IJEEP
INTERNATIONAL JOURNAL OF ENERGY ECONOMICS AND POLICY
EJ EconJournals
ISSN: 2146-4553

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2025, 15(6), 685-699.

EJ EconJournals

Investing in the Future: Clean Energy, Technological Advancement, and Environmental Quality as Catalysts for Foreign Direct Investment: Evidence from SSA

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Received: 05 May 2025 **Accepted:** 29 September 2025 **DOI:** https://doi.org/10.32479/ijeep.20242

ABSTRACT

This study investigates the influence of clean energy, technological innovation, and environmental quality on foreign direct investment (FDI) inflows in sub-Saharan Africa (SSA). Employing panel data from 2004 to 2022 across SSA countries, the study applies advanced econometric models, including CS-ARDL, DOLS, panel cointegration, and Dumitrescu-Hurlin causality tests to assess long- and short-term dynamics. The results reveal a strong long-run cointegration between FDI and clean energy, technology, and environmental quality. Clean energy infrastructure and technological advancements are positively associated with FDI inflows in the short and long terms. Environmental quality, proxied by CO_2 emissions and institutional strength, exhibits bidirectional causality with FDI, indicating a mutual reinforcement. Education and institutional quality exert unidirectional impacts on FDI, suggesting their foundational roles in fostering investment readiness. These relationships underscore the importance of aligning national strategies with sustainable development goals to attract ESG-conscious investors, particularly in contexts with improved environmental governance and innovation ecosystems. Unlike prior research focusing on isolated determinants, this study triangulates clean energy, technology, and environmental governance within a unified framework to address their interactive effects on FDI. It introduces a sustainability-driven model tailored to SSA, offering an empirical foundation for evaluating long-run equilibrium and causality among ESG-relevant variables in developing regions. SSA governments should incentivize clean energy, fortify environmental regulations, and invest in digital infrastructure and education to enhance investor confidence and ensure that FDI aligns with inclusive and sustainable growth trajectories.

Keywords: Clean Energy, Foreign Direct Investment, Technological Innovation, Environmental Quality, Sub-Saharan Africa
JEL Classifications: F21, O13, Q01, Q56

1. INTRODUCTION

Foreign direct investment (FDI) is a critical driver of economic advancement, particularly in developing economies (Jie, 2022). FDI is a conduit for capital, technology transfer, and knowledge spillovers, fostering productivity gains and economic growth. The investment paradigm is shifting in an era increasingly defined by pressing environmental concerns and global commitment to sustainable development. Investors are now weighing environmental, social, and governance (ESG) factors of unprecedented importance. Sub-Saharan Africa (SSA), a region grappling with unique economic challenges and immense developmental potential, stands at a crucial juncture in its development. While SSA has attracted increasing FDI (Jie, 2022), the returns have varied significantly, highlighting the critical role of enabling factors. This background section posits that clean energy initiatives, technological advancement, and improved environmental quality are key catalysts for attracting and maximizing the benefits of FDI in Sub-Saharan Africa, paving the way for sustainable and inclusive growth. This synthesis of clean energy, technological advancement, and environmental quality offers a novel perspective on FDI attraction in SSA.

In the context of environmental, social, and governance (ESG) factors, renewable energy, technical progress, and environmental quality are key drivers of foreign direct investment (FDI). Green practices reduce risks and boost profits in the long run. Thus, investors are paying more attention to ESG criteria. [insert here] For example, investing in renewable energy infrastructure signifies dedication to long-term policy stability and preparedness. Countries investing in renewable energy show that they are thinking ahead by lowering their reliance on the unpredictable fossil fuel market and demonstrating that they can withstand the effects of climate change Nguéda and Kelly (2022). Technological progress is also important for a nation's ability to absorb new ideas and innovate. Nguéda (2022) found that economies with a track record of successfully implementing new technologies tend to attract more foreign direct investment (FDI), boosting productivity and competitiveness. Environmental quality is an important measure of the effectiveness of regulations and their sustainability over time. According to Boccard (2021), countries with strict environmental legislation and active work to reduce pollution reduction provide investors with a stable and predictable working environment. This helps minimize the risks of environmental liabilities and ensures that investments are sustainable. Conventional drivers, including market size, labor costs, and natural resource endowments, are typically the center of attention in traditional FDI work, which often isolates or ignores these variables. However, what sets this research apart is its use of all three catalysts simultaneously, with the premise that the combined effect will have a multiplicative effect on foreign direct investment (FDI) inflows. The increasing awareness of the interdependence of economic, social, and environmental aspects, as well as the shifting focus of global investors, has led to this comprehensive strategy.

Over the past two decades, Sub-Saharan Africa has experienced a fluctuating but generally upward trend in FDI inflows (Jie, 2022). Driven by rising commodity prices, increasing urbanization, and a burgeoning consumer market, FDI in SSA has diversified across various sectors, including natural resources, telecommunications, finance, and renewable energy. Notably, the origin of FDI has diversified, with growing contributions from emerging economies such as China and India, alongside traditional investors from Europe and North America (Nguéda, 2022; Oladipupo, 2023). However, SSA continues to face significant challenges in attracting and retaining foreign direct investment (FDI). Political instability, weak institutions, corruption, and inadequate infrastructure remain major impediments. These factors increase investment risks, deter foreign investors, and hinder the effective utilization of FDI for sustainable development in the region. Investment uncertainty, stemming from macroeconomic and political instability, significantly affects the region's private and foreign direct investments.

Traditional biomass and fossil fuels are the primary energy sources in Sub-Saharan Africa, a region abundant in renewable resources but with extreme energy poverty. Many nations in sub-Saharan Africa have started to take action to increase the use of renewable energy sources because they see the promise of clean energy in reducing greenhouse gas emissions and boosting economic growth. Solar energy has grown substantially in recent years, owing to new finance channels and declining technical prices (Boccard, 2021). Additional renewable energy sources that are becoming popular include wind, hydropower, and geothermal power. By supplying the funding, knowledge, and experience needed to create projects and transfer technologies, FDI is vital for scaling up renewable energy infrastructure in SSA. Investments in renewable energy sources can also improve regional technology, leading to a positive feedback loop of innovation and long-term prosperity (Jie, 2022).

Technological advancement is crucial for boosting productivity, diversifying economies, and elevating living standards in Sub-Saharan Africa. Foreign Direct Investment is a significant conduit for transferring technology and introducing fresh knowledge, skills, and innovations to the region (Nguéda, 2022) [10]. Investing in areas such as telecommunications, information technology, and manufacturing can drive technological advancement and promote the growth of a skilled workforce. Furthermore, technological advancements can potentially improve the competitiveness of SSA economies, attract additional foreign direct investment, and foster export diversification. For example, the AQIDP, although designed to enhance environmental quality, may impose additional regulatory challenges on companies, which could affect their advancement in digital transformation.

Growing environmental awareness and stricter environmental regulations are prompting investors to prioritize environmental quality in their investment decisions. Sub-Saharan African countries committed to environmental protection and sustainable resource management are more likely to attract FDI from environmentally conscious investors. Investments in pollution control, waste management, and sustainable agriculture can enhance environmental quality and create new business opportunities for the region. Furthermore, improved environmental quality can enhance the attractiveness of SSA as a tourism destination and improve workforce health and productivity. Chinese FDI in Africa, for example, has faced scrutiny regarding its environmental impact, highlighting the importance of sustainable practices (Oladipupo, 2023).

The existing literature on FDI in SSA predominantly focuses on traditional determinants such as market size, trade openness, labor costs, and political stability (Asiedu, 2006; Anyanwu, 2012). Although valuable, these models overlook the evolving criteria that investors consider in a post-carbon, ESG-sensitive world. Studies examining sustainability-related factors tend to isolate them, examining either environmental policy, technology adoption, or renewable energy infrastructure, but seldom the synergistic interaction among all three. This segmentation fails to capture the integrated nature of modern investment decisions, in which clean energy, innovation ecosystems, and environmental governance interact to shape investor confidence. Furthermore, empirical evidence on how these variables collectively influence FDI inflows in SSA remains sparse, limiting their translation into policy recommendations. This study aims to provide a more holistic framework for understanding and leveraging sustainable FDI drivers in SSA by addressing this research gap.

This study addresses these gaps by offering a unique triangulation of clean energy, technological advancement, and environmental quality within the foreign direct investment framework in Sub-Saharan Africa. This study seeks to provide empirical evidence by analyzing the interactive effects of these variables, which can guide policymakers in developing strategies that effectively attract FDI while promoting sustainable development (Yeboah et al., 2024). This approach offers a more thorough framework for understanding how SSA countries can strategically leverage FDI to stimulate economic growth, improve environmental stewardship, and encourage the adoption of clean technology. This study aims to deliver practical recommendations for policymakers, aiding in the formulation of focused strategies that integrate FDI with sustainable development goals in SSA. The diagram illustrates the connection between international capital flows, governance quality, ICT (Information and Communication Technology) diffusion, and sustainable development goals. The quality of governance plays a pivotal role in this diagram. The hypothesis suggests a significant influence on the connection between international capital flows and the development goals. Effective governance can foster an environment conducive to the optimal use of international capital flows to pursue sustainable development goals.

2. LITERATURE REVIEW, HYPOTHESIS DEVELOPMENT, AND RESEARCH GAP

2.1. Renewable Energy Consumption and FDI

Renewable energy offers a variety of amenities, including free energy sources. This industry is massively propagating, and several jobs have been created to design and implement future renewable energy solutions. Approximately 6 billion people of the global population depend on fossil fuels from other countries, making them vulnerable to geopolitical collisions. For sustainable development, these issues should be mitigated as soon as possible. The International Renewable Energy Agency (IRENA) estimates that approximately 90% of the world's electricity should come from renewable energy sources by 2050. In addition, the enormous advantage of renewable energy is that an influential portion of it is considered green and clean energy. These are not the only factors that grant environmental advantages. The existing literature has found a positive link between FDI and renewable energy (RE). According to Doytch and Narayan (2016), FDI can increase the use of renewable energy and indicate a shift toward clean energy sources. Khandker et al. (2018) also found a positive relationship between FDI and renewable energy. This literature expresses that Bangladesh has performed marvelously in terms of stable economic growth and achieving millennium developments. Attracting more FDI could favor the development of investment in the renewable energy sector. Shahbaz et al. (2022) exposed many elements that affect a country's usage of renewable energy; the study examined data collected over almost 20-year years from 39 nations. FDI financial development is linked to enhancing the use of renewable energy and considers an adverse composition effect over time. Tan and Uprasen (2022) express both positive and negative sides, as strong environmental regulations can promote REC, and low-rigidity environmental legislation can reduce REC with the help of foreign direct investment (FDI). In Southeast Asia, FDI positively impacts renewable energy consumption (Mai, 2023). In another study, Keeley and Matsumoto (2018) found a remarkable increasing trend of foreign direct investment (FDI) in renewable energy projects, especially in emerging countries with extensive wind and solar energy. Through a survey of the literature and interviews with experts, this study seeks to recognize the factors impacting the placement decisions of these types of investments. Through semi-structured interviews, they identified 18 of the most important factors. In another study, Parab et al. (2020) built a model of sustainable development to exhibit the causality of integration among foreign direct investment inflows and renewable energy consumption. This indicates a one-way causality from renewable energy to FDI inflows and the presence of a long-run relationship. Sarkodie et al. (2020) stated that renewable energy consumption is crucial for decreasing greenhouse gas emissions, even though it is a sign of economic growth and other factors. From 1990 to 2017, 47 Sub-Saharan African countries tried to figure by using the Kyoto Protocol to estimate climate change mitigation and fossil fuels. Income level and governance can increase emissions by themselves; however, when combined with renewable energy, they can attenuate the impact on emissions. This study implies that the only way to solve this is to shift to cleaner energy sources in developing economies. Foreign direct investment in renewable energy consumption can contribute positively while requiring environmental or atmospheric, economic, and local social considerations. In this study, Khan et al. (2021) express that technological innovation and FDI can increase renewable energy and CO_2 emissions in the Belt and Road Initiative (BRI) in approximately 69 countries from 2000-2014. All BRI nations must prioritize financial development to encourage the use of renewable energy sources.

2.2. CO_2 Emission and FDI

Carbon dioxide (CO_2) emissions have a significant impact on foreign direct investment (FDI). Thus, foreign direct investment fetches neoteric technologies to the host countries. Multinational companies continuously invest in crystal-clear and proficient production processes that reduce carbon emissions. In this study, Eriandani et al. (2020) uncovered the bond between FDI in polluting industries and enhanced CO_2 emissions per capita in five ASEAN countries. This implies that it may play a role in environmental deterioration. Copeland and Scott Taylor (1993) emphasize that foreign direct investment can lead to rising carbon emissions in host countries, even if environmental rules are slack. Djellouli et al. (2022) examined the connection between renewable and non-renewable energy, economic growth, and environmental downfall by CO_2 emissions, covering approximately 20 African nations from 2000 to 2015. Another hypothesis is the pollution haven hypothesis (PHH), which states that lax environmental rules and regulations in host countries will lead to massive pollution in some industries, and consumption levels will be shifted from other countries through trade and foreign direct investment, causing a momentous rise in pollutant emissions (Savona and

Ciarli, 2019). Nowadays, some studies state that foreign direct investment is crucial to curtailing carbon dioxide emissions because of developments in management practices and modern technologies Zhu et al. (2016) Wang et al. (2019). Another study found that FDI affects carbon dioxide emissions, indicating a link between foreign direct investment and environmental factors in Italy. There is a complex relationship between foreign direct investment and carbon dioxide emissions Pazienza (2019) found a positive relationship between CO_2 emissions and FDI, exposing a workable adverse effect on the environment. They investigated organisation for economic co-operation and development (OECD) countries from 1989 to 2016 by constructing a panel data technique to consider the individual account technique, scale, and cumulative effects of foreign investments on carbon dioxide. In contrast, the magnitude of this positive impact was small.

Moreover, foreign investment has an adverse effect on CO_2 emissions as the volume of foreign investment increases. This study also emphasizes that FDI may have positive environmental consequences by conducting technological innovations that could lead to cleaner production systems and lower CO_2 emissions. Production-related actions are the main contributors to carbon dioxide emissions, as stated by Jalil and Mahmud (2009). Prior findings have disputed that foreign investments support economic welfare growth through advanced technology transfer employment Azman-Saini et al. (2010). In worldwide economies, foreign direct investment inflowed approximately 2 trillion dollars in 2015, according to UNCTAD (2019). Environmental sustainability can be achieved in host countries when high-level assent with appropriate ecological legislation raises green technology innovation through foreign direct investment. The pollution halo hypothesis is environmentally friendly, whereas the pollution haven hypothesis states that weak environmental regulations and organizations worsen the environment. Some previous findings about these theories could be more evident; for example, Shahbaz et al. (2015) Abdouli and Hammami (2017) also found that foreign direct investment civilizes environmental durability by decreasing CO_2 emissions. Moreover, FDI allows the transfer of the dispersion of green technologies to host countries.

Bukhari et al. (2014) expressed that FDI has a hostile environment that increases CO_2 emissions; however, capital formation might be mitigated by encouraging greener industrial methods by studying 1974-2010 data. Therefore, Pakistan should use environment-friendly methods in green technology. Rafique et al. (2020) highlighted that environmental costs do not fully cover technological innovation and financial development. Therefore, economic growth, urbanization, and energy use are connected with CO_2 emissions, whereas FDI and technological innovation have a negative association with CO_2 emissions in the BRICS countries from 1990 to 2017. Shaari et al. (2022) conducted a study in Malaysia and found that foreign direct investment did not directly collide with carbon dioxide emissions between 1989 and 2019 using the ARDL technique. The study found that industrial transportation energy consumption notably increased emissions, whereas energy use in agriculture reduced emissions. In Indonesia, foreign direct investment has a negative short-dated confederation with carbon dioxide emissions, whereas it has a positive sway on CO_2 emissions in the long term. While agricultural land and energy use increase emissions, forest land decreases emissions. In Southeast Asia, foreign direct investment positively influences renewable energy consumption, which can help curtail emissions, as carbon dioxide emissions GDP negatively influences renewable energy consumption (Mai, 2023). The effect of foreign direct investment on carbon emissions is intricate and varies according to national, sectoral, and organizational factors. Policymakers should consider this a serious issue.

2.3. Technological Innovation and FDI

The body of knowledge on the relationship between technological innovation and foreign direct investment (FDI) has dramatically expanded in the last few decades. This body of work sustains a common theme: Technological innovations in host economies can contribute to the inflow of FDI to the extent that they reduce investment risks, nurture competitive advantages, and produce novel investment opportunities that multinational enterprises are willing to pursue. Foreign direct investment (FDI) plays a significant role in technological innovation, offering benefits and challenges to host nations. According to Rafique et al. (2020), it provides access to financial resources, markets, and advanced technologies that are essential for research and development (R&D). The Impact of FDI on technological innovation varies across economies, as seen in the BRICS countries from 2000 to 2020, where FDI positively influenced trade openness, economic growth, and R&D, ultimately strengthening environmental sustainability. Technological innovation significantly reduces ecological emissions through spillover effects. Sivalogathasan and Wu (2014), Wu et al. (2015), and Erdal and Göçer (2015) also support this. Henriques and Borowiecki (2017) affirmed that innovation is crucial for environmental sustainability in 12 highly remunerative economies. Marasco et al. (2024) examined 28 nations from 1989 to 2019 and found that the relationship between FDI and technological innovation follows a U-shaped curve, depending on the technological level of the FDI. Similarly, Suki et al. (2022) observed that technological innovation enhances production capability in Malaysia while reducing carbon emissions. The adoption of renewable energy and technological innovation in 26 OECD countries from 1990 to 2014 further supports the Environment Kuznets Curve (EKC) framework, demonstrating that sustainable prosperity can be achieved through renewable energy and innovation (Ahmad et al., 2021).

In Egypt, Wang and Liu (2022) argued that for China to achieve sustainable progress, it must enhance carbon emission efficiency and promote domestic green innovation as FDI can indirectly contribute to carbon emissions. Yang et al. (2021) highlighted the importance of intellectual property rights (IPR) and transportation infrastructure in effectively utilizing technology spillover for economic and environmental sustainability. Zeng and Zhou (2021) state that while China has made significant advancements in technology and economic growth, concerns about rising pollution levels persist. Loukil (2016) revealed that the effectiveness of FDI in fostering innovation is not guaranteed in developing countries, as seen in 54 nations studied between 1980 and 2009, where technological capabilities must be built internally alongside FDI. Renewable energy sources, such as solar, wind, biofuels, and hydropower, are vital for reducing carbon emissions, with substantial cost reductions in solar and wind energy observed in recent years (IEA). According to Jindra (2006) and Ali et al. (2023), FDI facilitates technological transfer, allowing multinational corporations (MNCs) to share expertise, skills, and innovations with host nations. However, Fan (2003) states that technology transfer is not automatic; internal firms must have absorptive capacities to utilize foreign technologies effectively. While earlier views considered technological knowledge a public good, modern perspectives emphasize licensing and patent agreements. Gerschenkron's hypothesis suggests that greater technological gaps between developed and developing nations enhance the potential for emulation. Parfinenko (2020) and Akpan et al. (2014) revealed that FDI in BRICS countries increased from 6% to 19% between 2000 and 2018, reflecting technological advancement and high-technology exports. Ultimately, FDI catalyzes technological innovation, but its effectiveness depends on the efficiency of resource transfer, domestic absorptive capacity, and supportive policies in the host nations. A summary of the literature survey is presented in Table 1.

3. DATA AND METHODOLOGY OF THE STUDY

3.1. Theoretical and Conceptual Development of the Study

Endogenous growth theory, institutional theory, and the Eclectic Paradigm (OLI model) provide the theoretical framework for this study. These theories offer different but complementary views on the factors influencing foreign direct investment (FDI) and how clean technology, energy, and the environment might entice FDI. The OLI model, which stands for Dunning's Eclectic Paradigm, provides a thorough framework for comprehending foreign direct investment (FDI) decisions. If the three prerequisites of ownership (O), location (L), and internalization (I) are satisfied, corporations will participate in foreign direct investment (FDI). According to this study, clean energy availability, technical preparedness, and solid environmental governance are crucial location-specific characteristics that attract or repel foreign direct investment (FDI), mainly focusing on SSA nations' "L" (location advantages). Natural resources, market size, labor prices, infrastructure, and institutional quality are some of the "L" components that propose why companies invest in specific places. First, foreign direct investment (FDI) may use SSA's distinct locational advantages, even if the region faces several developmental obstacles. According to this study, investors concerned about the environment might benefit significantly from locations with access to sustainable energy resources, such as solar and wind power. Additionally, investor views and decisions are greatly influenced by the quality of environmental governance, which includes the strictness and enforcement of environmental legislation. Reduced investment risk and the attraction of long-term FDI are the results of a regulatory framework that is both stable and predictable, which is signaled by high environmental quality. According to the endogenous development theory, long-term economic development is driven by technical advancement and innovation. In contrast to conventional neoclassical models, endogenous growth models emphasize internal variables, such as human capital, R&D, and institutional frameworks, as drivers of innovation and long-term economic expansion. This hypothesis proposes that investments in clean energy infrastructure and technology capabilities might increase the region's absorption capacity, which in turn makes it more appealing for foreign direct investment in the context of sub-Saharan Africa.

Reduced carbon emissions, increased investment possibilities, and technical spillovers are all benefits of clean energy infrastructure, including smart grids and renewable energy projects. The sub-Saharan African (SSA) region can attract foreign direct investment (FDI) that is looking for ecologically responsible and sustainable investment possibilities by adopting technological innovation and renewable energy solutions. Institutional theory emphasizes the importance of high-quality regulations and environmental standards in determining investment climates. Investors from other countries seek stable and transparent business environments and high environmental quality. Inflows of foreign direct investment (FDI) into sub-Saharan Africa are strongly influenced by the quality of its institutions, such as regulatory frameworks, governance structures, and property rights. Carbon emission requirements and other pollution control measures are examples of environmental restrictions that may impact FDI choices. Environmentally concerned businesses looking to boost their image and enter green markets may be enticed by strict rules, which may initially turn off some investors. The critical variables in this study were included, which is justified by the three hypotheses that were taken together. In line with the OLI paradigm, clean energy is seen as an infrastructural asset peculiar to a particular region, increasing SSA's appeal to foreign direct investment. According to the Endogenous Growth Theory, technology is an internal growth engine that increases SSA's production and absorption capacity. Institutional theory emphasizes that regulatory standards and environmental quality are important institutional elements that influence investment.

3.2. Model Specification

To empirically investigate the relationship between clean energy infrastructure, technological advancement, environmental quality, and foreign direct investment (FDI) inflows in Sub-Saharan Africa (SSA) for the period 2004-2022, the following panel regression model is proposed:

$$FDI_{it} = \alpha + \beta_1\, CE_{it} + \beta_2\, TT_{it} + \beta_3\, EQ_{it} + \Gamma z_{it} + \mu_i + \epsilon_{it} \quad (1)$$

Where FDIit: Foreign Direct Investment inflow for country *i* in year *t*; CEit: Share of renewable energy in total energy production; TIit: Technological development proxy (e.g., ICT access, innovation index); EQIt: Environmental quality measure (e.g., EPI score or CO_2 emissions per capita); Zit: Vector of control variables (e.g., GDP, trade openness, political stability); μi is the country-specific fixed effects; and ϵit is the error term. Tables 2 and 3 display the variable definitions, data sources, and expected results from the empirical findings.

Clean energy infrastructure, measured as the share of electricity derived from renewable sources, serves as a critical locational advantage in line with Dunning's Eclectic Paradigm. The availability of sustainable energy reduces long-term operational costs and indicates environmental foresight. This particularly attracts investors who prioritize ESG criteria, especially in energy-intensive sectors. Empirical studies underscore this positive relationship). Alternatively,

Table 1: Literature summary table

Authors	Country	Methodology	REC	CO_2	TI	Causality
Doytch and Narayan (2016)	74	Blundell-Bond Dynamic Panel Estimator	+ve	-	-	REC < --- > FDI
Khandker et al. (2018)	Bangladesh		+ve	-	-	REC < --- > FDI
Djellouli et al. (2022)	20 (African nations)	EKC, CSD, Unit Root, Panel ARDL	−ve (On Co2 emission)	+ve (Co2 emission in the long run)	-	FDI < --- > REC, CO_2
Shahbaz et al. (2022)	39		+ve	-	-	FDI → REC
Lin et al. (2022)	China		-	+ve −ve	-	FDI < --- > CO_2
Huang et al. (2019)	China	Panel Quantile Regression	-	+ve −ve	-	FDI →CO_2
Zhang et al. (2023)	China	Vector Error Correction Model (VECM)	+ve	−ve	-	FDI < --- > REC, CO_2
Eriandani et al. (2020)	5 Asian Country	Panel Granger Causality Tests	-	−ve	-	FDI → CO_2
Bukhari et al. (2014)	Pakistan	Autoregressive Distributed Lag (ARDL)	-	+ve −ve	-	FDI → CO_2
Loukil (2016)	54	Panel Threshold Model	-	-	+ve −ve	FDI → TI
Zeng and Zhou (2021)	China	Dynamic Panel Simultaneous-Equation Model	-	-	+ve −ve	FDI < --- > TI
Marasco et al. (2024)	28	Generalized Method of Moments (GMM)	-	-	+ve	FDI < --- > TI
Rafique et al. (2020)	BRICS countries	AMG and Dumitrescu and Hurlin Panel Causality Test	-	−ve	+ve	FDI < --- > CO_2, TI
Wang and Liu (2022)	China	Panel Data Aalysis, VECM, Granger Causality Test	-	−ve	+ve	FDI < --- > TI, CO2
Ahmad et al. (2021)	26 OECD economies		+ve	−ve in the short-run	+ve	FDI < --- > REC, CO_2, TI
Ashiq et al. (2023)	5 South Asian	Ordinary Least Squares (OLS) and Fixed Effects Methodologies	-	−ve	+ve	
Yang et al. (2021)	China	EKC	-	-	+ve −ve	FDI < --- > TI
Khan et al. (2021)	69 (BRI nations)	Robust Standard Error Regression and GMM	−ve	+ve	+ve	TI < --- > FDI, REC FDI < --- > REC
Tan and Uprasen (2022)	BRICS countries	Panel Threshold Method and GMM	+ve −ve	-	-	FDI < --- > REC
Sarkodie et al. (2020)	47 Sub-Saharan African	Kyoto Protocol	+ve	−ve	-	FDI < --- > REC REC → CO_2
Pazienza (2019)	OECD countries	Panel Data Technique	-	+ve	-	FDI < --- > CO_2
Kor and Qamruzzaman (2023)	Bangladesh	Panel data analysis	+ve Impact of FDI on REC	-	-	FDI → REC
Kılıçarslan (2019)	BRICS countries and Turkey	Panel ARDL	−ve on FDI	-	-	REC → FDI
Omri et al. (2014)	Global 54 countries	Dynamic simultaneous-equation panel data models	-	−ve	-	REC < --- > FDI

Table 2: Variable definitions and data sources

Variable	Proxy/measurement	Source
FDI inflows (FDI)	Net FDI inflows (% of GDP) or USD inflow	World Bank WDI
Clean energy (CleanE)	% of electricity generated from renewable sources	IEA, World Bank
Technological advancement (Tech)	R&D spending	ITU, WIPO, World Bank
Environmental quality (EnvQ)	CO_2 emissions per capita	Yale EPI, World Bank

$$\frac{\partial FDI}{\partial \text{CE}} = \beta 1 > 0$$

Technological progress—captured through proxies such as ICT penetration and R&D investment—enhances a host country's absorptive capacity, indicating its readiness to integrate foreign technology and knowledge spillovers. According to the Endogenous Growth Theory, such capacity amplifies productivity and innovation potential, attracting technologically oriented FDI. Therefore, a positive sign for β2 is expected.

$$\frac{\partial \text{FDI}}{\partial \text{TI}} = \beta 2 > 0$$

Environmental quality is operationalized via the environmental performance index (EPI) or, inversely, by CO_2 emissions per capita. Strong environmental governance often reflects institutional integrity and policy predictability, which are factors positively associated with investor confidence. Research suggests that environmentally conscious investors prefer jurisdictions with transparent and enforceable regulatory frameworks.

Table 3: Summary expected signs of coefficients

Variable	Expected sign	Justification
Clean energy (CE)	+	The availability of clean energy reduces operational costs and aligns with ESG goals, thus attracting environmentally conscious investors.
Technological innovation (TI)	+	Higher ICT penetration and innovation capacity signal absorptive capability and future readiness, which is important to high-tech and knowledge-intensive investors.
Environmental quality (EQ)	+	A proxy for institutional quality, high environmental standards assure stability and reduce reputational risks.
Trade openness (TO)	+	Openness facilitates access to inputs and export markets, reducing trade barriers.
Political stability (PS)	+	Political certainty reduces risk and encourages long-term investment.

$$\frac{\partial FDI}{\partial EQ} = \beta 2 > 0$$

3.3. Estimation Strategies

3.3.1. The slope of heterogeneity

This concept refers to the correlation between independent and dependent variables, which differ throughout the groups or individuals in a panel data model called slope heterogeneity. The differences in slopes across the units indicate that the association between the variables must be evaluated independently for different units or groups.

$$\gamma_{i,t} = \mu_i + \beta'_{1i} x_{li,t} + \beta'_{2i};x_{2i,t} + \mathcal{E}_{i,t} \quad (2)$$

Where i = 1,...., N represents the cross-sectional dimension and t = 1,..., T the time dimension. μ_i is a unit-specific constant. β_{1i} is k1×1, β_{2i} is k2×1, and both are vectors of unknown slope coefficients with k = k1 + k2 being the total number of regressors. $x_{1i},_t$ is a k1 ×1 vector, and $X_{2i,t}$ is a k2 ×1 vector containing strictly exogenous regressors.

3.3.2. Cross-sectional dependency test

This test refers to the interconnection or correlation between the error terms of various cross-sectional units, firms, and individuals in the panel dataset. This may have crucial ramifications for assumptions in statistical models; if not used properly, it may lead to erroneous estimations and fraudulent conclusions. Pesaran's test is based on the unexceptional of all pair-wise relationship factors of the OLS remaining from the individual regressions.

$$y_{it} = \alpha_i + \beta'\chi_{it} + \mu_{it} \quad (3)$$

Here, i = 1,..., N and t = 1,...,T; where χ_{it} is a K × 1 vector of regressors, β is a K × 1 vector of parameters to be estimated, and α_i represents time-invariant individual nuisance parameters.

3.3.3. Panel cointegration test

This panel cointegration test helps identify whether a set of non-stationary variables has a long-term equilibrium correlation in a panel data framework. This test grants for heterogeneity throughout the cointegrating vectors and short-run dynamics in the cross-section terms.

$$Y_{it} = \alpha_i + \delta_i t + \gamma_t + X_{it} B_i + e_{it} \quad (4)$$

Where, for a time series panel γ_{it} and X_{it} for members i=1…., N over periods t=1,…., T. In general, X_{it} may be an m-dimensional vector for each member i. The parameters α_i and δ_i enable the capacity of member-specific fixed effects and deterministic trends. Y_t enables the ability to have common effects. β_i is the slope coefficient.

The fixed effects regression model is designed to estimate the effects of the idiosyncratic characteristics of individuals in a panel dataset. Considering that individual characteristics are not random and can affect the outcome variables, the effect of the soothsayers is not controlled by fixed characteristics.

$$\gamma_{it} = x_{it}\beta + \alpha_i + \epsilon_{it} \quad (5)$$

The panel data consist of observations settled chronologically, and panels, which means time series are curvaceous to one another, are pooled data. Most of the cross-sections are (N→∞, T). Now, in years t = 1,………, T for individuals i = 1,……., N. Assuming the variable Y is a continuous outcome, although the K is a regressor X1,……, XK can be measured. γ_{it} is an observation outcome, i at time t, X_{it} is the (1 × K) vector of covariates, β is the corresponding (K×1) vector of parameters; α_i is unobserved effects appropriating time-constant individual heterogeneity. Thus, ϵ_{it} is an idiosyncratic error that differs over time and subjects.

The random effects presuppose that unsighted or unobserved random effects are earmarked for every unit that impacts the dependent variable. Therefore, these effects are independent and have zero means. This effect is used when the impalpable individual effects are not connected to the regressors. The individual effects become random variables rather than fixed variables.

$$Y_{it} = \alpha + \beta' X_{it} + u_i + \varepsilon_{it} \quad (6)$$

In this random effects model, residuals may be interrelated between time individuals and cross-sections. Thus, this model presupposes that each individual has dissimilar intercepts and that the intercept is a random variable. Now, i = 1,……, N, where N is the number of cross-sections or individuals, and t = 1,…., T, where T is the period of the wave. u_i is the individual residual, the random characteristic, and εit is the residual of the combination of time series and cross sections.

An econometric method is used to evaluate cointegration associations in panel data, specifically where endogenous variables and means impact each other variables, known as dynamic ordinary least squares (DOLS). This enhances the concept of ordinary least squares (OLS) regression to solve specific challenges in panel cointegration analysis. DOLS is used to evaluate long-run equilibrium connections between non-stationary variables.

$$y_{it} = \varnothing_i + \delta_t + \beta'_i z_{it} + \sum_{j=-p}^{p} d_{ij} \Delta z_{i,t+j} + \mu_{it} \quad (7)$$

i =1,2,3,………………N

t =1,2,3,………………T

ϕ_i = Intercepts denoting individual fixed effects

δ_t = Time trend/effort

Z_{it} is a vector explanatory variable, β_i is the evaluated long-run impacts, leads, and lags are shown as ρ, whereas d_{ij} is the coefficient of a lag of the first distinguished explanatory variables. Then, μ_{it} indicates the error term that has followed the I(0) process.

This model is a panel data estimation procedure that directs problems of cross-sectional dependence, endogeneity, and slope heterogeneity. This method is suitable for scenarios in which the model error terms are connected between various cross-sectional units. It is competent in managing situations where some or all variables are non-stationary in the model, meaning their mean or variance fluctuates over time. A generalized CS ARDL equation is given below:

$$\overline{FDI}_{it} = \bar{\alpha}_{it} + \sum_{m=1}^{p} \bar{\beta}_{im} \overline{FDI}_{i,t-m} + \sum_{m=0}^{q} \bar{\gamma}_{im} \bar{Q}_{i,t-m} + \bar{\omega}'_t G_t + \bar{\epsilon}_{it} \quad (8)$$

Here, the decomposition is as follows

$$\bar{\alpha}_{it} = \frac{\sum_{i-1}^{N} \alpha_i}{N}$$

$$\overline{FDI}_{t-m} = \frac{\sum_{i}^{N} FDI_{i,t-m}}{N}, \bar{\beta}_m = \frac{\sum_{i}^{N} \beta_{i,m}}{N} \text{ where, m=0,1,2,3,……,p}$$

$$\bar{Q}_{t-m} = \frac{\sum_{i}^{N} Q_{i,t-m}}{N}, \bar{Y}_m = \frac{\sum_{i}^{N} Y_{i,j}}{N} \text{ where, m = 0,1,2,3,……,q}$$

$$\bar{\epsilon}_t = \frac{\sum_{i}^{N} \epsilon_{i,t}}{N}$$

To examine the causality connection in panel data, we use the Bootstrap Panel Granger Causality test of Dumitrescu and Hurlin (2012). It is a cross-sectional dependence and small-sample bias method; hence, bootstrap methods are used for causality inferences.

$$g_{it} = \alpha_i + \sum_{j-1}^{P} \gamma_{ij} Y_{i,t-j} + \sum_{j-1}^{P} \beta_{ij} X_{i,t-j} + \varepsilon_{it} \quad (11)$$

To illustrate this, X_{it} and Y_{it} symbolize the observations of two stationary variables for individuals *i* in period *t*; the coefficient may diverge throughout the individual sample, although it remains time-invariant. Moreover, *j* is the lag order, which is uniform throughout the panel. ε_{it} is the error term that captures the inexplicable variation in FDI.

4. EMPIRICAL MODEL ESTIMATION & INTERPRETATION

Table 4 presents the results of various Cross-Sectional Dependence (CSD) tests, including Breusch-Pagan's LM (1980), Pesaran (2004) CD, and others. All variables—FDI, renewable energy consumption (REC), CO_2 emissions (GO2), technological innovation (TI), institutional quality (IQ), and education (EDU)—exhibit statistically significant cross-sectional dependence at the 1% level for all test specifications. This confirms that shocks or policy changes in one country within the panel are likely to affect others, validating the presence of interdependencies across Sub-Saharan African economies. Consequently, these results justify the application of second-generation panel econometric techniques that account for cross-sectional dependence in this study.

The results of the panel unit root tests in Table 5 confirm that all variables—FDI, REC, GO2, TI, IQ, and EDU—are non-stationary at the level but become stationary after first differencing. This is consistent across the CADF, CIPS, and Herwartz and Siedenburg (2008) tests, where the first-difference test statistics are statistically significant at the 1% level (denoted by ***). The presence of unit roots at level and stationarity at the first difference indicates that the variables are integrated of order one, I(1). These findings justify the use of panel cointegration techniques for long-run relationship analysis in subsequent estimations.

The results of the panel cointegration tests in Table 6 strongly indicate the presence of long-run equilibrium relationships between FDI and all five explanatory variables: renewable energy consumption (REC), technological innovation (TI), CO□ emissions, institutional quality (IQ), and education (ED). Statistically significant values across multiple statistics (Gt, Ga, Pt, Pa) confirm cointegration at the 1% level (***). This implies that FDI movements are closely linked to sustainable development indicators over time. Notably, strong cointegration with REC and IQ supports the notion that green infrastructure and robust institutions are long-term attractors of foreign investment, consistent with the sustainability-focused FDI literature.

Table 7 provides insights into both the long-run and short-run relationships between FDI and other key variables. Here, all the variables have positive coefficients in the long and short run, meaning they all positively impact FDI. When these factors increase, they hardly contribute to attracting more FDI inflow. The coefficient of renewable energy consumption is 0.1057%, which means that a 1% increase in this factor is associated with a 0.1057% increase in FDI in the long run, demonstrating that a higher amount of REC positively influences FDI. Additionally, a 1% increase in carbon dioxide emissions is linked to a 0.1464% increase in FDI in the long run. However, countries with higher emissions attract FDI due to industrial operations. In contrast, the coefficient of technological innovation is positive and statistically significant, with a test statistic of 6.375 and a coefficient of 0.0255. A 1% increase in this factor is linked to a 0.0255% increase in foreign investment in the short run. Therefore, all other factors are positively significant in long-term relationships. However, most variables (REC, CO_2, TI, EDU) show positivity

Table 4: Result of CDS test

Variables	(Breusch and Pagan 1980)	Pesaran (2004)	Pesaran, Ullah et al. (2008)	Pesaran (2006)	Juodis and Reese (2022)
FDI	260.909***	42.98***	127.313***	48.856***	10.7659***
REC	440.194***	45.424***	116.838***	27.558***	10.0561***
GO2	357.619***	20.082***	177.943***	41.832***	10.4243***
TI	409.089***	19.537***	161.373***	10.922***	12.7507***
IQ	267.312***	32.693***	100.848***	45.628***	11.1703***
EDU	354.677***	36.413***	157.738***	54.701***	8.7893***

Table 5: Result of panel unit root test

Variables	CADF test statistic		CIPS test statistic		Herwartz and Siedenburg -2019	
	Level	First difference	Level	First difference	Level	First difference
FDI	−2.792	−5.199***	−2.526	−3.983***	0.0772	8.3968***
REC	−2.308	−2.476***	−1.249	−5.323***	−0.2913	8.2325***
GO2	−2.998	−4.541***	−2.3	−2.081***	1.7698	8.3194***
TI	−2.833	−2.091***	−2.561	−4.676***	1.8042	6.1498***
IQ	−1.102	−7.789***	−1.179	−7.088***	1.2747	4.1039***
EDU	−1.258	−4.964***	−2.467	−4.657***	−0.6738	6.2771***

Table 6: Result of panel cointegration test

Model	FDI--->REC	FDI--->TI	FDI--->CO2	FDI--->IQ	FDI--->ED
Gt	−15.854***	−10.412***	−9.66***	−14.405***	−8.115***
Ga	−14.304***	−5.775***	−10.291***	−5.887***	−8.92***
Pt	−10.343***	−4.623***	−8.273***	−8.575***	−13.959***
Pa	−12.928***	−5.071***	−5.475***	−14.271***	−12.146***
KRCPT					
MDF	15.179***	−2.531***	−3.53***	14.973***	15.656***
DF	−3.589***	22.134***	14.685***	2.398***	22.954***
ADF	−5.572***	−0.017***	19.322***	20.846***	17.311***
UMDF	7.124***	18.985***	17.797***	9.013***	−3.121***
UDF	−10.403***	4.034***	7.075***	21.94***	18.234***
PCT					
MDF	15.736***	7.299***	2.759***	1.652***	12.44***
PP	1.743***	−1.991***	−5.523***	9.847***	0.369***
ADF	11.159***	15.474***	8.706***	12.833***	12.557***

Table 7: Results of the CS-ARDL test

Variables	Coefficient	t-statistic	Standard error	Variables	Coefficient	t-statistic	Standard error
Panel A: Long -run coefficients				Panel -B: Short-run coefficients			
REC	0.1057	(0.0106)	9.9716	REC	0.0807	(0.0109)	7.4036
TI	0.0672	(0.0096)	7.025	TI	0.0255	(0.004)	6.375
CO_2	0.1464	(0.0039)	37.5384	CO_2	0.0755	(0.007)	10.7857
IQ	0.0757	(0.0058)	13.0517	IQ	0.018	(0.0118)	1.5254
EDU	0.0399	(0.0089)	4.4831	EDU	0.0711	(0.0054)	13.1666
C	0.1342	(0.0052)	−25.8076	etc	−0.5089	(0.0074)	68.7702
CD test		0.031693					
Wooldridge test for autoco		0.020319					
Normality test		0.625296					
Ramsey RESET test		0.329704					

and statistically significant coefficients; meanwhile, IQ has no statistically significant influence in the short run. To attract FDI, both renewable energy consumption and technological innovation are fundamental in the short- and long-runs. In the long-run coefficient, the influence of FDI has fully modified variables to their long-term equilibrium. Likewise, investing in renewable energy projects would attract more foreign investors and create a more attractive environment. In addition, sustainable development and environmental policy are raised by the positive relationship with CO2 emissions. However, it reflects the immediate actions or effects of increasing this sector to boost FDI. For instance, in the short-run, the coefficient for carbon dioxide (CO_2) emissions may prevent FDI, considering the instantaneous concerns of investors regarding environmental sustainability.

The impact of renewable energy consumption on foreign direct investment (FDI) is a subject of increasing interest among researchers and policymakers. During this interval, some researchers indicated a positive effect of renewable energy on FDI; however, some other studies found the opposite. These clash results highlight the need for an extensive comprehensive analysis to understand the shades of this dynamic; for the long-run and short-run coefficients, renewable energy and FDI have been exposed significantly. In the long run, renewable energy consumption significantly affects China's health quality in both the short-and long-term. Zhang et al. (2023) implied that using renewable energy can favor health quality; therefore, it indirectly benefits FDI by enhancing the business environment, drawing in more investment. The study on Somalia conducted by Warsame (2023) reveals that renewable energy gravely affects environmental erosion, and reducing ecological concerns and increasing the nation's petitions to foreign investors could positively influence FDI. Another study found that FDI in the solar and wind energy sectors is predominantly enticed by the institutional environment, natural resources, renewable energy legislation, and macroeconomic conditions, which play a vital role in attracting FDI in developing countries Keeley and Matsumoto (2018). Additionally, using renewable energy has the potential to positively impact FDI, economic expansion, and technological advancements in developing countries. This indicates that adopting renewable energy may be driven by economic expansion FDI, which might attract more FDI. Furthermore, technological innovation and economic growth would be enhanced in developing countries by the positive impact of renewable energy consumption; therefore, renewable energy infrastructure could be developed further. Industries that use high technology and are environmentally friendly should be cautious about environmental degradation. Simultaneously, there could be an increase in temperature, climate change, and pollution in every sector. More events can occur that ultimately destroy human health. Shahzadi et al. (2023) focused on environmental pollution, which has become a serious issue for long-term growth in India. This must ensure that renewable energy consumption results in sustainable economic development, emphasizing the necessity for integrated policies that promote renewable energy while regulating ecological repercussions.

Carbon dioxide emissions have an intricate effect on FDI, considering current market conditions, regulatory dynamics, and extensive patterns in environmental policy and technological advancement. Investors may focus on sustainability, flexibility, or pliability in the long run, and alignment with universal climate goals becomes increasingly significant. In the short run, investors should respond to the regulatory framework and market demands. This universal move toward sustainable growth in the future means that understanding these progressives is fundamental for corporations and policymakers. Research conducted by Ullah et al. (2022) indicate that without effective environmental regulations, FDI may aggravate emissions in the long run, as CO_2 and FDI have a long-term equilibrium relationship, which can lead to increased emissions, except when eased by policies. Consequently, this can lead to a prominent reduction in the emissions of CO_2 and other greenhouse gases into the environment. Therefore, the propensity for increased emissions to escort higher FDI, where ecological restrictions are less stringent, characterizes the short-run Impact of CO_2 emissions on FDI. This underscores the necessity of effective ecological policies to alleviate the detrimental impacts of FDI on emissions. The literature verifies the role of FDI in assisting technology transfer and driving economic growth. Technology has a tremendous influence on every sector. The synergistic connection between absorptive abilities and FDI inflows plays a vital role in improving the effectiveness of technological innovation, consequently sustaining economic growth.

In the long run, technological innovation positively enhances trade openness, research and development, and economic growth in some host economies. Foreign direct investment tremendously impacts technological advancement and creates a positive feedback loop that allures more investment in the sector. A recent study by Baltabaev (2014) implies that as countries accumulate more FDI stock over time, they can adapt and absorb new modern technologies from the worldwide limit, which tends to develop and improve, thereby magnifying the long-run development impact. The integration of economic openness and monotonous ecology embellishes the influence of trade openness on innovation, as in China. This magnifies worldwide trade and creates more foreign investments, allowing them to invest in many sectors and promote technological progress Lu et al. (2024). This can result in energy efficiency and sustainable development in the short run, increasing a country's appeal to FDI. FDI frequently leads to quick boosts in efficiency and productivity in the short run; however, this effect varies depending on the technology infrastructure and local environment. Additionally, developing nations struggle to raise benefits because of human capital shortages and infrastructure.

In contrast, developed nations display a higher capacity to leverage these technological transfers, which can hinder their capability to use technology for development goals (Ali et al. (2019). As FDI can stimulate technical innovation over time, the primary effect may not be advantageous; there will be a lag in its positive effects. Therefore, the impact of a short run of economic openness and environmental deterioration can impede the basic benefits of technological innovation on FDI and highlight the importance of generating an environment beneficial to innovation during potential instant problems resulting from higher investment.

The Dumitrescu-Hurlin (D-H) panel causality test (Table 8) reveals several directional relationships between FDI and its hypothesized determinants. Unidirectional causality is observed from renewable energy consumption (REC) to FDI (REC → FDI), suggesting that investments in clean energy infrastructure enhance a country's attractiveness to foreign investors, consistent with the findings of Yasmeen et al. (2023). Similarly, institutional quality (IQ) and education (EDU) also exhibit a unidirectional influence on FDI (IQ → FDI, EDU → FDI), confirming that strong governance and human capital development create a conducive investment climate (Asiedu et al., 2022). Bidirectional causality is evident between FDI and technological innovation (TI ↔ FDI) and FDI

Table 8: Results of DH causality

Null hypothesis	W-statistic	Zbar-statistic	Remarks
FDI<==/==>REC	10.0892	10.634	-->
REC<==/==>FDI	2.5377	2.6747	
FDI<==/==>TI	7.8862	8.312	<---->
TI<==/==>FDI	6.5281	6.8806	
FDI<==/==>CO_2	6.0318	6.3575	<---->
CO_2<==/==>FDI	5.9489	6.2701	
FDI<==/==>IQ	10.0499	10.5925	-->
IQ<==/==>FDI	1.7035	1.7954	
FDI<==/==>EDU	3.8756	4.0848	→
EDU<==/==>FDI	1.6354	1.7237	

and environmental quality (proxied by CO_2 emissions, $CO_2 \leftrightarrow$ FDI), indicating mutual reinforcement—FDI promotes innovation and cleaner technologies, while tech-friendly and environmentally stable economies attract more FDI Borensztein (Borensztein et al., 1998, Avik, 2001, Ali et al., 2019, Ashiq et al., 2023). These findings affirm that sustainable and institutional factors play an integral role in shaping FDI dynamics in SSA.

5. DISCUSSION OF THE FINDINGS

This study investigates the dynamic impact of renewable energy consumption (REC), carbon dioxide (CO_2), and technological innovation (TI) on foreign direct investment (FDI). This study aims to comprehend how other factors influence and engage with one another in these variables. Additionally, it highlights economic development, technical advancement, job creation, and other facilities provided by the government. FDI emerges as an essential root of investment, bringing global interconnectedness and turning undeveloped areas into commercial hubs.

As mentioned above, renewable energy consumption has a preponderantly positive influence on FDI. Several studies have demonstrated that renewable energy consumption is likely to promote inflows of FDI instead of dwindling FDI inflows, signifying that higher renewable energy sectors can attract more investments. This study's findings show that countries that boost renewable energy consumption would also enhance their attractiveness to international investors, leading to more FDI in these sources. This study reinforces the strong relationship between the inclusion of clean energy and technological innovation, as well as environmental degradation and FDI inflows related to SDG-7, demonstrating both coherences and dissimilarities in the larger academic discourse. These findings are consistent with a wave of empirical studies that confirm the positive linkage between FDI inflows and clean energy adoption because renewable initiatives stabilize the economy, reduce energy dependency, and increase investor confidence, notably in emerging economies. It also develops financial markets into international markets and allures FDI; thus, there is an analogous enhancement in renewable energy, boosting sustainable advancement. Improving the business environment and diminishing environmental difficulties by adopting renewable energy could attract more FDI inflows. In addition, government procedures and inducements geared toward promoting renewable energy sectors may further improve FDI by creating a proper and supportive administrative environment for renewable energy sectors. Additionally, it opens new markets for international industries to invest in infrastructure. Industries aim to emerge and develop opportunities in renewable sectors, such as bioenergy, wind, and solar, as this growth can attract more FDI inflows. Reliance on fossil fuels can be reduced by investing in renewable sectors and alleviating risks associated with price fluctuations and energy supply disruptions. This stability is important for foreign investors seeking a stable business operating environment. To create a good environmental image, a solid commitment to renewable energy can improve ecological reputation by making it more attractive. A country that is concerned about and prioritizes the development of renewable energy sectors can create a favorable and attractive environment because it aligns with global sustainability goals and decreases the amount of fossil fuel usage, which leads to a reduction in CO_2 emissions. Tang and Tan (2015) confirm that renewable energy consumption will not only lead to economic growth but also indicate energy security and thus make a country more attractive to foreign investors. This is further supported by Omri and Kahouli (2014), who show that clean energy transitions with a stronger policy framework and better environmental governance reduce investment risk and promote foreign participation. However, challenges to such a consensus exist. Sbia et al. (2014) offer an antithesis to this in less developed countries; low regulatory frameworks and poor energy infrastructures can deter FDI despite such countries trying to convert to renewable energy. According to Achour and Belloumi (2016), in the case of high fines upfront with renewable energy systems, FDI inflow will likely be discouraged, except if the host countries guarantee subsidies or policies to amortize the investor risk. These contradictions suggest that clean energy is an enabler of FDI only under certain macroeconomic and institutional conditions, and its effect is not uniform across all contexts and is contingent on a country's energy and regulatory landscape maturity.

This study also shows a powerful negative relationship between FDI and environmental degradation; environmentally stressed countries are not very attractive to long-term, sustainability-conscious investors. This is consistent with pollution aversion theory, which states that firms, particularly green or knowledge-based ones, seek cleaner and more stable environments to protect their brand reputation and reduce compliance costs. Nations with momentous environmental pollution may seem riskier investments due to possible regulatory changes and an unpropitious public image, which will decrease FDI inflows. The world economy has been facing a severe issue because of climate change caused by carbon emissions. Shahbaz et al. (2022) stated that financial development and foreign investment can reduce CO_2 emissions because they are concerned about the environment. According to Jalil and Feridun (2011), environmental deterioration in China negatively discouraged FDI because of high regulatory pressure and the cost of mitigating emissions. However, Wang and Liu (2022) suggest that FDI indirectly contributes to CO_2 emissions by impacting technological innovation. Research on the pollution haven hypothesis suggests that some FDI flows go to environmentally lax countries to reduce production costs. This duality of environmental impact further indicates that environmentally degraded FDI may have both a positive and negative relationship with long-term, responsible FDI, a heterogeneous effect based on the sector in which investment occurs, the intent of the investor, and the regulatory expectations that will prevail.

The strong positive relationship between technological innovation and FDI inflows is equally important to this study. This echoes earlier work by those who maintain that FDI inflows are most beneficial and frequent in economies with higher absorptive capacity, of which technological readiness and human capital development are two characteristics. Akinlo and Gregorio (Yoo and Yoo and others have shown that FDI and domestic innovation systems can synergize with foreign capital by introducing new technologies and local institutions that enable their utilization. This view is reinforced by Salim (2024), who illustrates that OIC countries with better information and communication technology (ICT) infrastructure attract more FDI inflows. Likewise, Özsoy et al. (2021) provide evidence of this effect in developed and globalized economies by showing that an increase in R&D expenditure and patent applications is positively associated with investor confidence because innovation reinforces market dynamism and policy consistency. However, this linkage is disputed as being universal in nature. Avik (2001) asserts that technological progress influences FDI only if it leads to commercial outcomes or when the institutional quality is sufficiently developed to safeguard intellectual property. Technological progress may not significantly affect foreign investment, where innovation is not well integrated into economic systems or legal frameworks are weak in some countries. There is a nuance to this argument, however, as Nunnenkamp and Spatz (2004) assert that only some types of industries—pharmaceuticals, electronics, and advanced manufacturing—respond to host country innovation levels in deciding where to locate FDI; the others, notably primary and low-tech industries, depend more on the availability of resources and labor costs. The results of this study are consistent with much of the existing literature and support the hypothesis that achieving SDG-7 (clean and affordable energy) is not only a prerequisite but also an enabler of sustainable foreign direct investment (FDI). If clean energy is integrated efficiently, it will lend the perception of long-term viability and transparency. For developing countries, smart grid technology is extremely valuable for developing their energy infrastructure.

In addition, innovations such as modern newcomers are investigating solar and hydrogen production systems for sustainable energy requirements. The combined solar-hydrogen power production of these two systems will provide greater energy efficiency and a more pliant solution in this dirty environment than traditional systems. This storage procedure can hold Joshua longer (Joshua et al., 2024). The author suggests that university campuses use these two integrations. However, it can be made more applicable with more advanced technologies to provide it in the outside environment seamlessly. In addition, hybrid power systems, such as solar, wind, and hydroelectric systems, are more reliable and cost-effective than renewable energy systems. Another innovation that has vastly grown is the use of sodium-ion and lithium-ion batteries, which can store energy. In addition, bifacial solar panels are expeditiously useful because they can capture sunlight from both sides of the panels. This will increase the energy storage capacity of developing nations. Offshore wind energy has the capability of massive and more advanced turbines, which can potentially generate more power than this single thing Goyal (2024).

The approval process for renewable energy installations should be more accessible, and tax exemptions and subsidies for clean energy projects should be provided. However, environmental degradation undermines investor trust unless it is used for short-term industrial purposes without enforcement. Technological innovation is a key pillar in promoting a country's competitiveness, especially in relation to environmental technology and digital transformation. These multidimensional insights imply that FDI is becoming increasingly subject to the macroeconomic stability of the host country and is also aligned with the host country's sustainability trajectory. Furthermore, policy coherence converges with the SDG proviso: To attract FDI, all countries must create a balanced ecosystem characterized by low and reliable clean energy, predictable environmental policies, and robust and transparent innovation systems. The growing literature on the financial returns of sustainability-led growth acknowledges these benefits and conditions of governance, institutional strength, and long-term policy commitments. Future research and policy regarding foreign investment in the post-carbon economy must identify the interaction effects among environmental and technological determinants and determine which determinant exerts a more substantial influence in countries with differing incomes and regional trade agreements.

6. CONCLUSION AND POLICY SUGGESTIONS

6.1. Conclusion

This study provides empirical insight into how clean energy, technological innovation, and environmental quality are pivotal determinants for attracting Foreign Direct Investment (FDI) in Sub-Saharan Africa (SSA) for 2004-2022. Using robust panel estimation techniques, we confirm that each of these variables not only influences FDI inflows individually but also collectively creates a synergistic effect that amplifies investor confidence and contributes to sustainable economic development. The positive and statistically significant coefficients for renewable energy consumption and technological advancement highlight the strategic role of innovation and energy transformation in modern investment decision-making. Moreover, the evidence affirms that environmental quality—governed by strong institutional frameworks and regulatory clarity—is a proxy for governance quality, which environmentally conscious investors increasingly prioritize. These findings underscore the shift in global capital flows, where ESG-driven investment considerations now rival traditional factors such as market size and labor costs. However, the study also acknowledges the contextual heterogeneity across SSA countries, with varying institutional capacities and energy policies influencing the magnitude of these effects. Countries with stronger governance, clearer policy signals, and active investment in renewable technologies tend to attract more sustainable and long-term FDI. Despite the strength of these findings, this study is not without limitations. The use of aggregated regional data may mask intra-regional disparities, and reliance on proxy indicators such as the Environmental Performance Index (EPI) or ICT penetration may not capture the full complexity of institutional and technological environments. Moreover, the lack of disaggregated sectoral FDI data limits the granularity of the conclusions regarding the specific industries that are most sensitive to sustainability variables. These limitations open avenues for future studies. Scholars should consider conducting sector-specific or firm-level analyses to explore how individual investors perceive and respond to clean energy policies, environmental governance and technological capacity in different SSA countries. Additionally, longitudinal case studies focusing on policy shifts, such as introducing carbon pricing, innovative grid technologies, or digital governance tools, would help isolate causal relationships. As ESG metrics become mainstream in global finance, future research should explore the interactive dynamics between institutional credibility, environmental standards, and innovation ecosystems. Strengthening these areas can better align FDI with the Sustainable Development Goals (SDGs), notably SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action), thereby ensuring that foreign investment acts as a genuine catalyst for inclusive and environmentally resilient development in the Philippines.

6.2. Policy Suggestions

i. To accelerate the adoption of renewable energy, governments should establish clear renewable energy targets aimed at reducing CO_2 emissions, improving energy security, and integrating carbon capture and storage (CCS) technologies into their energy systems. These targets should be supported by financial incentives, such as tax dispensations, subsidies, feed-in tariffs, and tariff breaks, to reduce the financial burden on investors and accelerate the deployment of clean energy projects. Decentralized energy systems, including off-grid and mini-grid solutions, should be expanded to remote areas to enhance energy accessibility. Microgrids and energy storage systems should be developed to improve energy efficiency, stability, and their economic viability. Regulatory frameworks must be streamlined to provide infrastructure support for renewable energy expansion, and Renewable Portfolio Standards (RPS) should be enforced to ensure that electricity utilities incorporate a fixed percentage of renewables in their supply mix. Furthermore, promoting urban renewable installations, such as rooftop solar and wind energy projects, will enhance sustainable energy consumption and reduce dependence on fossil fuels.

ii. To mitigate environmental degradation while maintaining economic growth, governments should implement carbon pricing mechanisms, such as carbon taxes and emissions trading systems (ETS), to encourage businesses to adopt cleaner energy sources. A well-designed carbon tax integrates the environmental costs of greenhouse gas emissions into economic activities, whereas an ETS creates a cap-and-trade system that limits emissions and incentivizes reductions through market-driven pricing. Carbon capture and storage (CCS) technologies should be promoted to reduce the carbon footprint of industries by capturing emissions before they enter the atmosphere. Policymakers should develop targeted FDI policies that consider regional environmental characteristics and ensure that foreign investments align with sustainability goals. Strengthening public-private partnerships (PPPs) will help accelerate investments in clean energy infrastructure, pollution control technologies, and climate resilience projects. Governments must also implement strict emission reduction policies while balancing economic competitiveness to create an attractive, yet environmentally responsible, investment climate.

iii. To foster technological innovation and attract sustainable FDI, governments should implement strong R&D incentives, including tax credits, public funding, and direct financial support for companies that invest in clean technology. Special attention should be given to startups and SMEs working on green technology advancements by providing grants, incubator programs and technical support. Encouraging collaboration through public-private partnerships will accelerate the development of clean energy innovations, while investing in workforce training and capacity building will ensure a steady supply of skilled professionals in the renewable energy sector. The development of innovative grid technologies, including microgrids and energy storage systems, should be prioritized to enhance the integration and efficiency of renewable energy sources in the power grid. Additionally, governments should attract foreign investors with cutting-edge clean technologies to facilitate technology transfer and knowledge spillovers, thereby strengthening the domestic technological landscape for sustainable energy solutions.

6.3. Limitations and Future Direction of the Study

While this study offers valuable insights into the roles of clean energy, technological advancement, and environmental quality in attracting FDI to Sub-Saharan Africa, it has limitations. First, the analysis relies on aggregate panel data, which may obscure country-specific dynamics and sector heterogeneity. Second, the proxy variables used, such as ICT penetration for technology and EPI scores for environmental quality, may not fully capture institutional or infrastructural depth. Additionally, endogeneity concerns, such as reverse causality between FDI and development indicators, could influence the robustness of the results of this study. Future research should adopt disaggregated or micro-level data to understand the nuances across industries and investment types. Case studies focusing on specific SSA countries with divergent energy and regulatory profiles can provide a richer context. Furthermore, integrating qualitative assessments of investor behavior and ESG compliance trends would enhance our understanding of how sustainability signals influence long-term FDI decisions in emerging markets.

6.4. Funding Statement

This research was supported by the Institute of Advanced Research (IAR), United International University (UIU). under Grant No. IAR/2025/pub/068

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