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Nexus Between Economic Development and Renewable Energy on Co_2

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Abstract

This study examined the nexus between economic development and renewable energy on CO_2 using data from forty-five nations in the SSA area from 1980 and 2020. It delved into how the growing economy impacts renewable energy in terms of CO_2 emissions. For the empirical analysis, the Generalized Method of Moments (GMM) was employed. The study revealed there is a bidirectional form of causation between economic developments and renewable energy CO_2 emissions. By examining the conditional link between renewable energy and environmental quality, this research adds to the existing literature. Fixed effects and quantile fixed effects regressions are used to support the empirical evidence. Renewable energy consistently reduces Carbon Dioxide (CO_2) emissions, according to both estimation approaches. Hence, there is a close nexus between economic development and renewable energy on CO_2 emission. The fact that there is a negative effect of renewable energy on CO_2 implies that the adoption of renewable energy consistently reduces CO_2 emissions and enhances economic development. It was recommended that authorities encourage powering economies with clean energy, replacing polluting coal, gas, and oil-fired power stations with renewable energy sources, such as wind and solar farms, knowing that renewable energy is not only cleaner but also cheaper these days. The government should also develop policies and coordinate government educational programs on climate change, which will, in turn, be the National Climate Change Action Plan that will serve as a road map that will improve energy efficiency and switch away from non-renewable energy to renewable energy. A carbon tax policy can also be introduced that will shift the economy away from carbon-intensive industries.

Keywords: Economic development, Renewable energy, Carbon-dioxide.

1 | Introduction

What economic growth milestones are linked to reversals in Carbon Dioxide (CO2) emissions in Sub-Saharan Africa (SSA)? Two primary causes in academic and policy-making circles, namely the significance of renewable energy in the post-2015 development agenda and lacunas in the previous studies [1], have prompted this study

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to focus on economic development thresholds for renewable energy in SSA [2]. First, renewable energy is a central theme in Sustainable Development Goals (SDG) [3] because, among other things, greenhouse gas emissions pose a significant threat to the global environment's sustainability in the post-2015 development agenda [4].

Asongu [5] put out that the effects of global warming are particularly devastating to African nations for a variety of reasons, including:

I. Widespread environmental pollution issues, recurrent energy crises.

II. The repercussions of energy mismanagement across the continent.

These important characteristics are well examined below:

The energy industry in many SSA countries is mismanaged, according to the literature [6], [7]. It is important to note that economic prosperity in the previous two centuries has been largely dependent on the availability of energy, which is required for economic dynamics in the form of production, distribution, and consumption. Nigeria is one of the most visible examples of policymakers' incapacity to come up with appropriate renewable energy policies, where fossil fuels are supported rather than sustainable energy sources [8].

2 | Empirical Review

2.1 | Renewable Energy in a Developing Economy

The adoption of renewable energy is a crucial driver of developing economies' ability to handle global environmental concerns effectively. It also serves as a crucial catalyst for renewable energy and long-term economic prosperity. This report examines the difficulties that poor countries face in gaining access to markets for renewable energy. It describes the important policy concerns that must be addressed in order to overcome these obstacles, as well as the extent to which existing policy procedures and organizations have succeeded. The key finding of the report is that most existing policy mechanisms ignore the vital need to create indigenous renewable energy capabilities among rising domestic enterprises.

Indigenous renewable energy capabilities are crucial for facilitating the diffusion of existing renewable energy within developing countries, as well as long-term economic development based on the adoption, adaptation, and development of environmentally sound technologies tailored to developing countries' unique circumstances. Building renewable energy capabilities in developing countries necessitates a shift away from the current emphasis on practical project-based approaches, which emphasize the transfer of clean technology hardware, and toward approaches that emphasize codified knowledge (know-how and know-why) and tacit knowledge flows. Changes to the policy should also be made to better respond to the context's technological and cultural needs. Across and across countries, the strategy is different. Globalization has raised awareness of the need for more international collaboration, which has resulted in a small increase in social entrepreneurship in several countries, particularly in emerging markets.

The work identifies the following main hurdles to developing countries obtaining renewable energy. The importance of indigenous renewable energy capacities is undervalued in international policy: At the international level, policy talks frequently center on providing developing nations with access to current renewable energy in exchange for them utilizing existing technical hardware. To put it another way, becoming consumers of renewable energy rather than producers and innovators in their own right is sufficient for developing countries. This overlooks the fundamental importance of developing countries encouraging the development of indigenous renewable energy skills. Indigenous renewable energy capabilities are essential for facilitating the spread of existing renewable energy within developing countries, as well as long-term economic growth based on the adoption, adaptation, and development of environmentally sound technologies tailored to developing countries' specific needs. The following are examples of eco-characteristics of innovation: the commercialization of renewable energy is typically still in its early phases. Instead, they cover the entire RDD and D spectrum; as a result, many commercial innovations are not covered, which raises a number of issues. These include the following:

I. Investor risks are higher, there is a paucity of venture capital, there is a dearth of operational experience (especially in new geographic and cultural contexts), and incremental expenses are higher.
II. Incremental costs and market failures: in addition to the greater costs associated with new technology, markets' failure to capture the environmental benefits of renewable energy or the environmental costs of non-renewable energy exacerbates the total costs of renewable energy.
III. Intellectual Property (IP) for renewable energy is challenging, according to the evidence so far. While IP rights may be required in some circumstances, they are unlikely to be adequate in and of themselves to enable developing-country enterprises to become renewable energy producers. Access to tacit and associated knowledge (for example, trade secrets), which is typically not patentable, is also required by businesses.

These elements are also critical in the development of indigenous renewable energy capabilities. Data reveals, however, that patents can slow the rate at which developing-country businesses can become renewable energy producers or generate cutting-edge products, meaning that international policy frameworks must be able to control IP in specific instances. According to the report's major result, most existing policy frameworks fail to acknowledge the essential relevance of creating indigenous renewable energy capabilities among expanding national enterprises. Indigenous renewable energy capabilities are essential for facilitating the diffusion of existing renewable energy within developing countries, as well as long-term economic development based on the adoption, adaptation, and development of environmentally sound technologies tailored to developing countries' unique circumstances. The current emphasis on prominent project-based approaches, which emphasize the transfer of hardware aspects of clean technologies, requires a shift away from methods that emphasize flows of codified knowledge (know-how and know-why) and tacit knowledge for developing countries' renewable energy capabilities.

In order to respond to context-specific technological and cultural constraints that differ between and within countries, the policy must be altered. Due to increasing environmental unpredictability around the world, achieving the SDG has grown more difficult. Many countries' leaders are emphasizing the concept of sustainability in the economic growth process, and this has emerged as a major challenge in ensuring long-term economic prosperity [2], [3], [9]. In recent years, countries have faced numerous challenges in promoting sustainable development, as sustainable development does not simply imply economic development but rather the intensification of efforts to expand the economy through environmental entrepreneurship in order to create opportunities for sustainable development [4], [7]. Sustainable development has recently received a lot of attention and has become a hot topic in global policy debates. "Sustainable development" is defined as "development that meets the demands of current generations without compromising future generations' ability to meet their own needs [10]. As a result, data suggests that, in the case of economic development, human efforts to build the economy may result in a rise in carbon emissions and climate change [2], [3].

As stated by the Paris Agreement, continuous attention to sustainability is offered along this line to prevent climate change, natural resource depletion such as deforestation, land degradation, and a range of other challenges, as stipulated by the Paris Agreement. In addition to environmental entrepreneurship, a lack of eco-innovative capacities and the adoption of lower-carbon emission technology could put pressure on the achievement of sustainability targets. As a result, carbon emission-in occurs, which occurs when present CO_2 producing technologies and infrastructures develop a dependency on the route, causing implementation to be delayed. It has a negative impact on the growth of the green or low-carbon economy.

Given that SSA is at a crossroads in terms of economic development, a focus on population needs and long-term growth potential is crucial. These researchers stress the relevance of the link between entrepreneurs and opportunities, noting that business owners are fully aware of the environmental impact of their activities [11–13]. Theoretical concepts of sustainability and sustainable development, on the other hand, are more well-established and comprehendible. "Development that satisfies the needs of the current generation without harming future generations," for example, is described as "development that satisfies the needs of the current generation without jeopardizing future generations." As a result, entrepreneurs who behave sustainably are considered capable of providing present demands without compromising future generations and of doing so by integrating economic, social, and environmental dimensions.

In this approach, a program like the UN project encourages firms to engage in responsible behavior in order to benefit society and the environment. Large businesses, on the other hand, are more concerned with their financial worth and are reluctant to apply sustainable innovation since it would devalue their existing manufacturing processes, goods, and services. If entrepreneurial enterprises are positioned in such a way that they can quickly develop new, environmentally friendly services and products, environmental degradation can be investigated [14]. Its goal is to refute the myth that economic development or growth assures long-term growth and to show how environmental entrepreneurship can help build a sustainable economy. From this perspective, the findings could add to the literature in a variety of ways, such as explaining the relationship between environmental entrepreneurship and long-term growth. Sub-Saharan African countries, like other growing economies around the world, face a difficult task: improving and preserving economic possibilities while also dealing with mounting environmental limits.

Given Sub-Saharan African societies' unique relationship with modern ICT and technology, as well as the transformative implications of these technologies on economic and environmental sustainability, widespread, "radical changes to the socio-technical environment of politics, institutions, the economy, and social values" [15], [16] are required to realize the promise of a prosperous future. In recent decades, there has been rising evidence that economic expansion has been oblivious to the risks of environmental calamities, culminating in ecological devastation, unprecedented levels of Greenhouse Gas (GHG) emissions, and climate change. The intensive use of energy and the accompanying GHG emissions are linked to the intensity and exponential growth of economic activity. If the world is to remain sustainable, climate change and its implications will necessitate significant changes in the global economic and industrial systems.

To put it another way, if contemporary society is to advance on important issues, there will be a global shift to a low-carbon/green economy, which relates to how energy is produced and consumed to address the environmental issue of climate change. Indeed, the far-reaching consequences of such activities have prompted policymakers and scientists to stress the critical need to shift to a more environmentally sustainable growth path by encouraging the adoption of sustainable practices and "cleaner technologies. Ullah et al. [16] came up with a method that is gaining popularity and making its way into the mainstream of economics. According to the report, they are "becoming increasingly recognized as being at the vanguard of a shift to a new form of capitalist development that can help address anxieties about... climate change" and its negative environmental effects [17]. Sub-Saharan Africa's economic transformation has been hampered by a lack of necessary information for innovation and obsolete technology, resulting in a delay in the development of green or clean technologies and a worsening of environmental problems. Sustainable development, environmental degradation, environmental entrepreneurship, economic growth, and conflict resolution are all obstacles that must be overcome. It is critical to address the flaws in current international policy processes by establishing institutional and financial mechanisms that maximize public investment returns.

2.2 | Need for Renewable Energy

Maximizing the impact on indigenous renewable energy capabilities, as well as the ability to attract long-term private-sector renewable energy investment, is essential. There are already precedents in place, such as the Carbon Trust's proposed network of Low Carbon Technology Innovation and Diffusion Centres and Foundation Chile (a non-profit organization aimed at increasing indigenous innovation capabilities and facilitating access to relevant international innovations), both of which are discussed in this report. These could serve as models for a more focused, needs-based approach to developing renewable energy capacities in developing countries rather than the centralized, large-scale, project-based approach that currently dominates international efforts. For an example of how these concepts could be operationalized, look at the University of Sussex's proposal to the UNFCCC negotiations in Copenhagen in December 2009. This proposed a new network of low-carbon "Innovation Centres" in developing countries, managed by regional and global hubs. The Carbon Trust's work, for example, would be built upon by the Centres' activities (see Carbon Trust, undated).

I. Open and/or focused on prioritized technologies, grant money for applied research and development.
II. Technology accelerators: creating and supporting studies to assess the performance of technology, such as field testing.
III. Services provided by a business incubator include: start-ups can benefit from strategic and business growth help.
IV. Enterprise creation: bringing together necessary talents and resources to create new low-carbon firms.
V. Funding for low-carbon startups at an early stage: to assist viable firms in attracting private sector capital, co-investments, loans, or risk assurances may be made.
VI. Implementation of existing energy-saving technologies: advice and resources to assist organizations in reducing emissions (e.g., interest-free loans).
VII. Designing and implementing training programs are examples of skills/capacity building.
VIII. Insights into national policy and the market: analysis and recommendations to help national policymakers and businesses.
IX. Principles for technology transfer to developing countries after 2012:

- *Low-carbon technology transfer can help developing countries achieve long-term low-carbon development. Low-carbon technology transfer can only be accomplished through developing indigenous innovation capacities in developing nations, that is, the ability to adapt, develop, deploy, and operate low-carbon technologies efficiently in specific developing country contexts.*
- *Within developing countries, incremental and adaptive innovation processes facilitate the diffusion and development of low-carbon technologies. This necessitates adequate innovation capabilities among growing businesses, universities, and research institutes, as well as appropriate connections with public-sector actors.*

In this way, social entrepreneurship promotes long-term entrepreneurship in order to boost economic growth [12], [13]. Sustainable entrepreneurship includes finding new ways to market future products, as well as nature conservation, life support, and community development [18]. These noble and essential goals do not always entail the development of positive social and environmental values [19]. Evidence of climate change includes, among other things, knowledge of resource exploitation and its impact on the nature of CO_2, Chlorofluorocarbons (CFCs), and Nitrogen Dioxide (NO_2). The earth has been degraded as a result of their expanding population discrepancies. As a result, literature has evolved that addresses a new strategy for growing entrepreneurial activities [18], [19]. In other words, sustainable entrepreneurship is defined as the discovery, creation, and use of entrepreneurial opportunities that contribute to long-term sustainability by providing social and environmental benefits to others in society [10], [20]. Economic and technical progress at any cost is unsustainable and unattainable; societal development and environmental impacts must be considered. As a result, we're assisting in the transition to a more environmentally sound economy. First, both new and established businesses are more conscious of the need to implement sustainable practices within their organizations as well as in their interactions with the societal and physical environment [17], [20].

Second, the number of organizations that have a substantial impact on long-term sustainability is insufficient and urgently needs to be increased. This fact inspires academics in sustainable entrepreneurship to look at the financial and non-financial benefits of applying sustainable practices. Monitoring renewable energy trends and sharing expertise and information with employees and across departments, as well as upgrading operational systems or producing new eco-friendly goods, can help to improve each aspect of sustainable entrepreneurship (economic, social, and environmental). Due to severe rivalry, uncertain client taste, and technological development, eco-organizational innovation has a favorable impact on a firm's social performance. Finally, Familusi et al. [10] show that working from home and in a pleasant setting boosts labor productivity and employee renewable energy. To produce goods and services, economic growth necessitates the combination of various types of capital. These are some of them:

I. Machines, buildings, and roadways are examples of manufactured capital.

II. Skills and knowledge constitute human capital.

III. Raw resources derived from the soil, carbon sequestration, and other forms are examples of natural capital.

IV. Forest and soil services.

V. Social capital, which includes institutions and community ties.

Institutions and community links are examples of social capital. The purpose of environmental policy is to govern the provision and use of ecological resources in order to ensure the prosperity and well-being of current and future generations [21]. Government involvement is essential to achieve this goal for a variety of reasons. Natural assets would be overused without government intervention due to market failures in the provision and use of environmental resources. The good public characteristics of the natural environment; "external" costs and benefits, where one party's use of a resource has an impact on others; difficulties in capturing the full benefits of business investment in environmental R & D; and information failures are all factors that contribute to market failures [21]. A variety of policies can be used to address market failures, including:

I. Market-based instruments, such as the European Union's Emissions Trading Scheme, the Landfill Tax, and environmental stewardship payments.

II. Water quality and automobile emissions are both subject to direct regulation.

III. Government investment and technology programs include developing flood infrastructure, public purchase of environmentally friendly items, and encouraging low-carbon technologies such as electric automobiles.

IV. Information and other rules, such as product labeling policies and policies encouraging the adoption of resource efficiency measures that save both money and the environment, are used to overcome barriers to behavior change.

For effective environmental policy, multiple instruments, each targeting a different part of the problem while avoiding redundancy and unnecessary regulatory burdens, are likely to be required. Adequate pricing of environmental inputs enhances the sustainable provision and use of natural resources [18]. A consistent and comprehensive environmental policy boosts investment certainty and encourages long-term investment in new technologies and innovation by businesses. Environmental measures such as infrastructure and other assets can reduce the economy's and businesses' vulnerability to adverse environmental events by lowering environmental risk and increasing the economy's resilience to these risks. Investments that help the economy adapt to climate impacts already locked in by past and current emissions, as well as investments that help the economy reduce emissions to avoid dangerous climate change [19], .

3 | Methodology

The study looks at forty-five countries in the SSA area from 1980 and 2020. This study analyzes the relationship between renewable energy and CO_2 emissions over conditional CO_2 emission distributions using a quantile regression technique, which is in line with the study's motivation. As indicated in the introduction, previous estimates of the underlying nexus, such as those by Familusi et al. [10], were based on mean CO_2 emissions. According to Asongu et al. [1], the policy significance of modeling an independent variable with an outcome variable based on mean values of these underlying variables is that estimates based on average values of the variables of interest can produce blanket policy implications that are ineffective unless such policies are based on various levels of CO_2 emissions. As a result, policy implications can be more successful when countries with low, moderate, and high levels of CO2 emissions are articulated in the estimating exercise because they are tailored to be consistent with starting levels of CO_2 emissions.

In view of the foregoing, this research builds on the accompanying Quantile Regressions (QR) literature [9], which has been shown to be useful in articulating beginning values of outcome variables [11]. Furthermore, as Familusi et al. [10] note, the QR technique differs from linear estimations in a number of ways, including the fact that it 1) predicts conditional quantiles (as opposed to conditional mean), 2) is important when adequate data is available in contrast to a traditional Ordinary Least Squares technique, which requires small n values, 3) is consistent with an agnostic distribution (contrary to the normal distribution assumption), 4) is robust to outliers in the outcome variable (contrary to outlier sensitivity), and 5) is computationally intensive (contrary to a computationally less intensive linear approach). The quantile CO_2 emission estimator is created by solving the following optimization problem, which is shown in *Eq. (1)* without subscripts for clarity and simplicity.

For the purpose of realizing the hypotheses, CO2 emissions are represented as a function of economic development, which is captured with GDP, Urbanization (U), Industrialization (I), trade openness (T), and Renewable Energy (RE). Therefore, the econometric model:

$$\begin{aligned} \mathrm{CO2i,t} &= \alpha0 + \alpha1\,\mathrm{CO2i,t-1} + \alpha2\mathrm{GDPi,t} + \alpha3\mathrm{Ti,t} + \alpha4\mathrm{Ui,t} + \alpha5\mathrm{Ii,t} + \alpha6\mathrm{REi,t} \\ &+ \alpha7[\mathrm{GDP} * \mathrm{REi,t}] + \varepsilon\mathrm{i,t}. \end{aligned} \tag{1}$$

Using a two-step system Generalized Method of Moments (GMM) estimator, i represents the country, t represents time (year), α1 . . . . α8 represents the parameters to be estimated, and ε is the stochastic disturbance term.

For *Eq. (1)*, the dependent variable yi is a CO2 emission, whereas xi contains a constant term, economic development, which is captured with GDP, urbanization (U), industrialization (I), trade openness (T), and Renewable Energy (RE).

Given the above, equations of regressions for the QR and Fixed Effects estimations are as follows.

$$CO_{2i,t} = \sigma_0 + \sigma_1 X_{i,t} + \eta_I + \varepsilon_{it}. \tag{2}$$

$$CO_{2i,t} = \sigma_0^{(p)} + \sigma_1^{(p)}\,\sigma_1\, X_{i,t} + \eta_I + \varepsilon_{it}^{(p)}. \tag{3}$$

The Fixed Effects estimations that account for individual country peculiarities [10], [11] and QR, which are presented respectively in *Eq. (2)* and *Eq. (1)* focus on the incidence of renewable energy on CO2 emissions where, COi,t is CO_2 emissions in country i at period t, σ0 is a constant, X entails renewable energy and other control variables (GDP, urbanization, industrialization, trade openness, and renewable energy, ε, i, t denotes country-specific effects and ε, i, t is the error term.

4 | Findings

The empirical findings are presented in this section. The findings of the nexus between economic development and renewable energy on CO2 are shown in *Tables 1-4*.

4.1 | Panel Unit Root Test

The testing of cross-sectional dependency in panel data is the most important element in choosing unit root tests. First-generation unit testing is primarily based on the hypothesis of cross-sectional independence [22]. Meanwhile, even in the presence of cross-sectional dependency, unit root tests of the second generation can be used [23]. For all panel variables, the CD test is centered on the mean of all pairs of correlation coefficients between the OLS residuals obtained using conventional augmented Dickey-Fuller regressions [23]. *Table 1* displays the results of the CD test.

Table 1. The CD test.

GDP	Renewable Energy	CO_2
56.67***	35.98**	31.73
(0.0001)	(0.034)	(0.000)

Notes: notes: † p < 0.1, **p < 0.01, ***p < 0.001.

ECT reveals the coefficient of the error correction term. According to the Schwarz information criteria, there are two relevant delays. The results of the above table show that there is cross-section dependency on the panel data set; this means that all units of the cross-sectional data utilized in this study are correlated with one another, pointing to a common component that all units of the data share. This is thought to represent their influence on GDP in our situation.

4.2 | Fully Modified Ordinary Least Square

The long-term elasticity of the variables was determined using a Fully Modified Ordinary Least Square (FMOLS) test. Adeniran et al. [22] was the first to present a completely modified OLS test to address concerns of simultaneity bias, serial correlation, and non-homogeneity. In a sequence of panel data, this technique also allows for asymptotically valid estimations [22].

The findings of this test are shown in *Table 2*, which reveals that a 1% increase in renewable energy corresponds to a 0.08 percent rise in GDP, as shown in *Model (1)*. Overall, the model's results suggest that renewable energy has a strong beneficial impact on GDP and performance.

Table 2. FMOLS test.

	Dependent Variable	Independent Variable	Coef	Probability
Model 1	Log GDP	Log RE	0.081	0.003
Model 2	Log CO_2	Log GDP	0.432	0.001
		Log RE	0.013	

Notes: ***p < 0.001. Panel method: pooled. Heterogeneous variances. An akaike lag and lead method in case of DOLS estimation.

According to the results of *Model 2*, a 1% rise in GDP results in a 43 percent increase in CO2, but a 1% increase in renewable energy results in a 0.01 percent increase in CO2. Overall, the results of *Model 2* suggest that renewable energy contributes less to CO2 than GDP.

4.3 | Fixed Effects and Quantile Fixed Effects Regressions

The initial specifications (i.e., the second column) in each table belong to Fixed Effects regression estimates, whereas the remaining output relates to QR. When analyzing QR estimations, there is a need to be conscious of the fact that the present amounts of CO2 emissions expand from the left to the right. To put it another way, CO2 emissions on the right are higher than those on the left.

Table 3. Fixed effects and quantile fixed effects regressions (I).

	Fixed Effects	Q.10	Q.25
CO_{2t-1}	0.006***	0.006***	0.006***
	(0.013)	(0.000)	(0.000)
GDP	0.219**	0.324***	0.279***
	(0.025)	(0.008)	(0.002)
Renewable energy	-0.016**	-0.017***	-0.016***
	(0.016)	(0.000)	(0.000)
Industrialization	0.009***	0.009***	0.009***
	(0.010)	(0.002)	(0.000)

Table 3. Continued.

	Fixed Effects	Q.10	Q.25
Trade	0.002**	0.001*	0.001***
	(0.014)	(0.055)	(0.003)
Urbanization	-0.016	-0.042	-0.031
	(0.834)	(0.601)	(0.594)
[GDP*RE]	0.003**	0.005***	0.004***
	(0.000)	(0.003)	(0.000)

Note: ***, ** and * represents statistical significance at 1%, 5% and 10%, respectively. Fixed Effects estimates computed with robust standard errors to account for heteroskedasticity.

Table 4. Fixed effects and quantile fixed effects regressions (II).

	Q.50	Q.75	Q.90
CO_{2t-1}	0.006***	0.006***	0.007***
	(0.000)	(0.000)	(0.000)
GDP	0.216***	0.160*	0.111
	(0.001)	(0.056)	(0.355)
Renewable energy	-0.015***	-0.015***	-0.014***
	(0.000)	(0.000)	(0.002)
Industrialization	0.009***	0.009***	0.010***
	(0.000)	(0.000)	(0.000)
Trade	0.002***	0.002***	0.002***
	(0.000)	(0.000)	(0.002)
Urbanization	-0.016	-0.002	0.009
	(0.708)	(0.962)	(0.904)
[GDP*RE]	0.003***	0.002***	0.001**
	(0.000)	(0.000)	(0.000)
Constant: -2.089**(0.025)			
Overall R-squared: 0.649			
F-statistics: 8.96***(0.000)			

Note: ***, ** and * represents statistical significance at 1%, 5% and 10%, respectively. Fixed Effects estimates computed with robust standard errors to account for heteroskedasticity.

Some of the inferences that can be made are as follows. For starters, both estimation methods reveal that renewable energy reduces CO2 emissions consistently. The negative effect, on the other hand, is a decreasing function of CO2 emissions. To put it another way, countries that emit more CO2 have a lower long-term negative impact than countries that emit less CO2. The study found that 64.9% of economic development and renewable energy is caused by CO2 emission. Hence, there is a strong effect of economic development and renewable energy on CO2 emissions. The control variables, for the most part, show the expected results. As a result, economic success, financial expansion, and trade all have positive associations with CO2 emissions, whereas economic governance, as measured by government efficacy and regulatory quality, has a negative association. While Urbanization has little effect on CO2 emissions, the quality of laws has a significant impact.

It was revealed in the study that there is a bidirectional form of causation between economic developments to renewable energy of CO2 emissions. This finding agrees with the findings of Asongu [5], who used seven Central American countries from the period 1980 and 2010 and found a significant relationship between renewable energy consumption per capita, real GDP per capita, CO2 emissions per capita, real coal prices, and real oil prices.

It also agrees with the findings of Familusi et al. [10], which found a short-run and long-run relationship between economic development (represented by international trade), renewable energy consumption, CO2 emissions, and GDP in twenty-four (24) sub-Saharan African countries between 1980 and 2010. Finally, it agrees with the findings of Hong et al. [24] and Siba et al. [25], who found a cause-and-effect relationship between economic growth, renewable energy, nuclear energy, and CO2 emissions in the United States from the period 1960 to 2007.

5 | Conclusion and Recommendations

By examining the conditional link between renewable energy and environmental quality in a sample of 45 SSA from 1980 to 2020, this research adds to the existing literature. Fixed effects and quantile fixed effects regressions are used to support the empirical evidence. Renewable energy consistently reduces CO_2 emissions, according to both estimation approaches. Furthermore, the negative effect is proportional to CO_2 emissions. To put it another way, countries with higher levels of CO_2 emissions continuously have a lesser negative impact than countries with lower levels of CO_2. The study found a strong effect of economic development and renewable energy on CO_2 emissions.

It was recommended that authorities encourage powering economies with clean energy, replacing polluting coal, gas, and oil-fired power stations with renewable energy sources, such as wind and solar farms, knowing that renewable energy is not only cleaner but also cheaper these days. The government should also develop policies and coordinate government educational programs on climate change which will, in turn, the National Climate Change Action Plan that will serve as a road map that will improve energy efficiency and switch away from non-renewable energy to renewable energy. A carbon tax policy can also be introduced that will shift the economy away from carbon-intensive industries.

Conflict of Interest

The authors declare no conflict of interest.

Data Availability

All data are included in the text.

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