers per 100 inhabitants. This is FTS per 100 persons. This secured internet provider per a million persons.	WD Indicators
Economic Growth (ECO)	This is the GDP growth rate percentage (in constant US$).	WD Indicators
Financial Development (FD)	Domestic credit to the private sector as a ratio of GDP.	WD Indicators
Trade Openness (TOP)	Trade percentage of the GDP.	WD Indicators
Inflation (INF)	Consumer price index. (2010 = 100).	WD Indicators

3.1.2. Analytical Technique

Following [21,54,55], the triangular relationship between poverty, economic growth, and information and communication technology commences as follows:

$$POV_{it} = (ICT_{it}, ECO_{it}) \tag{1}$$

where *POV* is poverty, *ICT* denotes information and communication technology while *ECO* represents economic growth,

Expressing Equation (1) in econometric form becomes:

$$POV_{it} = \alpha_i + \beta ICT_{it} + \phi ECO_{it} + \varphi Z_{it} + \varepsilon_{it} \tag{2}$$

Here, *POV$_{it}$* denotes poverty, α denotes country-specific intercept, *ICT$_{it}$* is information and communication technology, *ECO$_{it}$* denotes economic growth, and *Z$_{it}$* is a vector of other

exogenous variables that affect poverty i.e., financial development (*FD*), trade openness (*TOP*), macroeconomic uncertainty proxied by inflation rate (*INF*) (see [42,53,54]) while *i* denotes the countries, 1, 2, . . . , *N*; *t* is the time period, 1, 2, . . . ,T and ε_{it} a time-varying error term. The parameters to be estimated are denoted by β, ϕ and φ. The a priori outcomes of these parameters are $\beta > 0$, suggesting that the effect of ICT on poverty is expected to be positive; $\phi > 0$, indicating the poverty-induced effect of economic growth and $\varphi_i > 0$, showing the positive effects of other exogenous variables except inflation which is expected to exert a negative impact on the core variables.

Principal Component Analysis (PCA): The study employs the principal component analysis (PCA) to generate the ICT index value from mobile cellular subscription (MCS) per 100 people, fixed telephone subscription (FTS) per 100 people, and secure internet server (SIS) per 1,000,000 people [18,42]. Principally, the PCA is an approach that transforms a set of series into a smaller composite index. Steps involved in the computation of PCA have been well documented in extant studies [18,43,50,56]. We decomposed the MCS, FTS, and SIS as a weighted average called ICT value.

Cross-sectional dependence: In panel data analysis, the usual assumption is that disturbances in panel models are cross-sectionally independent, especially when a large cross-section (N) is involved [55]. Meanwhile, in reality, the cross-sectional dependence in panel analysis appears to be the rule of the game, thus it cannot be underestimated [57,58]. Therefore, assuming cross-section independence may pose serious problems that may result in estimator inefficiency and invalid test estimates. Pesaran's cross-sectional dependence (CSD) test is to detect potential CSD by detecting the systematic residual correlation across different units through pairwise correlation coefficients between regressors or residual series [58]. Following [59], given a panel data of the following:

$$y_{it} = \alpha_i + \beta^1 x_{it} + \varepsilon_{it} \tag{3}$$

where $i = 1, 2, \ldots, N$ and $t = 1, 2, \ldots, T$, and *X* is an n-dimensional column vector of regressors. The null hypothesis is that there is no cross-section dependence, and it is explicitly stated as: $H_0 : \rho_{ij} = Corr(\varepsilon_{it}, \varepsilon_{jt}) = 0$ for $i \neq j$. Where ρ_{ij} is the product-moment correlation coefficients of the residuals for a balanced panel sample expressed in Equation (4) as:

$$\hat{\rho}_{ij} = \frac{\sum\limits_{t \in (i,j)}^{-kj} \widehat{u_{it}} \widehat{u_{jt}}}{\left(\sum\limits_{t \in (i,j)}^{T_{kj}} \widehat{u_{it}^2} \right)^{1/2} \left(\sum\limits_{t \in (i,j)}^{T_{kj}} \widehat{u_{jt}^2} \right)^{1/2}} \tag{4}$$

Thus, the cross-section dependence test as proposed by Pesaran obtained a statistic based on the average of the pairwise product-moment correlation coefficients, $\widehat{\rho_{ij}}$ as follows:

$$CD_p = \sqrt{\frac{2}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T_{ij} \widehat{\rho_{ij}} \to N(0,1) \tag{5}$$

Given a relatively small T as the case of this study, the asymptotically standard normal Pesaran *CD* test is represented in Equation (5). The decision rule here is that if the *t*-statistic value is significant, the Pesaran *CD* test rejects the null hypothesis of no cross-section dependence and concludes that there is cross-section dependence in the panel data.

3.1.3. Unit Root Tests

In panel data, some unit root tests are applicable to homogeneous panels while others apply to heterogeneous panels. Put differently, panel unit root tests are further classified as first-generation and second-generation panel unit root tests. The first-generation unit root tests apply to homogeneous panels while the second-generation unit root tests apply to heterogeneous panels (these tests allow the unit root processes to vary among the cross-

section units). Homogeneous panels are assumed to have common unit root processes for all the cross-section units, examples include the Levin-Lin-Chu (LLC) test, Breitung test, and Hadri test for this study. Thus, the null and alternate hypotheses for homogeneous unit root tests (except the Hadri test as an extension of the KPSS test to panel data which reverses the order of the hypotheses) are set as:

H$_0$: $\rho = 1$ *(Indicates the presence of unit root).*

H$_1$: $\rho < 1$ *for all i (i.e., stationary for all cross-section units).*

Heterogeneous panels are assumed to have, possibly different unit root processes, examples of which include Im, Pesaran & Shin test (IPS), Maddala-Wu test, and Choi test. The null and alternate hypotheses for heterogeneous panels are set as:

H$_0$: $\rho = 1$ *(Indicates the presence of unit root).*

H$_1$: $\rho < 1$ *for some i (i.e., stationary for some cross-section units and non-stationary for others).*

However, a problem with heterogeneous panel unit root tests is that it is difficult to identify which cross-section unit (country) parades non-stationarity, and which one exhibits stationarity. In addition to the stated heterogeneous unit root tests, cross-sectionally augmented IPS (CIPS) suggested by [60] is employed to deal with the CSD. The test permits for correlation among error terms across units to address the potential spurious inferences [58].

Westerlund Cointegration Test: To check for the long-run relationship between poverty, ICT, economic growth, financial development, trade openness, and inflation, this study utilizes the [60] panel cointegration test. It does not allow for an equal length of time series [61]. This approach is not only reliable for cross-sectional time-series studies such as the case at hand, but its outcomes are also robust and reliable as a cointegration technique [18]. The [60] approach is divided into segments: the Group statistics (G$_\tau$ and G$_\alpha$) and the Panel statistics (P$_\tau$ and P$_\alpha$) based on ECM. The hypotheses of the group statistics are stated thus:

Null: H$_0$: *There is evidence of no cointegration in at least one of the cross-section units.*

Alternative: H$_1$: *There is cointegration in at least one of the cross-section units.*

That is, H^G:$\lambda_i{}^K = 0$ for all *i* that is tested as against H$_i{}^G$:$\lambda_i{}^K < 0$ for at least *i*.

In summary, the two grouped-mean tests have the alternative hypotheses of cointegration in at least one cross-section unit.

For the panel statistics tests:

Null: Adjustment to equilibrium is homogeneous across cross-section units.

Alternative: Evidence of cointegration.

The assumption here is that $\lambda_i{}^K = \lambda^K$ for all *i*,

H$_0{}^P = \lambda_i{}^K = 0$ as against H$_i{}^P$:$\lambda_i{}^K < 0$.

Fully Modifies OLS and Dynamic OLS Tests:

The next step is the estimation of the coefficients of the long-run association, using the FMOLS and DOLS approaches. The choice of these methods was informed by the fact that they give standard error estimates that are consistent and make them robust for statistical inferences [43]. Consider the following model:

$$\text{POV}_{i,t} = \alpha_i + \varkappa_{i,t}\beta + u_{i,t}$$

where:

i = number of cross-sectional units; *t* = time; α_i is the country-specific effects, $\text{POV}_{i,t}$ is poverty, β represents the vector parameter (k,1) and $u_{i,t}$ stands for the stationary disturbance terms.

It is assumed that:

(i) $\varkappa_{i,t}$ = (k,1) vector of the explanatory variables;
(ii) $\varkappa_{i,t}$ are I(1) for the cross section units such that
(iii) $\varkappa_{i,t} = \varkappa_{i,t-1} + \varepsilon_{i,t}$

After correcting for the serial correlation and accounting for endogeneity in the OLS estimator, the FMOLS is finally specified as:

$$\hat{\beta}_{FM} = \left\{ \sum_{t-1}^{N} \sum_{t=1}^{T} (X_{i,t} - \overline{X}_i)^2 \right\}^{-1} \sum_{t=1}^{N} \left\{ \sum_{i=1}^{T} (X_{i,t} - \overline{X}) P\hat{O}V_{i,t}^* - T\hat{\delta}_{\varepsilon\mu} \right\} \dots\dots$$

where:

$P\hat{O}V_{i,t}^*$ signifies the transformed variable for $POV_{i,t}$ that accounts for correction of endogeneity and $\hat{\delta}_{\varepsilon\mu}$ is the term for serial correlation correction.

The DOLS regression estimation is also specified as:

$$POV_{i,t} = \alpha_i + x_{i,t}\beta + \sum_{k=-p_1}^{p_2} \delta_k \Delta POV_{i,t-k} + \sum_{k=-q_1}^{q_2} \lambda_{ik} \Delta x_{i,t-k} + \mu_{i,t} \dots$$

where:

α_i is the country-specific effect and λ_{ik} is a lead coefficient. $\mu_{i,t}$ is the error term.

Pairwise Dumitrescu-Hurlin (D-H) Panel Causality Test: A further step in this study was to examine the causality among the variables using the D-H causality test). The test is formulated as follows:

$$Y_{it} \text{ and } X_{i,t} = \alpha_i + \sum_{k=1}^{k} \lambda_{ik} Y_{i,t-k} + \sum_{k-1}^{k} \beta_{ik} X_{i,t-1} + \varepsilon_{it} \dots$$

where:

Y_{it} and X_{it} represent the observable stationarity variables while a uniform lag order (K) is assumed with stable panel data. λ_i is the autoregressive parameter and β_i stands for the coefficient of the regression.

The D-H test is appropriate whether T > N or N > T. Although this technique assumes no cross-sectional dependency, yet, it generates robust, strong, and reliable estimates [55] for both balanced and heterogeneous panels.

In a variety of studies, the causality between poverty and ICT has been justified just as the correlation between economic growth and ICT had been established. Furthermore, other studies have shown the relationship between ICT and economic growth for low, medium, and high-income countries and established that causality exists between these two variables. The studies show that ICT as a leapfrogging factor in the attainment of the economic developmental status of the developed economies such that a bi-directional relationship between ICT and GDP was proved. The expanded Neoclassical growth model explains how inputs of production function which include labour and technological advancement increase output. In addition, it demonstrates how technology, labor, and capital could all work together to lessen poverty in an economy. Other studies such as [4,19,43], further confirmed that long-run and positive correlation exists between ICT and economic growth. The advent and increase in the use of ICT, which has reduced the world into a global village, was confirmed using econometric methods which include panel quantile regression and the control of fixed effects by [4] as having positive causation effects on economic growth.

Also, [50] confirmed a bi-directional association between energy consumption represented by ICT and economic growth in investigating the validity of the symbolic transfer entropy test between 1970 and 2015 in OECD countries. By implication, ICT caused economic growth and vice versa in both studies. Mixed causalities were observed by [37] for 32 sub-Saharan African countries in a study on the effect of financial development and economic growth in Africa. In the study, 24 out of these countries exhibited no causality while 8 revealed causalities running from financial sector development to economic growth. Nonetheless, the poverty-economic growth nexus examined by several other scholars indicates the existence of a unidirectional association that runs from poverty reduction as represented by employment generation to GDP such that increasing the rate of employment enhances productivity. The main finding in the causality relationship between economic growth and infrastructural development for top ranking African countries by showed a

unidirectional effect that runs from infrastructural facilities such as ICT to economic growth. The study further argued that the positive association between ICT and GDP can address the problem of poverty in Africa.

3.2. Study Limitations

One major limitation of this study is the missing out on some digital technologies in the composition of ICT components due to data availability challenges. These include broadband subscription, mobile web services, artificial intelligence, e-commerce, social media, and smart device application which are all products of the ICT revolution. They contribute immensely to human awareness, innovation, and economic growth and therefore cannot be underestimated. In addition, the issue of investment which according to the neoclassical and endogenous growth models is a major determinant of economic growth. Subsequent studies should therefore endeavor to incorporate these variables to give a broader understanding of the impact of ICT on economic growth within the SADC economic region.

4. Findings and Discussions

The issue of cross-sectional dependence has become an issue in panel data analysis. The Pesaran CSD was employed in this study to account for the associated shortcomings that may result from cross-sectional reliance between the countries under consideration.

Table 1 above presents the result of the Pesaran cross-dependence test which shows that the null hypothesis of the presence of cross-sectional dependence is rejected at a 1% significance level. The presence of cross-sectional reliance suggests that variations in variables between the countries under consideration can influence one another.

Panel Unit Root Tests: To account for the presence of unit root in the panel data, and determine the order of integration, the Levin-Lin and Chu (LLC) and Breitung panel unit root tests were performed on the series. It is evident from Table 2 that all the variables: poverty (POV), information and communication technology (ICT), economic growth (ECO), financial development (FD), trade openness (TOP) and inflation (INF) were made stationary at their first difference I(1).

Table 2. Pesaran cross-section dependence test.

Variable	Pesaran LM Test	Pesaran Cross-Dependence
POV	56.12328 ***	5.66431 ***
ICT	206.8047 ***	82.30556 ***
ECO	39.20150 ***	1.50041 ***
FD	186.5012 ***	78.00327 ***
TOP	208.0145 ***	82.52043 ***
INF	73.3157 ***	56.25310 ***

***, represent the level of significance at 1%.

Table 3 above shows the unit root tests. These outcomes justified the use of [60] cointegration test which equally suggests that long-run association exists between the variables.

Table 3. Panel Unit Root Tests.

Test\\ Variable	IPS		Breitung	
	I(0)	I(1)	I(0)	I(1)
POV	−2.7273	−3.6221 ***	−2.0644	−4.6076 ***
ICT	1.2022	−4.2053 ***	0.2431	−2.8850 ***
ECO	2.6487	−0.5710 **	−1.8483	−5.0640 ***
FD	−2.7641	−4.8112 ***	0.3843	0.0248 **
TOP	−0.0840	−3.2276 ***	0.2560	−2.3663 ***
INF	1.7016	−1.1678 ***	0.4628	−1.0608 ***

*** and **, signify a rejection of null hypotheses at 1% and 5% error levels in that order respectively.

The lags and leads were automatically selected by AIC criterion.

Based on the results of the G_τ, P_τ and P_α statistics presented in Table 4, the null hypotheses of no cointegration are rejected at $p < 0.01$ level of significance.

Table 4. Westerlund Panel Cointegration Test.

Test	Test Value	Z-Value	*p*-Value	Robust *p*-Value
G_τ	−1.556 ***	−0.383	0.651	0.649
G_α	−0.278	1.558	0.884	0.803
P_τ	−10.040 ***	−4.801	0.606	0.664
P_α	−1.401 ***	0.014	0.785	0.798

*** indicates level of significance.

The Mean-Group FMOLS, Mean-Group DOLS and Robustness Mean-Group Estimators

Table 5 presents the results of the three estimation models employed in this study: The Mean-Group FMOLS, Mean-Group DOLS and Robustness Mean-Group Estimators. From these results, the two core variables namely information and communication technology (ICT) and economic growth (GDPGR) were positive and statistically significant at 1% level. The coefficients of the two variables indicate that 1% increase in ICT and economic growth will have corresponding effects on the consumption pattern of the people and by implication, cause poverty to reduce. In a way, there is evidence supporting that the leapfrogging argument holds for the SADC region [33,46,47]. These findings concur with extant literature on the positive effects of ICT on poverty reduction on one hand [7,8,21,23,32] and economic growth and poverty on the other hand [12,19]. With respect to other specifications, the outcomes of the long-run coefficients for financial development (FD) and trade openness (TOP) were equally positive and statistically significant at 1% and 5% levels respectively on poverty. In support of these findings are [62–67]. In summary, all the variables under consideration exhibited poverty-reducing effects in SADC sub-region of sub-Saharan Africa except inflation. The effect of inflation was poverty-inducing at a 1% level of [68–70].

Table 5. The Mean-Group FMOLS, Mean-Group DOLS and Robustness Mean-Group Estimators.

	Group-Mean FMOLS	Group-Mean DOLS	Group-Mean Estimator
Variable			
LOG ICT	0.050 *** (0.000)	0.846 *** (0.000)	0.345 *** (0.003)
LOGGDPGR	2.563 *** (0.000)	0.382 *** (0.001)	4.001 *** (0.001)
LOGFD	0.241 *** (0.001)	0.766 ** (0.002)	0.235 ** (0.053)
LOGTOP	0.125 ** (0.002)	0.648 *** (0.000)	0.305 ** (0.051)
LOGINF	−0.107 *** (0.000)	−0.242 *** (0.001)	−0.211 *** (0.000)

*** and **, signify a rejection of null hypotheses at 1% and 5% error levels in that order respectively.

The results of the Zbar-statistics as shown in Table 6 indicate that a bidirectional causality existed between ICT and poverty, economic growth and poverty, ICT and economic growth, ICT and financial development, ICT and trade openness and economic growth and trade openness. On the other hand, a unidirectional causality existed from financial development to poverty, trade openness to poverty, inflation to poverty and economic growth to inflation. In conclusion, above analyses suggest that the countries within the SADC will benefit more as a region in terms of economic growth, poverty reduction, trade openness and ICT penetrations. For instance, [34] opined that the effect of ICT on economic growth in developing economies is stronger than the developed countries.

Table 6. Panel causality test (Pairwise Dumitrescu-Hurlin).

Null Hypothesis	Zbar-Stat	Prob.
LGICT does not cause LGPOV	0.8432 ***	0.0000
LGPOV does not cause LGICT	−1.6851 ***	0.0012
LGECO does not cause LGPOV	2.6655 ***	0.0000
LGPOV does not cause LGECO	−0.1258 ***	0.0000
LGFD does not cause LGPOV	2.4246 ***	0.0003
LGPOV does not cause LGFD	8.5505	3.0011
LGTOP does not cause LGPOV	6.5701 ***	0.0000
LGPOV does not cause LGTOP	22.3501	2.0006
LGINF does not cause LGPOV	−1.4352 ***	0.0000
LGPOV does not cause LGPINF	0.3242	2.1523
LGICT does not cause LGECO	0.3341 ***	0.0000
LGECO does not cause LGICT	3.4252 ***	0.0002
LGICT does not cause LGFD	5.0735 ***	0.0001
LGFD does not cause LGICT	6.5157 ***	0.0004
LGICT does not cause LGTOP	0.1148 ***	0.0000
LGTOP does not cause LGICT	6.5157 ***	0.0007
LGICT does not cause LGINF	−0.0019 ***	0.0008
LGINF does not cause LGICT	5.7372 ***	0.0002
LGECO does not cause LGFD	8.5160 ***	0.0001
LGFD does not cause LGECO	13.0587 ***	0.0000
LGECO does not cause LGTOP	1.0128 ***	0.0012
LGTOP does not cause LGECO	2.7045 ***	0.0014
LGECO does not cause LGINF	3.6003 ***	0.0000
LGINF does not cause LGECO	1.2541	0.2006
LGFD does not cause LGTOP	6.1505 ***	0.0002
LGTOP does not cause LGFD	9.0375 ***	0.0001
LGFD does not cause LGINF	7.2070	0.3461
LGINF does not cause LGFD	3.7861 ***	0.0003
LGTOP does not cause LGINF	1.2437	0.2452
LGINF does not cause LGTOP	6.8123 ***	0.0040

*** represents $p < 0.001$ significance level of rejection. Results were based on annual data (panel) from 2005–2019. 4 lags were selected based on Akaike Information Criteria. E-view 9.5 was used in performing the test.

5. Concluding Remarks

In this article, the long-run relationship between poverty, ICT, and economic growth was evaluated in 15 SADC countries using the panel cointegration approach for the period 2005–2019. To account for the presence of cross-sectional dependence which may render our analyses invalid, the [59] CD test was carried out with the rejection of the null hypothesis of the presence of cross-sectional dependence in the variables. The outcomes of the panel unit root tests further revealed that the series was made stationary at their first differencing which paved the way for the Westerlund cointegration test. It was established that long-run association exists among the variables of interest namely poverty, information, and communication technology, economics, and the other established variables in the literature. Empirically, it was further established that the long-run effects of ICT, economic growth, financial development, and trade openness are poverty-reducing and hence, ICT was seen as a tool for accelerating economic growth in SADC as a region. This provides an answer to our second research question. Furthermore, the study established the existence of leapfrogging hypothesis for this region and provides an answer to the third research question. However, inflation remains a major challenge to the region as the effect was poverty-inducing. In determining the first research question, the [71] causality test were performed on the variables to know the directions of the variable's causality. A bi-directional causality existed between ICT and poverty, economic growth and poverty, ICT and financial development, and ICT and trade openness while unidirectional causality was established running from poverty and ICT to trade openness.

Important policy implications of the study are as follows:

1.　For the continued benefits of poverty-reducing effects of ICT, economic growth, financial development, and trade openness to be maintained, there is the need to strengthen the existing bilateral relationship among member countries of the region.
2.　As applicable in other advanced and some developing economies, the digital competence of the region needs to be synchronized for better and more effective service delivery.
3.　In addition, forward-looking policies that will review the roaming rates from countries outside the region should be considered. This is expected to improve the region's revenue, and economic activities and ultimately enhance the ICT-poverty reducing outcome for the region.

However, the negative effects of inflation within the SADC region call for joint efforts in terms of policy formulation and implementation to ameliorate its adverse effects on the region. Further studies should dwell much on the use of primary data with Logit and Probit techniques. Not only that, but the composition of ICT should also be expanded to include broadband penetration, e-government, telecommunication infrastructure, and online services to serve as robust checks for further studies. Also, digital technologies as spillover effect can further be investigated.

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