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Effect of Renewable Energy on Co_2 Emission in Sub Saharan Africa

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Abstract

This study examined the effect of renewable energy on CO_2 emissions in a group of forty-five nations in Sub-Saharan Africa using the data spanned from 1980 and 2020. It is pertinent to note that renewable energy usage can be felt in industrialization; therefore, industrialization as a variable was captured alongside. For this, a two-step system GMM estimator was employed, which accounts for endogeneity while ignoring variable bias. The study found that higher industry value additions resulted in increased CO_2 emissions, whereas increased renewable power generation resulted in less environmental damage. If the increase in renewable power generation is causal, it cuts carbon emissions by 0.22 percent. Furthermore, it was discovered that the usage of renewable energy mediates the link between industry value additions and CO_2 emissions. It was recommended that authorities of SSA countries should encourage the usage of renewables through various policies and programs.

Keywords: Renewable, Carbon dioxide, Emission, Sub sahara Africa.

1 | Introduction

The demand for new economic models supported by high-performance technology has merged when it comes to environmental issues as well as limits connected to natural resources. The aforementioned factors encouraged the establishment of new concepts as well as new management techniques based on how organizations employ resources in conjunction with cost reduction. These factors, of course, necessitate new strategic frameworks to assure long-term viability [1].

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All businesses that aim to be environmentally friendly, sustainable, and profitable must encourage a fair sort of innovation capable of permitting innovative approaches to complicated environmental concerns, such as lowering energy and resource consumption and supporting sustainable economic activity. Environmental industries have evolved as a significant section of the economy as a consequence of these realities, and they are those businesses that harness the power of innovation to respond to such difficulties [2]. Renewable energy refers to the process of lowering the environmental effect of economic operations, as well as the logical and sustainable use of natural resources. This is regarded as not just a key to competitiveness but also a vital aspect in resolving natural resource challenges, climate change, and energy security.

The term "renewable energy" was first used in the specialist literature over two decades ago, and it was defined as "new goods and processes that give customer and corporate value while dramatically reducing environmental consequences" [3]. The term "renewable energy" is frequently used in combination with other terms in comparable settings, such as "environmental innovation" and "sustainable innovation. Renewable energy, as a critical component of innovation, is a driver of social and economic advancement, with a particular focus on providing chances for long-term economic growth [4], [5]. This phenomenon, which offers a wide range of applications, is thought to be capable of ensuring societal and economic development, company competitiveness, increased productivity, and profitability through resource management and access to environmentally friendly products, technologies, and markets [6].

With respect to the economy, renewable energy strives to minimize energy and material costs while also boosting goods, services, markets, customers, and new business models. Renewable energy attempts to improve people's quality of life and generate new, long-term jobs on a social level. In terms of the environment, renewable energy attempts to protect biodiversity and maintain ecological balance by fostering environmental effect reduction, sustainable and innovative views on climate change, and responsible natural resource management [2].

In recent years, research into the origins of carbon dioxide emissions has exploded [7–11]. The existence of a nonlinear (inverted U-shaped) link between GDP per capita and carbon dioxide emissions across nations, known as the Environmental Kuznets Curve (EKC) phenomenon, was one of the most significant frameworks investigated in this area. Malaysia [12], China [13], Croatia [14], Turkey [15], Algeria [16], and Sub-Saharan Africa [16] have all used the EKC framework [17]. Also, research suggests that economic development, urbanization, commerce, and the usage of renewable energy are all key predictors of carbon dioxide emissions among nations [18–20].

The STRIPAT econometric framework was used in these investigations [21], [22]. While global renewable energy usage has been relatively constant over the previous decade, Sub-Saharan African countries have been among the top users. At the same time, carbon dioxide emissions in this region vary greatly, ranging from 0.04 tCO2 per capita in the Democratic Republic of Congo to 8.15 tCO2 in South Africa. As a result, this section investigated the link between renewable energy utilization and carbon emissions in forty-five Sub-Saharan African nations from 1980 and 2020. The findings of this study complement previous studies in a variety of ways.

First, whereas past research has focused on the renewable energy-CO2 emissions nexus, the present study looks at how the renewables sector might help to moderate the industrialization-CO2 emissions relationship. Second, this study investigates if the EKC relationship still exists when structural changes are taken into account (including industrial contribution to GDP). Third, we employed a two-step system generalized technique of moment to study the effect of renewable energy generation and industrialization on carbon dioxide emissions (Generalized Method of Moments (GMM)). Fourth, current EKC frameworks in Sub-Saharan African countries should be amended.

2 | Empirical Review

Renewable energy outputs on CO_2

In order to assess the effect on GDP, the role of renewable energy in explaining carbon dioxide emissions was investigated using the EKC framework. For example, Zoundi [23] observed that GDP increased carbon dioxide emissions, but renewable energy reduced air pollution in the long term for a sample of 25 African nations during the period 1980–2012, using the co-integration approach. In a similar line, Shafiei and Salim [24] found that adopting renewable energy lowered carbon dioxide emissions for the OECD nations from 1980 to 2011. Furthermore, GDP per capita had a favorable influence on carbon dioxide emissions. The EKC theory was utilized by Dogan and Seker [25] to predict the link between renewables and carbon-dioxide emissions in the European Union from 1980–2012. The results of their dynamic ordinary least squares estimator demonstrated that renewable energy and open trade lowered carbon dioxide emissions.

Furthermore, the non-causality tests reveal a bi-directional link between renewable energy and carbon dioxide emissions. Saidi and Omri [26] look at the relationship between renewable energy and carbon dioxide emissions in 15 major energy-consuming nations. The Granger causality test shows that in the long run, there is bi-directional causation between renewable energy and carbon dioxide emissions but that there is no connection in the short run. Using the data from 1984 to 2016, Salahuddin et al. [27] discovered that renewable energy reduced CO2 emissions and raised aggregate national savings in a sample of 34 Sub-Saharan African nations. Sadorsky [28] looked studied the link between renewable energy use and CO2 emissions in a group of G7 nations. The panel co-integration approach was used to discover that in the long term, causation flows from GDP per capita and CO2 emissions to renewable energy usage. As a result, renewable energy is not a useful tool for reducing emissions in G7 countries.

Using an ARDL estimator, Sebri and Ben-Salha [29] found no substantial causal effect of renewables on CO2 emissions in the BRICS from 1971 to 2010. The study discovered a link between economic development and renewable energy. Baloch et al. [30] used an augmented mean group estimator to investigate the association between renewable energy, GDP growth, and CO2 emissions in the BRICS from 1990 to 2015. In contrast, the study revealed that with the exception of South Africa, renewable energy utilization resulted in lower CO2 emissions in all BRICS nations. Using the vector autoregression approach, Tiwari [31] investigated the link between economic development, renewable energy use, and carbon emissions in India from 1960 to 2009. According to the findings, an incentive to promote renewable energy consumption will also boost economic development and limit the emission of CO2.

Furthermore, economic development has increased air pollution. From 1971 to 2013, Boontome et al. [32] looked at the link between renewable energy utilization, economic development, and carbon emissions in Thailand. Nonrenewable energy consumption and GDP growth both increase CO2 emissions, according to the panel cointegration results. According to the authors, switching to green energy sources will reduce environmental deterioration without compromising economic development possibilities. Dong et al. [33], [34] used the common correlated effects mean group approach to examine the link between renewable energy, GDP growth, and CO2 emissions in a sample of 128 countries from 1990 to 2014. Renewable energy was shown to be important in lowering CO2 emissions in each geographic location, according to the findings. South America and Eurasia have the most noticeable consequences. Over the period 2000–2014, Mahmoodi [35] reviewed the renewable energy-CO2 emissions nexus for a sample of eleven developing nations.

The study discovered bidirectional causation between renewable energy usage and carbon emissions using panel co-integration estimates and VECM models. Furthermore, other assessment methods showed that renewables reduce emissions overall. Abbasi et al. [36] investigated the role of renewable energy in Thailand's goal of reducing CO2 emissions by 25% by 2030. For the period 1980–2018, the ARDL simulation model revealed that the depletion of fossil fuels increased carbon dioxide emissions. In contrast, renewable energy use has a short-term negative effect on carbon dioxide emissions. The authors emphasized the necessity for a quick shift in the energy industry toward green energy use to realize the targets of carbon mitigation. In a study published in 2017, Jebli and Youssef [37] looked at the relationship between renewable energy and carbon dioxide emissions in North Africa from 1980 to 2011. Long-term projections reveal a one-way causation between renewable energy and carbon dioxide emissions.

In a similar spirit, Waheed et al. [38], using the ARDL estimator, conclude that increasing renewable energy usage reduces carbon emissions in Pakistan. Bhattacharya et al. [39] studied the role of renewable energy in reducing CO2 emissions in 85 countries from 1991 to 2012. The study used a GMM estimator to determine that rapid adoption of renewable energy technologies should result in lower CO2 emissions. Nathaniel and Iheonu [40] used the AMG approach to study the effect of renewable and non-renewable demands on CO2 emissions in a sample of 19 African countries from 1990 to 2014. The data found that although renewable energy had no significant effect on environmental degradation, fossil fuel consumption increased CO2 emissions.

While energy is one of the most important predictors of carbon dioxide emissions, another element of environmental deterioration that has attracted attention in empirical research is industrialization [41]. Consider BRI nations like China: "despite the economic benefits of fast industrialization, [China] has depleted resources such as labor, materials, and investment, as well as suffered considerable environmental damage" [42]. Industrialization, according to Li and Lin [43], was related to higher energy demand and changed energy consumption models during the early stages of economic growth, resulting in increased carbon dioxide emissions. The detrimental effects of industrialization on carbon dioxide emissions might be mitigated by better infrastructure and agglomeration.

When investigating the industrialization and carbon dioxide emissions connection, however, many additional aspects need to be taken into account. Industrialization, for example, has resulted in urbanization and increased trade openness, both of which have affected carbon dioxide emissions [33], [34]. Other research has looked into the effect of industrialization on carbon dioxide emissions directly. For example, Shahbaz et al. [44] examined the link between Bangladesh's industrialization, energy usage, and carbon dioxide emissions from 1975 to 2010. The study discovered that energy consumption enhanced environmental deterioration and that there was a non-linear, inverted U-shaped link between industrialization and CO2 emissions, using the ARDL bounds testing technique. Using the ARDL estimator, Ullah et al. [45] looked at the relationship between industrialization and CO2 emissions in Pakistan from 1980 to 2018.

The findings imply that an increase in the contribution of industry to GDP led to an increase in CO2 emissions in the short and long run. Furthermore, the research found that urbanization and economic expansion have a favorable effect on environmental deterioration. In addition, Mahmood et al. [46] used the ARDL model to investigate the industrialization- CO2 emissions nexus in Saudi Arabia from 1968 to 2014. Industrialization has had a considerable favorable influence on environmental deterioration, according to the findings (CO2 emissions). To minimize CO2 emissions, the authors advise that more severe industrial policies be implemented. Other studies in Korea, China, and the United Arab Emirates have similarly proven the large effect of industrialization on CO2 emissions [47–49].

The following hypotheses were formulated based on the foregoing discussion:

H01: industrialization enhances the increase in the emissions of carbon dioxide in Sub-Saharan Africa.

H02: environmental quality is enhanced by renewable energy in Sub-Saharan Africa.

H03: there is a negative effect of renewable energy in industrialization on the emissions of carbon-dioxide in Sub-Saharan Africa.

3 | Methods

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), and Trade openness (T). Therefore, the econometric model:

$$CO_{2i,t} = \alpha_0 + \alpha_1 CO_{2i,t-1} + \alpha_2 GDP_{i,t} + \alpha_3 GDP_{2\,i,t} + \alpha_4 T_{i,t} + \alpha_5 U_{i,t} + \alpha_6 I_{i,t} + \varepsilon_{i,t.} \quad (1)$$

Using a two-step system GMM estimator, i represents the country, t represents time (year), α1 . . . . α6 represents the parameters to be estimated, and ε is the stochastic disturbance term. As presented in the studies of Ben Jebli et al. [50] and Lin et al. [51], the two-step GMM estimator is usually employed when:

I. The empirical model incorporates lagged dependent variables.

II. The number of panels (countries) exceeds the number of time periods (in years).

III. Endogeneity and simultaneity must be considered.

For example, suppose the incorporation of delayed CO2 emissions causes this problem to arise. Many studies employ the two-step GMM approach to study the drivers of CO2 emissions across nations for these reasons [52–56]. The data for this study comprised forty-five Sub-Saharan African nations and spanned the years 1980 and 2020. tCO2 emissions per person were used to calculate CO2 emissions (*Fig. 1*). Gross Domestic Product (GDP) per capita was calculated in constant international dollars. We used net FDI inflows as a percentage of GDP as a proxy for FDI. In terms of GDP, trade was the total of exports and imports. The percentage of the people living in cities was referred to as urbanization. Renewable energy was measured as a proportion of total power generation, while industrialization was measured as the value added of industry (including building) as a percentage of GDP. *Table 1* displays the correlation matrix.

Table 1. Correlation matrix.

	CO_2	Industry	Renewable Energy	GDP	Urbanization	Trade
CO_2	1					
Industry	0/4476	1				
Renewable energy	-0.3279	0.1454	1			
GDP	0.7983	0.5035	-0.2719	1		
Urbanization	0.5165	0.3366	-0.1027	0.4666	1	
Trade	0.6846	0.5121	-0.2625	0.5717	0.4076	1

Table 1 depicts that the major variable correlations do not surpass 0.8, indicating that multicollinearity should not be an issue in this study. Industry, GDP, trade openness, and urbanization are all positively connected with CO2 emissions, but renewable energy has a negative correlation coefficient with CO2 emissions, according to the correlations matrix.

4 | Findings

The summary of major findings is shown in *Table 2*. The link between industry, control factors, and CO_2 emissions is estimated in column 1. First, we discovered that in Sub-Saharan Africa, there was a positive association between industrialization and CO_2 emissions, a 1% rise in the proportion of industry in GDP resulted in a 0.3 percent increase in CO_2 emissions per person. We also found an inverted U-shaped relationship between GDP per capita and CO_2 emissions, supporting the statistical presence of the EKC in this research sample, with a turning point at USD 27,000.

As a result, the EKC had no economic effect in our study [37], [51], and we were unable to find the EKC for African nations. We discovered that trade openness had a favorable influence on CO_2 emissions in Sub-Saharan African nations when we looked at other factors. A one percentage point rise in commerce, for example, resulted in a 0.11 percent increase in CO_2 emissions. These findings are in agreement with previous cross-national studies [57]. Furthermore, trade openness has been shown to have a favorable effect on environmental deterioration [50]. The findings of this study reveal that trade liberalization hasn't helped the region's environmental circumstances, implying that trade structure should shift away from energy-intensive goods and services and toward knowledge-intensive goods and services. Indeed, according to Ncanywa et al. [58], the economic complexity of items produced in Sub-Saharan Africa is low, which has hampered trade diversification in the region. The effect of urbanization on CO_2 emissions is negligible.

Table 2. Major results.

	I	II	III
CO_2t-1	0.8646	0.8567	0.8776
	(38.08)***	(33.13)***	(45.63)***
Industry	-0.000001	0.00075	0.00114
	(0.01)	(0.38)	(0.74)
Renewable		-0.00220	-0.00076
		(4.84)***	(6.33)***
Trade	-0.0961	-0.0998	0.00002
	(5.03)***	(4.13)***	(0.03)
GDP	0.00296	0.00375	0.00354
	(3.59)***	(4.05)***	(5.70)***
Urbanization	0.00105	0.00089	0.00114
	(7.34)***	(4.59)***	(8.50)***
Constant	-0.52645	-0.51139	-0.53813
	(4.04)***	(3.07)***	(6.29)***
AR(1)	0.000	0.000	0.000
AR(2)	0.314	0.286	0.357
Hansen p-value	0.231	0.165	0.367
F-stat	51,974.11	407,941.01	794,303.71
N	620	620	620

Renewable power output was added in column 2. Renewable energy's coefficient was negative and significant at the 1% level, as predicted. If the increase in renewable power generation is causal, it cuts carbon emissions by 0.22 percent. These findings are in agreement with previous cross-country studies [24], emphasizing the need to shift from fossil fuel to renewable energy usage. In column 3, we also include an interaction term between industry and renewable energy.

The interaction term is negative and large, implying that the renewable energy sector is critical in mitigating the negative CO2 emissions consequences of industrialization. As we add more variables and an interaction term between renewable energy and industrialization, the coefficients in columns 1–3 change.

The AR (2) and Hansen p-values show that the instruments used in this investigation are valid and trustworthy. The F-statistics are more than 10, indicating that the econometric specification is relevant to this study's analysis. Furthermore, empirical research reveals that when modeling environmental indicators, it is critical to account for human capital [59], [60]. As a result, we include the UN's education index in column 2. Finally, the proportion of women in parliament is included in column 3 to capture the effect of female political empowerment on environmental degradation [61]. Renewable energy mitigates the effect of industrialization on CO2 emissions in all scenarios. As a consequence, the findings show that both industrialization and renewable energy have a significant influence in forecasting CO2 emissions in Sub-Saharan African countries.

Table 3. Other controls.

	I	II	III
CO_2t-1	0.8473	0.8846	0.8587
	(43.46)***	(48.64)***	(49.06)***
Industry	0.0024	0.0028	0.0036
	(2.04)**	(2.28)**	(4.66)***
Renewable	0.00028	0.00018	0.00076
	(0.39)	(0.31)	(1.37)
Trade	0.0011	0.0010	0.0012
	(5.60)***	(6.75)***	(6.88)***
GDP	0.05128	0.03339	0.05042
	(4.84)***	(3.21)***	(7.65)***
Urbanization	0.00086	0.00074	0.00039
	(0.50)	(0.44)	(0.28)
Constant	-0.52645	-0.51139	-0.53813
	(4.04)***	(3.07)***	(6.29)***
AR(1)	0.000	0.000	0.000
AR(2)	0.967	0.362	0.357
Hansen p-value	0.338	0.430	0.217
F-stat	90,806.71	60,281.68	167,722.10
N	531	614	603

*p < 0.1; ** p < 0.05; *** p < 0.01

5 | Conclusion and Recommendations

This section delved into the link between industrialization, renewable energy, and CO2 emissions in a group of forty-five nations in Sub-Saharan Africa from 1980 and 2020. For this, a two-step system GMM estimator was employed; it accounts for endogeneity while ignoring variable bias. By adding the industry and renewable energy sectors, we stray from the EKC framework. According to the findings of this study, higher industry value additions resulted in increased CO2 emissions, whereas increased renewable power generation resulted in less environmental damage.

If the increase in renewable power generation is causal, it cuts carbon emissions by 0.22 percent. Furthermore, we discover that the usage of renewable energy mediates the link between industry value additions and CO2 emissions. The findings of this study have a number of relevant policy consequences. First, authorities may encourage the growth of renewables by providing low-interest loans and tax breaks for the purchase and installation of renewable energy producers.

Finally, each country can develop a local renewable energy deployment strategy that describes the government's primary goals in this area. Aside from that, governments can enact policies requiring buildings with an area greater than a particular threshold to use renewable energy to replace a portion of their energy use. In certain nations, incentives for biogas or hydropower producers are possible. Second, regulations aiming at promoting renewable energy technology across industries must be implemented. This may be accomplished by reducing tax rates for those who embrace green energy technologies, providing low-interest loans and grants to businesses and individuals, and subsidizing green energy.

Author Contributions

Olayemi Babawole Familusi conceptualized the study and led the research design and data analysis. Oluwaseun David Omoyeni conducted the literature review and assisted in data collection and methodology development. Osinachi Macdonald Samchuks contributed to statistical modeling and interpretation of results. Adetayo Olaniyi Adeniran supported manuscript writing, editing, and visualization of findings. All authors reviewed, revised, and approved the final manuscript.

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Data Availability

The data supporting the findings of this study are publicly available from recognized energy and environmental databases. Further details can be provided by the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest associated with this study.

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