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Estimating the Connection between ICT, FDI, Trade, Renewable Energy and Growth in Sub-Saharan Africa

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ABSTRACT

This paper examines the connection between Information and Communication Technologies (ICTs), Foreign Direct Investment (FDI), trade, renewable energy and growth in sub-Saharan Africa (SSA). Earlier studies only addressed this issue in the context of a single country; utilizing a time series procedure. This study employs both heterogeneous panel analysis and dynamic fixed effect techniques to analyze dataset that were collected. Findings suggest that ICT, trade and renewable energy consumption exert positive and statistically significant effect on growth in the long run. However, the effect of FDI is not statistically significant in the long run estimate. Evidence from the short-run analysis suggests that renewable energy could draw back growth in the short run; though is effect is productive in the long run. Other variables of interest show no significant effect in the short run estimate. An improvement in ICT infrastructure and trade liberalization is desirable for long-term growth in SSA.

ملخص

تهدف هذه الورقة إلى تحليل العلاقة بين تكنولوجيا المعلومات والاتصالات(ICT)، والاستثمار الأجنبي المباشر(FDI) ، والتجارة، والطاقة المتجددة، والنمو الاقتصادي في منطقة إفريقيا جنوب الصحراء (SSA). بخلاف الدراسات السابقة التي اقتصرت على دولة واحدة باستخدام بيانات السلاسل

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الزمنية، تستخدم هذه الدراسة تحليلا لوحيا غير متجانس وتقنيات التأثير الثابت الديناميكي لتحليل البيانات المجموعة. أظهرت النتائج أن تكنولوجيا المعلومات والاتصالات، والانفتاح التجاري، واستهلاك الطاقة المتجددة، تساهم بشكل إيجابي أظهرت النتائج أن تكنولوجيا المعلومات والاتصالات، والانفتاح التجاري، واستهلاك الطاقة المتجددة، تسهم بشكل إيجابي وذو دلالة إحصائية في تحقيق النمو الاقتصادي على المدى الطويل. ومع ذلك، فإن أثر الاستثمار الأجنبي المباشر لم يكن ذا دلالة إحصائية في تقديرات الأمد الطويل. أما على المدى القصير، فقد أظهرت النتائج أن الطاقة المتجددة قد تبطئ النمو مؤقتا، على الرغم من فعاليتها الإيجابية على المدى البعيد. ولم تظهر بقية المتغيرات المدروسة تأثيرا معنويا في الأمد القصير. توصي الدراسة بضرورة تحسين البنية التحتية لتكنولوجيا المعلومات والاتصالات وتوسيع نطاق تحرير التجارة كوسائل فعالة لدعم النمو المستدام في بلدان إفريقيا جنوب الصحراء.

RÉSUMÉ

Cet article examine la relation entre les technologies de l'information et de la communication (TIC), les investissements directs étrangers (IDE), le commerce, les énergies renouvelables et la croissance en Afrique subsaharienne (ASS). Les études précédentes n'ont abordé cette question que dans le contexte d'un seul pays, en utilisant une approche chronologique. La présente étude utilise à la fois l'analyse des commissions hétérogènes et les techniques d'effet fixe dynamique pour analyser l'ensemble des données collectées. Les résultats indiquent que les TIC, le commerce et la consommation d'énergies renouvelables ont un effet positif et statistiquement significatif sur la croissance à long terme. Cependant, l'impact des investissements directs étrangers n'est pas statistiquement significatif dans les estimations à long terme. Les données issues de l'analyse à court terme indiquent que les énergies renouvelables peuvent entraîner un ralentissement de la croissance à court terme, même si leur impact est positif à long terme. Les autres variables importantes n'ont pas d'effet significatif sur les estimations à court terme. Il est recommandé d'améliorer les infrastructures des technologies de l'information et de la communication et de libéraliser le commerce afin de favoriser la croissance à long terme en Afrique subsaharienne.

Keywords: ICT, Foreign Direct Investment, Trade, Renewable Energy, Growth, SSA

JEL Classification: F14, F36, O47, O55, Q43

1. Introduction

In recent years, the global economy has experienced tremendous increase in factors of production, trade in goods and overall economic activity. The increasing rate of globalization has led to the improvement in Information and Communication Technologies (ICTs), Foreign Direct Investment (FDI) and international trade. Studies have shown that trade, technologies and FDI could have some implications on the rate of economic progress (Asongu & Acha-Anyi 2020; Raheem *et a*l., 2019). Globally, economic activities have grown significantly as numerous countries strive to attain economic growth and development. For instance, modern technologies have been introduced in the telecommunication, banking and maritime sectors to improve service delivery. The improvement in technology had played essential role in internet usage across the telecommunication, finance, international trade and economic development (Park et al, 2018).

According to data from the World Bank, ICT, trade, and FDI have contributed significantly more to GDP in many developed and emerging economies than in Sub-Saharan Africa (SSA) countries. For instance, over the past two decades, the ratio of ICT to GDP in East Asia and the Pacific has consistently exceeded 18%. In 2023, the trade to GDP ratio in the European Union reached 93.69%, while Latin America and the Caribbean recorded an FDI-GDP ratio of 3.06%. In contrast, SSA's trade to GDP and FDI to GDP ratios were 58.73% and 2.11%, respectively, in the same year (World Bank, 2024). These figures highlight the comparatively lower contributions of trade and FDI to GDP in SSA compared to other regions.

Sub-Saharan Africa has emerged as a key area of interest in discussions surrounding economic growth and development. Evidence from developed countries has shown that advancements in ICT, increased inflows of FDI, expanding international trade and adoption of renewable energy are widely recognized as having significant potential to accelerate economic growth (Raghutla, 2019). In the last two decades, the development in the ICT sector in SSA indicates that ICT import as a percentage of total import declines from 6.48% to 4.64% from 2001 to 2021. Similarly, FDI net inflow as a percentage of GDP marginally fall from 3.80% to 3.70%, in the same period. A drop in trade as a share of GDP was observed between 2011 and 2021 when it reduced from 66.71% to 57.06%. The development in the energy sector clearly indicates renewable energy as a percentage of total energy consumption decreased from 72.63% in 2001 to 70.57% in 2021 (World Bank, 2024). All these statistics show that the region has experience decline in ICT, trade flows, FDI and renewable energy used over the last two decades. Economic performance in the region reveals that economic growth (measured by real GDP annual growth) marginally increased from 4.18% in 2001 to 4.33% in 2021, on average. However, the growth in the region witnessed different episodes of fluctuations. The highest growth recorded was 6.60% in 2024 and the lowest was -2.01% in 2020 (World Bank, 2024). These statistics imply that growth in the SSA region has been relatively unstable and this research enquiry intends to determine how the improvement in the variables of interest would enhance economic growth.

The theoretical link between growth and its determinants such as technology and investment could be traced to the Neo-classical paradigm. The proponents of the model, such as Solow (1956), posits that economic growth per capita is determined mainly due to the increase in capital investment and technological progress. Similarly, endogenous growth theory has established a strong association between technological diffusion (which can come through ICT and FDI) and economic growth (Romer, 1990). The diffusion of FDI and adoption of ICT could accelerate the rate of productivity and ensure creation of varieties of consumables and industrial products.

The empirical literature in the theme's context has shown links between the variables. For instance, ICT has been linked to promote economic growth (Jing & Abrahim, 2020; Fernandez-Portillo et al., 2020; Appiah-Otoo & Song, 2021). Some studies have shown the connection between FDI and growth (for example, Yucei, 2014; Abbes et al., 2015; Pegkas, 2015; Rehman, 2016; Yimer, 2023). Diverse evidences have been revealed between trade and growth (see Ismail and Mayhideen, 2015; Raghutla, 2019; Sakyi and Egyir, 2017; Zahonogo, 2017). The nexus between renewable energy and growth has been explored by some studies (for instance, Omri et al., 2015; Kocak and Sarkgunesi, 2017; Wang et al., 2022).

ICT has been observed to have contributed to economic prosperities, creation of jobs, research and development as well as social change in developed countries (Raheem, et al., 2019). However, some developing economies have not taken full advantage of ICT to enhance productivity and economic growth. Poor ICT infrastructure in some developing countries, especially, SSA economies have resulted to limited access to information on important economic variables such as market, prices, source of raw materials, employment, business opportunities and other market conditions (Rehman, et al., 2021).

Additionally, ICT has been argued to be a two edged-sword, the positive effects of ICT on the growing economy have been well documented. Nonetheless, some economic challenges have been associated with ICT. Empirical studies, such as, Raheem *et al*. (2019) noted that ICT promotes industrialization, which could lead to environmental degradation and pose harmful effect on the society. Industrialization which is associated with ICT development could increase energy consumption that can result to poor environmental conditions and detrimental effect on the economy (Park, et al., 2018).

The substitution of conventional energy sources to renewable energy in most advanced economies has generated an environmental friendly and sustainable growth process. The use of renewable energy (for example, hydro, geothermal, wind, solar, wave and biomass) for production has been considered to have low harmful effect on the environment and the economy (Shahbaz, et al., 2019). Renewable energy technologies and production have become the central element in the energy policy of most developed countries. However, majority of SSA countries still rely massively on the use of traditional energy sources (fossil fuels) which often result to extensive environmental cost, such as, pollution and climate change. This could generate detrimental effect on sustainable growth and development.

A few gaps in the existing literature on the theme has been identified. First, previous studies related to the theme focused on the interaction of economic growth amid variables, namely, CO_2 emission, financial development, energy consumption (see for instance, Rehman, 2016; Sakyi and Egyir, 2017; Park, et al., 2018; Raheem et al., 2019) with limited attention on the connection between ICT, FDI, trade, renewable energy and growth. Second, a singular study that was assessed on the theme was conducted by Rehman et al. (2021) which utilized time series dataset for Pakistan and employed a fully modified OLS regression. This current study provides a more comprehensive approach to the enquiry by employing dataset from SSA countries and estimating both the short run and long run relationships among the variables. Third, earlier studies employed estimation procedure, such as, pooled regression fixed effect and generalized method of moments (Pegkas, 2015; Kocak and Sarkgunesi, 2017; Yimer, 2023). Our study used a robust pooled mean group technique that combines the effect of pooled OLS and mean group estimators, generating efficient estimates by incorporating both individual-specific and time specific effects. Therefore, this study examines both the short and long run interaction between ICT, FDI, trade, renewable energy and economic growth in SSA countries.

The remainder of the paper is organized as follows: Section 2 provides the review of literature. The theoretical underpinning and methodology are provided in section 3. Section 4 presents the results and provides the interpretation of the findings. Conclusion and recommendation are documented in section 5.

2. Literature Review

This section presents literature review of variables influencing economic growth that are integrated in this study.

Theoretical studies on the relationship between ICT and economic growth can be classified under two paradigms, namely, Neo-classical theory and endogenous theory. These two theories emphasized the importance of technological change in economic growth but differ in arguments. In the case of Neo-classical, the contribution of technological change in growth process was not explained in the model. It was later accounted for in what is referred to as Solow residual. However, the endogenous growth theory accounted for technological change in the growth model and posits that economic growth is largely driven by growth in knowledge which is captured in technological progress (Romer, 1990).

In the Classical theory, Harrod (1939) and Domar (1946) show that savings from overseas via loans, foreign portfolio investments and FDI augment domestic savings with a targeted effect on economic growth. According to the theory, the net national income is determined jointly by the net national savings ratio and national capital accumulation ratio. Foreign Direct Investment has been considered as a process of technological transferred from more advanced economies to the developing or less-developed ones. Technological transfer from abroad via FDI has remained a key driver for countries to enhance growth. Solow (1956) identified how investment through the dynamics of capital stock can affect growth. The exogenous growth theory was challenged by proponents of endogenous growth model, namely, Lucas (1988), Barro (1990) and Romer (1990) who suggested that stock of knowledge, growth in knowledge and physical capital are essential for long run growth.

Among the key theoretical contributions on the link between trade and growth was the proposition of Bhagwati (1973). The analysis shows that an export oriented and unrestricted trade regime generates a liberal and conducive environment that promote favourable spill-over economic growth effects. Several theoretical models (see Helpman & Krugman, 1985; Grossman & Helpman, 1990) predict that increase in trade openness can lead to faster and less volatile economic growth through technological diffusion, increased competition, economics of scale and increasing returns to scale.

In many studies, the theoretical relationship between energy and economic growth is captured in the famous Neo-classical model. Energy is considered as one of the factor inputs, in addition to capital and labour in the production process. This has been further extended to what is popularly known as growth hypothesis or energy-led growth hypothesis that postulates that increase in energy consumption promotes economic growth (Apergis and Tang, 2013). According to this hypothesis, energy consumption complements labor and capital in stimulating economic growth. However, the conservation hypothesis posits that economic growth causes increase in energy consumption. In other words, increase in economic activities promotes energy consumption. The third argument is the feedback hypothesis which postulates a bidirectional relationship between economic growth and energy consumption. The feedback hypothesis indicates that economic growth and energy consumption are strongly dependent. This implies that capital investment in other sectors of the economy could lead to increase in energy consumption and investment in the energy sector induces economic growth (Lin and Moubarak, 2014).

Next line of review is on the empirical literature on the theme, which is explored based on the various connections among the variables.

2.1. ICT and Economic Growth

The empirical arguments on the connection between ICT and economic growth had provided diverse evidences. Using a sample of developed, emerging and developing economies, Niebel (2018) analyzed the impact of ICT on economic growth. Findings show that developing and emerging countries are not gaining more from investments in ICT compare to developed economies. Fernandez-Portillo et al. (2020) examined the impact of ICT development on economic growth in OECD countries using a partial least square approach. Empirical findings indicate that to a large extent ICT development drives economic growth of the economies. Cheng et al. (2020) explored the relationship between ICT diffusion, financial development and economic growth by employing a dynamic Generalized Method of Moments technique. The results indicate that ICT diffusion can improve economic growth in high-income countries, however, the effect is ambiguous in middle and low-income countries. Similarly, Appiah-Otto and Song (2021) utilized a composite ICT index on a panel of 123 countries, comprising 45 high-income, 58 middle income and 20 low-income countries. It was found that ICT increases economic growth in all countries, however, poor countries appear to gain more from ICT development. Based on dataset from Eurozone, Laitsou (2021) indicated that ICT capital contributed positively to economic growth. ICT investment under the economic crisis conditions seems to have a greater impact on development than the period without economic crisis.

2.2. FDI and Economic Growth

Several empirical studies had investigated the connection between FDI and economic growth. While some employed time series analysis on a single country, others explored a panel data analysis. The findings of these studies have been mixed. Abbes et al. (2015) studied the relationship between FDI and economic growth in 65 developing countries using panel cointegration and Granger causality test. The result shows a uni-directional causality from FDI to economic growth which suggests that FDI is an important driver of growth in the sampled countries. Using a Fully Modified OLS procedure, Pegkas (2015) posited that FDI is a significant variable that positively affected economic growth in the Eurozone countries. Yimer (2023) investigated the effects of FDI on economic growth in Africa using dynamic common correlated effect procedure for an error correction model. Mixed evidences were obtained from the results. While the long run effect of FDI on economic growth is significant and positive, the short run effect is statistically insignificant.

Carbonell and Werner (2018) explored the effect of foreign direct investment on economic growth in Spain using an unrestricted Autoregressive Distributed Lags (ARDL) model. The results asserted that FDI has no positive and significant effect on economic growth. Based on a Meta-Analysis study on empirical literature on FDI and growth in China, Gunby et al. (2017) found that effect of FDI on Chinese economic growth is significantly smaller than one would expect from a naive aggregation estimate. Rehman (2016) investigated the relationship between FDI and economic growth in Pakistani economy using a vector error correction model (VECM) technique. The results suggested that FDI depends on economic growth.

2.3. Trade and Economic Growth

Empirical studies on the connection between trade and economic growth have generated diverse evidences. Raghutia (2019) examined the impact of trade openness on economic growth in five emerging market economies using a fully modified OLS technique. The findings show that trade openness plays important role in stimulating economic growth and development in Brazil, Russia, India, China and South Africa. Based on dataset from six Gulf Cooperation Council (GCC) countries, Jouini (2014) investigated the link between international trade and economic growth using a Pooled Mean Group (PMG) estimation procedure. Empirical analysis reveals the existence of cointegration between trade and economic growth. Further evidence suggest that trade openness exert positive and significant effect on economic growth both in the short run and long run. Sakyi et al. (2015) analyzed the relationship between trade openness and economic growth in 115 developing countries; comprises low-income, lower middle-income and upper middle-income countries. Evidence from the analyses indicated a bidirectional relationship between the two variables. Employing a PMG estimation technique on datasets from 42 SSA countries, Zahonogo (2017) suggested that a trade threshold exists below which greater trade openness has a beneficial effect on economic growth and above which the trade effect on growth declines.

2.4. Renewable Energy and Economic Growth

Studies on renewable energy and economic growth had generated insightful findings. Isik *et al*. (2017) examined the relationships between renewable energy consumption and economic growth in the United States, France, Spain, China, Italy, Turkey and Germany using an innovative Bootstrap panel Granger causality model. The findings indicate support for the energy-led growth hypothesis in Spain and growth-led hypothesis in China, Turkey and Germany whereas evidence of bidirectional relationship was revealed for Italy and U.S. Similarly, using heterogeneous panel causality estimation technique, Kocak and Sarkigunesi (2017) explored the relationship between renewable energy consumption and economic growth in the Black Sea and Balkan countries. The results show that renewable energy consumption has a positive and long-term relationship with economic growth. Evidences from the panel causality show support for growth hypothesis in Bulgaria, Greece, Macedonia, Russia and Ukraine; feedback hypothesis in Albania, Georgia and Romania and neutrality hypothesis in Turkey. Based on a fully modified ordinary least squares (FMOLS) and heterogeneous non-causality procedures, Shabaz et al. (2019) examined the effect of renewable energy consumption on economic growth. The empirical analysis indicates the presence of a long-run relationship between renewable energy consumption and economic growth in the sampled countries. Kasperowicz et al. (2020) investigated the long-run relationship between renewable energy consumption and economic growth. The study found that there is a long-term equilibrium relationship between economic growth and renewable energy consumption and that renewable energy consumption has a positive impact on economic growth.

3. Data and Methodology

3.1. Theoretical Framework and Model Specification

This study draws from the Solow-Swan growth model, independently developed by Solow and Swan (1956). Simplifying that output is basically determine by capital, labor, and technology inputs, explains long-term growth dynamics. This paper employs the model to analyze how ICT, FDI, trade, and renewable energy influence growth. The model assumes a production function linking output to capital, labor, and technology, with constant returns to scale.

$$Y_t = f(A, K, L)_t = A_t K_t^{\alpha} L_t^{1-\alpha} \quad (1)$$

Where Y_t represents output (GDP) at time t, K_t denotes the capital stock (gross capital formation) at time t, L_t represents labor input at time t, and A_t represents exogenous technological progress (ICT, FDI, and trade) at time t. However, the technological progress is exponentially proportional to exogenous technological growth which is given as:

$$A_t = (1 + g)^t \quad (2)$$

Where g represents the exogenous technological growth rate.

Hence, ICT improves productivity (A) through efficiency and innovation. FDI boosts capital accumulation (K) via increased investment. Trade openness expands market access, impacting output (Y). Renewable energy affects productivity (A) and capital accumulation (K), altering production costs and reducing environmental impacts.

Consequently, this study's model draws from Solow and Swan (1956) and significantly influenced by Rehman et al. (2021) model which explores the link between ICT, FDI, trade, renewable energy, and economic progress in Pakistan through an empirical functional model given as:

$$GDPG_t = f(ICT, FDI, TRD, REC)t \quad (3)$$

Where $GDPG_t$ = gross domestic product growth rate at time t, ICT_t = information and communication technology at time t, FDI_t = foreign direct investment at time t, TRD_t = trade openness at time t, and REC_t = renewable energy at time t. Furthermore, by modifying equation (3) through the incorporation of gross capital formation (GCF) and inflation rate (INF) in a panel-dataset, the functional model for this study is provided as follows:

$$GDPG_{it} = f(ICT, FDI, TRD, REC, INF, GCF)_{it} \quad (4)$$

The econometric form of the model is thus:

$$GDPG_{it} = \beta_0 + \beta_{1i}ICT_{it} + \beta_{2i}FDI_{it} + \beta_{3i}TRD_{it} + \beta_{4i}REC_{it} + \beta_{5i}INF_{it} + \beta_{6i}GCF_{it} + \mu_t \quad (5)$$

Equation (5) sets the stage for empirical exploration, providing a theoretical framework for understanding the complex interactions of ICT, FDI, trade, renewable energy, and growth. It offers insights for interpreting the evolving economic landscape in selected SSA nations. As a result, the following theoretical deductions are presumed:

$$\frac{\partial(GDPG)}{\partial(ICT)} > 0, \frac{\partial(GDPG)}{\partial(FDI)} > 0, \quad \frac{\partial(GDPG)}{\partial(TRD)} > 0, \quad \frac{\partial(GDPG)}{\partial(REC)} > 0, \quad \frac{\partial(GDPG)}{\partial(INF)} < 0, \quad \text{and} \quad \frac{\partial(GDPG)}{\partial(GCF)} > 0 \quad (6)$$

3.2. Estimation Strategy

This paper explores several diagnostic tests on the data and rigorous pre-estimation procedures before utilizing the Pooled Mean Group technique. The initial phase employs pre-estimation techniques like descriptive analysis, correlation matrix, panel unit root tests (LLC, IPS, ADF-Fisher), lag selection test, and panel cointegration tests (Kao, Johansen-Fisher) to evaluate data characteristics, multicollinearity, stationarity, lag period, and cointegration.

The second approach employs a dynamic panel framework to estimate varied data, employing appropriate methods. Utilizing data traits, the study employs ARDL (p,q) model in error correction with three estimators, including mean group (MG), pooled mean group (PMG), and dynamic fixed effect (DFE) model, following Pesaran and Smith (1995), Pesaran et al. (1999). The ARDL formulation as per Loayza & Ranciere (2006) is given as:

$$\Delta(Y_i)_t = \sum_{j=1}^{p-1} Y_j^i \Delta(Y_i)_{t-j} + \sum_{j=0}^{q-1} \delta_j^i \Delta(X_i)_{t-j} + \varphi^i[(Y_i)_{t-1} - \{\beta_0^i + \beta_1^i (X_i)_{t-1}\}]\epsilon_{it} \tag{7}$$

In the model, Y represents GDP growth, while X comprises independent variables like ICT, FDI, trade, renewable energy, inflation rate, and gross capital formation, and **δ** are short-term coefficients; β represents long-term coefficients, and **φ** denotes adjustment speed to long-term status. Panel ARDL methods (PMG, MG, DFE) compute Equation (7), accounting for long-term equilibrium and dynamic adjustment heterogeneity (Demetriades & Law, 2006).

Pesaran & Smith (1995) and Pesaran, Shin, & Smith (1999) innovated ARDL methods as cointegration tests, stressing parameter estimate consistency in long-term relationships. PMG and MG estimators avoid cointegration tests, enabling varied stationarity orders in panel data. ARDL tackles endogeneity, allowing simultaneous short and long-term impact estimation (Pesaran & Shin, 1999).

Furthermore, the PMG estimator improves efficiency over MG, supporting the study's long-term homogeneity slope assumption (Pesaran et al., 1999). The Hausman test evaluates significant differences among PMG, MG, and DFE, assessing statistical significance in coefficients' consistent estimators between the models. For instance;

$$H^* = (\beta_{PMG} - \beta_{MG})^i [Var(\beta_{PMG}) - Var(\beta_{MG})]^{-1} (\beta_{PMG} - \beta_{MG}) \tag{8}$$

$$H^{*} = (\beta_{PMG} - \beta_{DFE})^{i}[Var(\beta_{PMG}) - Var(\beta_{DFE})]^{-1}(\beta_{PMG} - \beta_{DFE}) \quad (9)$$

Where H is the test statistic, β_{PMG}, β_{MG}, and β_{DFE} are the coefficient estimates from PMG, MG, and DFE models respectively, and Var(β_{PMG}), Var(β_{MG}), and Var(β_{DFE}) are the variance-covariance matrices of the coefficient estimates from PMG, MG and DFE models respectively.
Statistical significance of H (e.g., at 5% or 1%) rejects the null hypothesis, favoring DFE over PMG. Conversely, non-significant H fails to reject the null, indicating PMG consistency and no preference between PMG and DFE models, similar for PMG and MG estimators.

3.3. Data Collection Technique and Sample Size

This study utilized a sample encompassing twenty-one (21) SSA countries in four different regions (see the appendix section for the selected countries). Data from the years 2000 to 2021 were analyzed to explore various trends. The selection of these countries was primarily based on data accessibility. The timeframe of the study spans significant shifts in the macroeconomic indexes, such as trade liberalization policies embraced by most SSA countries in 2000s, industrial growth and export promotion polices, the downturn from 2007 to 2009 due to the global financial crisis, the uptick from 2009 to 2013 fueled by ongoing industrial expansion, and the decline from 2014 to 2016 associated with increased unconventional oil production and the strengthening of the U.S. dollar.
Consequently, secondary data from diverse sources were employed for the study. For example, the GDP growth, FDI, ICT, trade, inflation, and gross capital formation were sourced from the World Bank Development Indicators database, while renewable energy was sourced from the Energy Information and Administration database. The selection of variables, guided by literature, is justified due to their pivotal roles in economic development, forming the study's objectives. Finally, Table 1 offers comprehensive details on measurements, sources, and expected relationships of these variables.

Table 1: Variable Description, Measurement, and Source

Variable	Description	Measurement	Data Source	Variable Source	Expected Sign
GDPG	Gross domestic product growth rate	Per capita gross domestic product growth rate (% annual)	WDI	Rehman et al. (2021)	Dependent Variable
ICT	Information and communication technology	Investment in ICT with private participation (% of GDP)	WDI	Rehman et al. (2021)	Positive
FDI	Foreign direct investment	Foreign direct investment, net inflows (% of GDP)	WDI	Rehman et al. (2021)	Positive
TRD	Trade openness	Total trade (import and export), (% of GDP)	WDI	Rehman et al. (2021)	Positive
REC	Renewable energy consumption	Renewable energy consumption (% of total final energy consumption)	EIA	Rehman et al. (2021)	Positive
INF	Inflation rate	Inflation, consumer prices (annual %)	WDI	Control variable	Negative
GCF	Capital	Gross fixed capital formation (% of GDP)	WDI	Control variable	Positive

Source: Authors' Compilations[3]

4. Empirical Results and Discussions

4.1. Results

In this section, the empirical results are systematically presented, along with their interpretations. In this respect, the order of presentation within this section proceeds from descriptive statistics to preliminary tests such as correlation, panel unit root tests, optimal lag selection tests, and panel cointegration tests, into the results of the panel regression analysis. Hence, it should logically follow that the presentation of results regarding the study and subsequent deep discussions would be presented in an orderly manner.

Descriptive statistics appended in Table A1 (refer to the appendix section) do not show the presence of outliers. Skewness and kurtosis have indicated

[3] WDI represents World Bank Development Indicators Database, whereas EIA signifies Energy Information and Administration Database.

mixed distributions, with renewable energy consumption having smaller tails and deviating from normality. This may imply that energy consumption behavior has been irregular and hence might affect growth patterns. Likewise, the correlation analysis appended in Table A2 shows that a low level of correlation exists among the variables. No multicollinearity problem is present, hence allowing us to analyze the effect of each variable independently. For example, the negative relationship between trade and GDP growth suggests that there might be some trade-related constraints to economic performance. Moreover, the unit root tests, reported in Table A3, indicate that some variables are stationary at the zero level, such as GDP growth and FDI, while others like trade and renewable energy require first differencing to be stationary, reflecting a diverse integration order of the dataset. Furthermore, the result of optimal lag selection, which is presented in Table A4, along with lag exclusion in Table A5, resulted in the optimal lag length of 1 to ensure estimates that are robust but not overfitted. Finally, the cointegration tests shown in Tables A6 and A7 confirm that there are long-run relationships between the variables, with up to six cointegrating equations, hence supporting the evidence of stable long-run dynamics between ICT, FDI, trade, renewable energy, and economic growth in SSA.

Based on these preliminary tests, panel model estimation investigates the complex static and dynamic nature of these relationships. The choice of methodologies includes the mean group and pooled mean group for heterogeneous panel analysis, as well as the dynamic fixed-effect modeling for homogeneous panel data, to make sure that the estimation is robust enough to provide long-run static and short-run dynamic estimates of the impacts of ICT, FDI, trade, and renewable energy on economic growth. The Hausman test shall guide the selection of an appropriate model. In view of the cointegration established above, the investigation further uses advanced panel cointegration regression techniques in the form of FMOLS, DOLS, and CCR to further ensure the robustness check for the preceding analysis. This will ensure proper estimates of the impacts of the variables both in the long and short run, and the results are summarized in the following table below:

Table 2: Model Estimation Table

VARIABLE	HETEROGENEOUS PANEL ANALYSIS				HOMOGENEOUS PANEL ANALYSIS	
	Long Run Static Estimates: Dependent Variable - GDPG					
	MG		**PMG**		**DFE**	
	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.
ICT	0.211	0.752	0.267***	0.000	0.179**	0.053
FDI	0.780*	0.089	0.329***	0.000	0.127	0.125
TRD	0.274	0.195	0.068***	0.000	0.044**	0.023
REC	0.008	0.992	0.420	0.136	0.102**	0.024
INF	-0.642	0.132	-0.132**	0.001	-0.212**	0.001
GCF	0.008	0.946	-0.119***	0.000	0.052	0.233
	Short Run Dynamic Estimates: Dependent Variable - GDPG					
ECT(-1)	-1.151***	0.000	-0.776***	0.000	-0.983***	0.000
ΔICT	-0.286	0.408	-0.204	0.242	-0.128	0.144
ΔFDI	-0.124	0.508	0.264	0.218	-0.006	0.924
ΔTRD	-0.062	0.338	-0.084	0.283	0.020	0.439
ΔREC	-0.122	0.671	-0.338	0.162	-0.122**	0.012
ΔINF	-0.001	0.992	-0.081	0.131	0.024	0.594
ΔGCF	0.258**	0.049	0.345**	0.004	0.090	0.174
Constant	1.797	0.847	-1.327**	0.001	-6.167**	0.039
Hausman Test	**H_0: $\beta_{MG} = \beta_{PMG}$** **t-stat. = 1.15**		**prob.= 0.979**		**H_0: $\beta_{DFE} = \beta_{PMG}$** **t-stat. = 17.36**	**prob.= 0.008**
Countries	21		21		21	
Observation	441		441		441	
	PANEL COINTEGRATING REGRESSION ANALYSIS					
VARIABLE	**FMOLS**		**DOLS**		**CCR**	
	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.
ICT	0.194***	0.000	0.232	----	0.191***	0.000
FDI	0.625***	0.000	0.000	----	0.643***	0.000
TRD	-0.051***	0.000	-0.607	----	-0.058***	0.000
REC	0.024	0.134	0.201	----	0.028	0.199
INF	0.055***	0.000	0.402	----	0.064***	0.000
GCF	-0.247***	0.000	0.306	----	-0.246***	0.000
Constant	7.535***	0.000	0.000	----	7.352***	0.000
Hausman Test	**H_0: $\alpha_{FMOLS} = \alpha_{DOLS}$** **t-stat. = 210**		**prob.= 0.000**		**H_0: $\alpha_{CCR} = \alpha_{FMOLS}$** **t-stat. = 1.14**	**prob.= 0.980**
Countries	21		21		21	
Observation	21		19		21	

Source: Authors' Computations, Stata Output[4]

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[4] **Note: *** = 1% significance level, ** = 5% significance level, and** * = 10% significance level. GDPG = gross domestic product growth rate, ICT = information and communication technology, FDI = foreign direct investment, TRD = trade, REC = renewable energy, INF = inflation rate, GCF = gross capital formation. Furthermore, MG = mean group estimation,

Thus, in Table 2 above, the Hausman test was applied for homogeneous slope hypothesis testing. By comparing the MG and PMG models, the obtained result provided a p-value of 0.979, larger than the 10 percent significance level. Therefore, the null hypothesis of long-run slope homogeneity could not be rejected. Hence, the PMG estimator was chosen on the grounds of consistency and efficiency under slope homogeneity. Next, the PMG model was contrasted against DFE using the Hausman test. This is because the result considered rejecting the null hypothesis, with the p-value of 0.008 being below the 5% threshold, hence making DFE a preferred choice in estimating the long-run and short-run dynamic effects of ICT, FDI, trade, and renewable energy on economic growth in SSA. Consequently, the long-run results from the DFE estimator showed that ICT, trade, renewable energy, and the inflation rate are the statistically significant drivers of economic growth in SSA, and all have the expected signs. While ICT, trade, and renewable energy elicit positive impacts on growth, inflation exerts negative impacts. However, FDI and GCF had insignificant impacts. At the same time, the short-run dynamic model was statistically significant for only renewable energy, whose one-unit increase decreased growth by 0.12%. Other variables like ICT, FDI, trade, and GCF have insignificant results in a short-run analysis. The error correction model confirmed co-integration with a correction rate of 98.3%, hence long-term stability of the relationships. Further robustness tests through application of the Hausman test were comparative estimations using models of FMOLS, DOLS, and CCR. The preferred one was FMOLS since it had more reliable and efficient long-term estimates than other estimators. The results from the long-term equilibrium relationship showed that ICT, FDI, and inflation were significant, while trade and GCF were not statistically insignificant. These findings are consistent with global trends and confirm what is increasingly being recognized: that ICT and renewable energy can be crucial in leading SSA's economic growth.

PMG = pooled mean group estimation, DFE = dynamic fixed-effect estimation, FMOLS = fully-modified ordinary least square estimation, DOLS = dynamic ordinary least square estimation, and CCR = canonical cointegration regression.

4.2. Discussions

These findings confirm the generally documented long-run positive effects of ICT, trade, and renewable energy on SSA's economic growth. However, the value added of this contribution to the literature consists of the particular mechanisms and contexts in which these variables support or impede growth and how they interact in both the short and long runs. One important implication that can be derived from this analysis is that ICT-led growth through improved connectivity and access to information occurs due to the fact that SSA economies could only then aspire to productivity enhancement. This can happen provided some preconditions are fulfilled, such as there is reasonable technological infrastructure and proper regulatory frameworks. In countries with comparatively low development in their ICT infrastructure, this may minimize the potential for growth resulting from digital innovation. Trade openness is another area with a high positive long-run impact, though SSA faces the limited diversification of the structure of trade, trade imbalance, and dependence on commodity exports. There is no doubt that trade liberalization policies are welcome; however, in SSA, their full effects can only be felt if complemented by export base diversification and strengthening domestic industries. The observed effect of trade is positive and in line with previous studies results, Ngouhouo et al. (2021), but it points to the need for complementary policies to be implemented if competitiveness in international markets is to be enhanced. The second interesting result is that of renewable energy, which is negative in the short run, a scenario where such investments might be necessary for long-term sustainability; however, the initial cost and infrastructural barriers in SSA might well outweigh short-term growth benefits. This would mean that, in the short term, a proper balance between the expansion of renewable energy and the support policies for other sources of energy should be struck so that this mitigates the growth-reducing effects of the transition and, therefore, would help SSA countries realize the full potential of renewable energy in achieving sustainable development.

But the adverse effect of inflation on growth in both the short and long run is a cause for concern. High inflation depletes purchasing power, distorts resource allocation, and disincentivizes investment. Hence, policy attention needs to focus on taming inflation to allow a favorable environment for growth. Those countries in SSA that can afford to keep inflation low will more likely realize the returns of ICT, FDI, and trade openness. Moreover, the study depicts complementarity among some variables. For example, FDI is more effective in countries with open trade policies, and thus, there is a need for reforms that should be targeted simultaneously at investment climates as well as trade openness. Additionally, renewable energy can facilitate trade by reducing energy costs and enhancing the competitiveness of SSA products on world markets. These complementary effects are useful in advising policymakers who seek to maximize the potential of ICT, FDI, trade, and renewable energy for growth. Results confirm many well-known long-run growth drivers; however, this study underlines some rather neglected short-run dynamics. In fact, in the short run, the interaction between renewable energy, trade, and FDI is more complex, and countries may need to employ a sequential approach with a view to maximizing long-term gains while minimizing any adverse effects on the short run. In this respect, the study draws on several variables and emphasizes contextually placing them into specific challenges SSA countries face in infrastructure deficits, policy inefficiencies, and market volatility. In other words, the final conclusion is that this enriches the literature, but a better understanding of how ICT, FDI, trade, and renewable energy interact under various conditions in SSA is needed. These findings underline the importance of policies that will provide an enabling environment for these variables to complement one another, with particular reference to regional constraints and market dynamics. Further research in the direction of case studies at the country level must be explored in order to better understand the heterogeneity of the impacts across SSA nations.

5. Conclusion

Therefore, this paper gives an empirical analysis of the interrelationship existing among ICT, FDI, trade, renewable energy, and economic growth in 21 countries of SSA. Their selections are based on their comprehensive data availability and both trade and FDI-to-GDP ratios. Thus, we analyze the relationship that exists among the variables of interest through heterogeneous-mean group and pooled mean group and homogeneous-dynamic fixed-effect panel data analysis. The Hausman test supports the choice of the analytical technique. The empirical results from the estimation of dynamic fixed-effect suggest that in the long term, ICT, trade, and renewable energy significantly impact the economic growth of SSA. However, it seems that these variables, with the exception of ICT, FDI, and trade, are insignificant in the short term. More importantly, the negative sign of the estimate of the coefficient of the use of renewable energy in the short term suggests that it hinders growth. A reason is that because of the underdeveloped renewable energy projects and low investment in the region during all these years, it is a cumulative result. Financial, technological, and regulatory complexities—all have to be overcome through joint collaboration of the governments with the private sector and also with international stakeholders. The fully modified OLS regression was also used to test the robustness of the long-run relationships, which re-established the significant role of ICT and the other three variables—trade and FDI—on economic growth. However, renewable energy consumption was unable to attain a conventional level of statistical significance, which underlines caution when reverting to this source. Consequently, the findings of this study carry a number of important policy implications. First, since ICT has a positive and significant impact on economic growth, major investments in ICT infrastructure are necessary as a means toward promoting sustainable development in the region. Second, trade liberalization policies will have to be adopted as stimulus for further growth in the long run. At last, attracting more FDI inflow is necessary to facilitate technology transfer and capital accumulation and thus support long-term growth.

References

Abbes, S. M., Mostefa, B., Mohammad, G. & Zakarya, G.Y. (2015). Causal interactions between FDI and economic growth: Evidence from dynamic panel co-integration. Procedia Economics and Finance, 23, 276-290

Appiah-Otoo, I. & Song, N. (2021). The impact of ICT on economic growth-comparing rich and poor countries. Telecommunications Policy, 45, 102082, 1-15

Asongu, S.A. & Acha-Anyi, P.N. (2020). Enhancing ICT for productivity in sub-Saharan Africa: Thresholds for complementary policies. African Journal of Science, Technology, Innovation and Development, 12(7), 831-845

Barro, R.J. (1990). Government spending in a simple model of endogenous growth. Journal of Political Economy, 98(2), S103-S125

Bhagwati, J. (1973). The theory of immiserizing growth: Further applications. In M. Connolly & A. Swoboada (Eds), International trade and money (pp. 45-54) Toronto: University of Toronto Press

Carbonell, J.B. & Werner, R.A. (2018). Does foreign direct investment generate economic growth? A new empirical approach applied to Spain. Economic Geography, 94(4), 452-456

Cheng, C., Chien, M. & Lee, C. (2020). ICT diffusion, financial development and economic growth: An international cross country analysis. Economic Modelling. https://doi.org/10.1016/j.econmod.2020.02.008

Demetriades, P. & Law, S.H. (2006). Finance, institutions and economic development. International Journal of Finance & Economics, 11(3), 245-260

Domar, E. (1946). Capital expansion, rate of growth and employment. Econometrica, 14, 137-147

Fernandez-Portillo, A. & Almodovar-Gonzalez, M. & Hernandez Mogollon, R. (2020). Impact of ICT development on economic growth.

A study of OECD European union countries. Technology in Society, 63, 1-9

Grossman, G.M. & Helpman, E. (1990). Trade, innovation and growth. American Economic Review, 80(2), 86-91

Gunby, P., Jin, Y. & Reed, W.R. (2017). Did FDI really cause Chinese economic growth? A meta-analysis. World Development, 90, 242-255. http:dx.doi.org/10.1016/j.worlddev.2016.10.001

Harrod, R.F. (1939). An essay in dynamic theory. Economic Journal, 49, 14-33

Helpman, E. & Krugman, P. (1985). Market structure and foreign trade: increasing returns, imperfect competition, and the international economy. MIT Press, Cambridge

Isik, C., Dorgu, T. & Turkd, E.S. (2017). A nexus of linear and non-linear relationships between tourism demand, renewable energy consumption and economic growth: Theory and evidence. International Journal of Tourism Research. http://dx.doi.org/10.1002/jtr.2151

Ismail, N.W. & Mahyideen, J.M. (2015). The impact of infrastructure on trade and economic growth in selected economies in Asia. ADBI Working Paper, No. 553, Asian Development Bank Institute (ADBI), Tokyo

Jing, A.H.Y. & Ab-Rahim, R. (2020). Information and communication technology (ICT) and economic growth in ASEAN-5 countries. Journal of Public Administration and Governance, 10(2), 20-33

Jouini, J. (2014). Linkage between international trade and economic growth in GCC countries: Empirical evidence from PMG estimation approach. The Journal of International Trade and Economic Development, 24(3), 341-372

Kasperowicz, R. Bilan, Y. & Streimikiene, D. (2020). The renewable energy and economic growth nexus in European countries. Sustainable Development. https://doi.org/10.1002/sd.2060

Kocak, E. & Sarkgunesi, A. (2017). The renewable energy and economic growth nexus in black sea Balkan countries. Energy Policy, 100, 51-57. http://dx.doi.org/10.1016/j.enpol.2016.10.007

Laitsou, E., Kargas, A. & Varoutas, D. (2021). How ICT affects economic growth in the Euro area during the economic crisis. Economic Research and Electronic Networking, 21, 59-81

Loayza, N.V. & Ranciere, R. (2006). Financial development, financial fragility and growth. Journal of money, credit and banking, 38, 1051-1076. http://dx.doi.org/10.1353/mcb.2006.0060

Lucas, R.E. (1988). On the mechanisms of economic development. Journal of Monetary Economics, 22, 3-42

Lin, B. & Moubarak, M. (2014). Renewable energy consumption economic growth nexus for China. Renewable and Sustainable Energy Reviews, 40(3), 111-118

Ngouhouo, I., Nchofoung, T., & Njamen Kengdo, A. A. (2021). Determinants of trade openness in sub-Saharan Africa: do institutions matter? International Economic Journal, 35(1), 96-119.

Niebel, T. (2018). ICT and economic growth- comparing developing, emerging and developed countries. World Development, 104, 197-211

Omri, A. Mabrouk, N.B. & Tmar, A. (2015). Modeling the causal linkages between nuclear energy, renewable energy and economic growth in developed and developing countries. Renewable and Sustainable Energy Reviews, 42, 1012- 1022. http://dx.doi.org/10.1016/j.rser.2014.10.046

Park, Y., Meng, F. & Baloch, M.A. (2018). The effect of ICT, financial development, growth and trade openness on CO2 emissions: an empirical analysis. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356- 018-3108-6

Pegkas, P. (2015). The impact of FDI on economic growth in Eurozone countries. The Journal of Economic Asymmetries, 12, 124-132. http:/dx.doi.org/10.1016/j.jeca.2015.05.001

Pesaran,M.H. & Smith, R. (1995). Estimating long-run relationship from dynamic heterogenous panels. Journal of Econometrics, 68(1), 79-113 http://dx.doi.org/10.1016/0304-4076(94)01644-F

Pesaran, M.H., Shin, Y. & Smith, R.P. (1999). Pooled mean group estimation of dynamic heterogeneous panels. Journal of the American Statistical Association, 94, 621-634 https://doi.org/10.1080/01621459.1999.10474156

Raghutla, C. (2019). The effect of trade openness on economic growth: Some empirical evidence from emerging market economies. Journal of Public Affairs. https://doi.org/10.1002/pa.2081

Raheem, I.D., Tiwari, A.K. & Balsalobre-Lorente, D. (2019). The role of ICT and financial development in CO2 emissions and economic growth. Environmental Science and Pollution Research. https:/doi.org/10.1007/s11356-019- 06590-0

Rehman, A., Ma, H., Ahmad, M., Ozturk, I., & Işık, C. (2021). Estimating the connection of information technology, foreign direct investment, trade, renewable energy and economic progress in Pakistan: evidence from ARDL approach and cointegrating regression analysis. Environmental Science and Pollution Research, 28(36), 50623-50635.

Rehman, N.U. (2016). FDI and economic growth: empirical evidence from Pakistan. Journal of Economic and Administrative Sciences, 32(1), 63-76

Romer, P.M. (1990). Endogenous technological change. Journal of Political Economy, 98(2) S71-S102

Sakyi, D. & Egyir, J. (2017). Effects of trade and FDI on economic growth in Africa: an empirical investigation. Transnational Corporations Review. http://dx.doi.org/10.1080/191864444.2017.1326717

Sakyi, D., Villverde, J. & Maza, A. (2015). Trade openness, income levels and economic growth: The case of developing countries, 1970-2009. The Journal of International Trade and Economic Development, 24(6), 860-882

Shahbaz, M., Raghutla, C., Chittedi, K.R., Jiao, Z. & Vo, X.V. (2019). The effect of renewable energy consumption on economic growth: Evidence from the renewable energy country attractive index. Energy, https://doi.org/10.1016/j.energy.2020.118162

Solow, R.M. (1956). A contribution to the theory of economic growth. The Quarterly Journal of Economics, 70(1), 65-94

Solow, R.M. and Swan, T.W. (1956). Economic growth and capital accumulation. Economic Record, 32, 334-361, https://doi.org/10.1111/j.1475-4932.1956.tb00434.x

Wang, Q., Dong, Z., Li, R. & Wang, L. (2022). Renewable energy and economic growth: New insight from country risks. Energy, 238, https://doi.org/10.1016/j.energy.2021.122018

World Bank (2023). World Development Indicator. World Bank, Washington DC.

World Bank (2024). World Development Indicator. World Bank, Washington DC.

Yimer, A. (2023). The effect of FDI on economic growth in Africa. The Journal of International Trade and Economic Development, 32(1), 2-36

Yucei, G. E. (2014). FDI and economic growth: The case of Baltic countries. Research in World Economy, 5(2), 115-127

Zahonogo, P. (2017). Trade and economic growth in developingcountries: Evidence from sub-Saharan Africa. Journal of African Trade. http://dx.doi.org/10.1016/j.joat.2017.02.001

Appendix

Selected SSA Countries

S/N	COUNTRY
1	Botswana
2	Eswatini
3	Namibia
4	South Africa
5	Cameroon
6	Central African Republic
7	Benin
8	Burkina Faso
9	Cote d'Ivoire
10	Ghana
11	Nigeria
12	Niger
13	Senegal
14	Togo
15	Burundi
16	Kenya
17	Mauritius
18	Rwanda
19	Seychelles
20	Tanzania
21	Uganda

Table A1: Summary of Descriptive Statistics

VARIABLE	GDPG	ICT	FDI	TRD	REC	INF	GCF
Mean	4.111	4.780	2.767	65.293	60.520	5.554	20.987
Median	4.471	3.879	1.899	53.446	72.665	4.193	19.563
Maximum	15.329	26.059	56.264	235.820	96.040	41.509	56.467
Minimum	-36.392	0.000	-2.739	16.352	0.000	-3.233	2.781
Std. Dev.	3.925	3.243	3.913	39.101	30.678	5.604	7.639
Skewness	-3.110	2.553	6.608	1.978	-0.731	2.407	1.484
Kurtosis	29.039	13.768	79.747	7.194	2.125	12.910	7.278
Jarque-Bera	13797.374	2734.000	116746.433	640.047	55.894	2336.414	521.818
Probability	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sum	1899.207	2208.333	1278.474	30165.260	27960.440	2566.096	9695.782
Sum Sq. Dev.	7102.449	4849.223	7059.390	704806.307	433871.227	14478.906	26903.274
Observations	462	462	462	462	462	462	462

Note: GDPG = gross domestic product growth rate, ICT = information and communication technology, FDI = foreign direct investment, TRD = trade, REC = renewable energy, INF = inflation rate, and GCF = gross capital formation.

Table A2: Correlation Matrix

VARIABLE	GDPG	ICT	FDI	TRD	REC	INF	GCF
GDPG	1.000						
ICT	0.053	1.000					
FDI	0.067	-0.061	1.000				
TRD	-0.089	-0.108	0.545	1.000			
REC	0.129	-0.089	-0.329	-0.637	1.000		
INF	-0.036	0.055	0.098	0.090	0.061	1.000	
GCF	0.158	-0.113	0.439	0.470	-0.323	0.024	1.000

Table A3: Summary of Panel Unit Root Tests

Var	Homogeneous Root:				Heterogeneous Root:								Order
	LLC				IPS				ADF-Fisher				
	Constant		Trend		Constant		Trend		Constant		Trend		
	Level	**1st Diff.**	**Level**	**1st Diff.**	**Level**	**1st Diff.**	**Level**	**1st Diff.**	**Level**	**1st Diff.**	**Level**	**1st Diff.**	
GDPG	-9.67***	-17.89***	-9.22***	-10.28***	-10.05***	-21.18***	-10.99***	-16.64***	178.22***	390.56*	179.60***	280.40***	I(0)
ICT	-6.76***	-22.49***	-7.57***	-12.78***	-7.95***	-22.08***	-7.04***	-14.61***	154.30***	409.83***	127.52***	245.92***	I(0)
FDI	-1.31*	-22.56***	-2.59**	-17.70***	-3.51***	-21.33***	-3.25***	-17.11***	87.03***	428.24***	86.51***	289.20***	I(0)
TRD	-2.88**	-12.56***	-2.05**	-6.34***	-1.62*	-11.97***	-1.46*	-8.46***	56.29*	216.66***	49.79	148.16***	I(1)
REC	5.30	6.333	5.10	8.889	6.861	-2.70**	3.72	-1.433*	15.07	75.41**	19.45	67.20**	I(1)
INF	-9.68***	-17.72***	-7.10***	-14.74***	-7.87***	-17.48***	-5.57***	-16.39***	145.50***	326.11***	109.74***	276.92***	I(0)
GCF	-2.56**	-12.98***	0.05	-12.32***	-1.13	-11.34***	0.84	-10.28***	57.23*	215.86***	41.78	180.72***	I(1)

Note: *** = 1% significance level, ** = 5% significance level, * = 10% significance level. LLC = Levin, Lin, & Chu. IPS = Im, Pesaran, & Shin, ADF = Augmented Dickey-Fuller, GDPG = gross domestic product growth rate, ICT = information and communication technology, FDI = foreign direct investment, TRD = trade, REC = renewable energy, INF = inflation rate, GCF = gross capital formation. The selection of the maximum number of lags relies on the Akaike Information Criterion (AIC). The null hypothesis posits that the series possesses a unit root (non-stationary)

Table A4: Lag Selection Test

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-9080.113	NA	1.79e+12	48.07996	48.15283	48.10888
1	-7549.745	2995.959	7.07e+08	40.24203	40.82498*	40.47340*
2	-7492.950	109.0816	6.79e+08	40.20079	41.29382	40.63460
3	-7419.790	137.8037*	5.98e+08*	40.07296*	41.67607	40.70921
4	-7390.589	53.92176	6.65e+08	40.17772	42.29090	41.01641

***** indicates lag order selected by the criterion, LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, and HQ: Hannan-Quinn information criterion

Table A5: Lag Exclusion Test

	GDPG	ICT	FDI	TRD	REC	INF	GCF	Joint
Lag 1	14.29632	229.6114	57.23347	270.7578	35.25291	85.98387	438.0728	1107.662
	[0.046155]	[0.000000]	[5.37e-10]	[0.000000]	[1.00e-05]	[7.77e-16]	[0.000000]	[0.000000]
Lag 2	8.726552	1.895756	35.03508	21.62131	11.42296	20.23895	22.34426	122.6593
	[0.272889]	[0.965384]	[1.10e-05]	[0.002952]	[0.121204]	[0.005076]	[0.002215]	[3.01e-08]
Df	7	7	7	7	7	7	7	49

Table A6: Kao Residual Cointegration Test

	Null Hypothesis: No Cointegration		**t-Statistic**	**Prob.**
ADF			-10.87521	0.0000
Residual variance			23.50842	
HAC variance			7.746331	

Table A7: Johansen-Fisher Cointegration Test

Unrestricted Cointegration Rank Test (Trace and Maximum Eigenvalue)				
Hypothesized	**Fisher Stat.***		**Fisher Stat.***	
No. of CE(s)	**(from trace test)**	**Prob.**	**(from max-eigen test)**	**Prob.**
None	24.95	0.9830	80.22**	0.0003
At most 1	318.7***	0.0000	318.7***	0.0000
At most 2	747.1***	0.0000	507.5***	0.0000
At most 3	370.3***	0.0000	233.3***	0.0000
At most 4	184.4***	0.0000	136.5***	0.0000
At most 5	93.40***	0.0000	73.36**	0.0020
At most 6	86.12**	0.0001	86.12**	0.0001