Drivers of Carbon Emissions in Kenya: The Perspective of Technology

Abstract

The empirical studies so far have portrayed from a different perspective that technology, foreign direct investment (FDI), and economic growth have diverse outcomes on carbon dioxide (CO2) emissions. African economies specifically Kenya are currently threatened with more CO2 emissions for which proper strategies need to be adopted to reduce and mitigate this situation. To address this issue, the Autoregressive Distributed Lag (ARDL) technique was utilized, which differentiates between the long-term and short-term effects of drivers of CO2. Granger causality was applied to analyze the causality between the series. The study uses time series data for Kenya for the period from 1990 to 2022. The short-run and long-runresults indicate a negative relationship between technology and carbon emissions. Specifically, an increase in technology reduces the level of carbon emissions while anincrease in economic growth and FDI inflow increases carbon emissions.The study has identified the negative nexus between technology and carbon emissions in Kenya. This means that technological innovation can increase labor productivity and utilization of resources, thereby reducing carbon emissions. Therefore, Kenya should increase research and utilization of low and efficient carbon technologies to decouple economic growth from environmental pollution. Based on the result, various strategies have been proposed, including using different technologies to produce renewable fuels. The use of green and clean technologies can help mitigate the negative impact of technological progress on the environment. Additionally, technological progress, particularly in information and communication technology, will reduce greenhouse gas emissions and improve environmental quality.

Keywords: Technology, carbon emissions, environmental quality, patent

1. INTRODUCTION

Climate change and greenhouse gas (GHG) emissions are global issues that significantly influence the environment, ecosystems, technological progress, economic development, and human health. Climate change is an ongoing process that can lead to altered climatic conditions and has the potential to affect the stability of ecosystems and biodiversity. It also has significant impacts on human health and can contribute to the occurrence and distribution of disease patterns (Zargar & Rather, 2022). Global environmental policies to reduce CO2 emissions include targeting the extreme emitters in the electricity industry, implementing carbon pricing and taxes, tightening environmental policies to reduce carbon leakage through international trade, and adopting sustainable climate change policies based on COVID-19 practices (Adam et al., 2022). Global environmental issues, particularly the reduction of carbon dioxide (CO2) emissions, have become a significant concern worldwide (Basumatary et al. 2021) . The excessive consumption of fossil fuels has led to limited reserves and the release of large amounts of CO2, contributing to environmental problems such as global warming and climate change (Akhter et al., 2016). To address these issues, various strategies have been proposed, including using different technologies to produce renewable fuels or useful chemicals through the photocatalytic reduction of CO2 (Zhu et al., 2021).

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Literature has emphasized the relevance of the environmental Kuznets curve (EKC) as proposed by Grossman and Krueger (1995), who posit that environmental practices and quality are impacted by economic growth, energy consumption and production activities. The Environmental Kuznets Curve (EKC) theory provides theoretical contributions to the relationship between economic development and environmental degradation. It suggests an inverted U-shaped nexus, where environmental damage initially increases during the early stages of economic development but then decreases after a certain level of economic progress is reached (Yilmaz, 2022; Boudinar, 2022). Kuznets (1955) laid the foundation for this theory and discussed the specific relationship between economic growth and environmental quality (Lau et al., 2023).

Muganyi et al. (2021) showed that the interplay between technological advancement carbon emissions and environmental quality has become a topical issue among environmental economics and scientists. Technological innovations and institutional quality have a significant impact on environmental quality. Enhancing technological innovations and institutional effectiveness can help resolve environmental degradation issues and achieve sustainable development (Gao & Fan, 2023). Prior research has shown that technology, trade openness, foreign direct investment,and economic growth can contribute to environmental pollution, particularly in CO2 emissions (Nawaz et al., 2023). The discussion so far has portrayed from a different perspective that Technology advancement, FDI, and economicgrowth have diverse outcomes on CO2 emissions. African economies specifically Kenya are currently threatened with more CO2 emissions for which proper strategies need to be adopted to reduce and mitigate this situation. Therefore, our study will assist the government, financial, technological, and environmental regulatory institutions, and other organizations as well as policymakers in pursuing more definite practical, pragmatic, and proper innovative initiatives related to CO2 emissions in Kenya.

2. LITERATURE REVIEW

This part of the study delves into the details of prior literary works on the association between technology, economic growth, foreign direct investment,and carbon emissions.

2.1 Theoretical Literature

The Environmental Kuznets Curve (EKC) theory suggests that as per capita income increases, environmental degradation initially worsens but eventually improves. This theory is based on the idea that as income rises, societies have the resources and desire to invest in environmental protection (Grossman & Krueger, 1995; Gisore, 2017). Several studies have examined the EKC hypothesis in different countries and regions. Wen and Dai (2021) find evidence of the EKC in China, with pollution levels initially increasing and then decreasing as per capita income rises. Maranzano et al. (2021) highlight the role of education in validating the EKC hypothesis and propose a new model called the Educational EKC. Boudinar, (2022) focuses on developed countries and investigates the existence of the EKC hypothesis. Dai et al. (2015) examine the relationship between rural economic development and non-point source pollution in Jiangsu Province, China, and verify the EKC hypothesis. Lawn, (2006) extends a theoretical model and argues that achieving improved environmental quality requires policies focused on sufficiency, equity, natural capital maintenance, and qualitative improvement of human-made goods.

Thus, this research provides empirical evidence on the role of technological innovation in mitigating CO2 emissions. Environmental economists and scientists have identified technological advancements such as ICT infrastructure development, technological advances

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in the use of hydrogen fuel cells, carbon pricing, forest restoration, energy efficiency, and electric vehicles indicating that the efficiency of technology influences CO2. Therefore, in this research, we expect an inverse association between technology and CO2 emission in Kenya.

2.2 Empirical Literature

2.2. 1 Technology and Carbon Emissions (CO2) Nexus

Technology plays a significant role in carbon emissions (CO2). Several studies have examined the relationship between technology and CO2 emissions. Chaudhry and Chandni (2023) suggest that innovation technology is a primary contributor to CO2 emissions in India, both in the long term and short term. However, other research indicates that technological innovation can also decrease environmental degradation (Ozpolat & Özsoy, 2022). The impact of technology on environmental quality depends on various factors such as the type of technology, energy sources, and institutional quality (Gao & Fan, 2023). Information and communication technology (ICT) usage also contributes to CO2 emissions in the long run, although the relationship is not significant in the short run (Kim, 2022). The impact of technology on carbon emissions also varies depending on the specific indicators used. For example, ICT variables are found to be effective instruments for carbon reduction, while R&D expenditure and patents do not significantly influence carbon emissions (Milindi & Inglesi-Lotz, 2022). Additionally, the expansion of renewable electricity and the promotion of trade openness can help mitigate CO2 emissions (Dehdar et al., 2022). Overall, technology and its various components have a complex relationship with carbon emissions, with both positive and negative effects depending on the specific context and indicators used (Aysun & Bayar, 2022). The quality of governance and institutions plays a significant role in determining the relationship between technology and environmental quality. Countries with better institutional quality and governance tend to have lower carbon emissions and better environmental quality. This indicates that technology is a significant contributor to CO2 emissions reduction (Yilmaz Bayar, 2022).

2.2.2 Foreign Direct Investment (FDI) and Carbon Emissions (CO2) Nexus

Foreign direct investment (FDI) has a significant impact on carbon emissions in different countries and regions. The relationship between FDI and carbon emissions is complex and varies depending on factors such as the level of education, environmental management systems, and technological innovation (Wang et al., 2023. Education levels play a moderating role, where FDI inflows may result in higher emissions in economies with low levels of schooling, but can reduce CO2 emissions when education levels exceed certain thresholds (Khan et al., 2023). Studies have shown that FDI can lead to increased carbon emissions in some cases, particularly in developing countries with low levels of education (Serge et al., 2023), which suggests that countries with weaker environmental regulations and lower environmental quality attract more FDI, leading to increased pollution levels (Xie & Zhang, 2023; Chiriluş & Costea, 2023; Zhang et al., 2023). However, in other cases, FDI has been found to harm carbon emissions, especially when combined with effective environmental management systems and higher levels of education (Wang et al., 2023; Khan et al., 2023). Additionally, technological innovation plays a crucial role in mediating the relationship between FDI and carbon emissions, with FDI influencing carbon emission efficiency through its impact on technological innovation (Zheng et al., 2022). FDI quality upgrading can significantly reduce urban carbon emissions, especially in cities with low industrial rationalization (Waweru &Mose, 2022), high investment in science and technology, strong

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environmental regulation, and high dependence on foreign capital (Fang et al., 2023). Dong (2023) identified direct impact and spatial spillover effect of FDI on carbon emissions have temporal and regional differences in China, emphasizing the need for optimizing FDI quality and governance to achieve energy conservation and emission reduction goals. FDI can have both positive and negative impacts on environmental quality, with its effects depending on factors such as the rationalization degree of industrial structure, investment in science and technology, environmental regulation, and dependence on foreign capital. These findings highlight the importance of considering education, environmental management systems, and technological innovation when examining the impact of FDI on carbon emissions. According to the above arguments, FDI inflow increases carbon emissions tends to increase.

2.2.3 Economic Growth and Carbon Emissions (CO2) Nexus

Economic growth has been found to have a significant influence on CO2 emissions in several studies. In the European Union (EU) countries, economic growth was found to have a statistically significant effect on CO2 emissions, with a 1% change in GDP leading to a 0.072 change in CO2 emissions on average (Madaleno & Nogueira, 2023). A study on Indonesia also found a positive relationship between economic growth and CO2 emissions in the long run (Taufiq et al., 2022). In the Beijing-Tianjin-Hebei region, economic growth was found to reduce CO2 emissions, while CO2 emissions also contributed to economic growth to some extent. Additionally, economic growth facilitated industrial structure upgrading, and the advanced industrial structure promoted economic growth, but the rationalization of the industrial structure had a limiting effect on economic growth (Néjib & Guenichi, 2023). Similarly, in West Africa, economic growth was found to increase CO2 emissions, following the Environmental Kuznet Curve hypothesis. However, in the presence of improved governance quality, economic growth did not significantly influence CO2 emissions in the region (Ifelunini et al., 2023). Other factors such as trade, urbanization, and renewable energy also influenced CO2 emissions in the region (Waweru & Mose, 2022). In Tunisia, economic growth was positively correlated with carbon emissions, indicating that the country has not yet reached the required level of per capita income for an inverted U-shaped Environmental Kuznets Curve. Energy consumption and financial development were also found to contribute to environmental damage in the long run (Madaleno & Nogueira, 2023). These findings highlight the need for effective governance and environmental policies to mitigate the impact of economic growth on CO2 emissions.

3 METHODOLOGY

This chapter captures relevant data collection methods and data analysis techniques.

3.1 Research Design

The study employed a quantitative research design to investigate the relationship between technologyprogress and carbon emissions in Kenya for the period 1990 to 2022. African economies specifically Kenya are currently threatened with more CO2 emissions for which proper strategies and policies need to be adopted to reduce and mitigate this situation. Time series secondary data was obtained from the World Bank database. Table 1providesa detailed description of the study variables.

Table1.Definition of Variables

Variables	Unit of Measurement	Definition	Data source	Expected sign

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Dependent variable				
Carbon emissions (CO2)	Metric tons	Carbon dioxide emissions	World Bank	No prediction (Nawaz et al., 2023)
Independent variables				
Technology (TECH)	Numbers	Patent applications (residents and non-residents)	World Bank	Negative (Gao & Fan, 2023)
Foreign Direct Investment (FDI)	Per cent	Foreign Direct Investment, net inflows (% GDP)	World Bank	Positive (Xie & Zhang, 2023)
Economic Growth (ECG)	Constant 2015 US dollars	GDP per capita is Gross Domestic Product divided by midyear population	World Bank	Positive (Nawaz et al., 2023)

3.2 Model Establishment

The research employed the following model to investigate the role of technological progress on carbon dioxide emissions.

$$\mathrm{CO2_t} = \mathrm{f(TECH_t, FDI_t, ECG_t)} \quad (1)$$

To eliminate skewness and serial correlation problems the data variables were transformed into natural logs.

Hence, we can re-write the above equation as follows:

$$\mathrm{lnCO2_t} = \beta_0 + \beta_1 \mathrm{lnFDI_t} + \beta_2 \mathrm{lnTECH_t} + \beta_3 \mathrm{lnECG} + \varepsilon_t (2)$$

Where ε_t– representsthe error term, t represents time dimensions, *shows* the constant term, and β_1 *to* β_3– are coefficients variables.

ARDL estimation model was applied as shown in Equation 3

$$\Delta \mathrm{lnCO2_t} = \alpha_{01} + \sum_{i=1}^{p} \alpha_{1i} \Delta \mathrm{lnCO2_{t-i}} + \sum_{i=0}^{w} \alpha_{2i} \Delta \mathrm{lnTECH_{t-i}} + \sum_{i=0}^{w} \alpha_{3i} \Delta \mathrm{lnCOV_{t-i}} + \beta_{11} \mathrm{lnCO2_{t-1}} + \beta_{21} \mathrm{lnTECH_{t-1}} + \beta_{31} \mathrm{lnCOV_{t-1}} + \varepsilon_{1t}$$
(3)

Equation 4 was used to analyze the long-run relationship between the target variables.

$$\mathrm{lnCO2_t} = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i} \mathrm{lnCO2_{t-i}} + \sum_{i=0}^{w} \alpha_{2i} \mathrm{lnTECH_{t-i}} + \sum_{i=0}^{w} \alpha_{3i} \mathrm{lnCOV_{t-i}} + \varepsilon_{it} (4)$$

To check for causality association error correction term equation 5 was used.

$$\Delta lnCO2_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i} \Delta lnCO2_{t-i} + \sum_{i=0}^{w} \alpha_{2i} \Delta lnTECH_{t-i} + \sum_{i=0}^{w} \alpha_{3i} \Delta lnCOV_{t-i} + \emptyset_1 ECT_{t-1} + \varepsilon_{1t} \qquad (5)$$

The lagged error correction term ECT_{t-1}, in equation 5 measures the speed of adjustment to the long-run equilibrium and also the long-run causality relationship.

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Where COV_t – Matrix of Control variables (FDI and ECG) and ECT_{t-1} is the error correction term.

3.3 Estimation Procedure

Phillips –Peron (PP) unit root test was employed to scrutinize stationarity in the series. The F-bounds co-integration test was applied to confirm the presence of a long-run relationship between study variables. Before the estimation, lag length and best model estimator were identified. ARDL estimation method was used to analyze the determinants of carbon emission. ARDL is highly robust regardless of the stationarity and endogeneity of the target variables (Pesaran et al., 2001). Granger causality test was conducted to check for association between study variables. All models were subjected to diagnostic tests such as autocorrelation (Breusch-Godfrey test) and heteroscedasticity (Breusch-Pagan test) to avoid misleading results.

4 RESULTS AND DISCUSSION

This chapter reports the analysis results and discussion.

4.1 Unit Root Test

The research applied the Phillips-Perron (PP) unit root test to investigate the unit root problem. The PP result is reported in Table 2.

Table2. Unit Root Test

Variable	**Level**		**Variable**	**First difference**		**Integration order**
	t-Statistics	**P-Value**		**t-Statistics**	**P-Value**	
CO2	-0.751313	0.8192	∆CO2	-6.071111	0.0000	I(1)
ECG	1.700120	0.9994	∆ECG	-3.910589	0.0054	I(1)
TECH	-3.153463	0.0325				I(0)
FDI	-4.936749	0.0003				I(0)
Note: Null Hypothesis: data series has a unit root						

Based on the unit root result, carbon emission and economic growth are non-stationary and only become stationary after the first difference. FDI and technology were stationary at the level. Considering most variables are integrated of order I (1) including dependent variables the study proceeded to investigate the long-run relationship.Investigation of lag length is important to reduce serial correlation problems. Vector autoregression (VAR) lag selection result (-7.927380*) has confirmed that the appropriate lag length is 5 and the best estimation method is the Akaike information criterion (AIC), as supported by the minimum value.

4.2 Cointegration Test

The study adopted the Pesaran et al. (2001) cointegration test to investigate the long-run relationship between the study variables. Table 3shows the F-bound cointegration test result.

Table3.Cointegration Results

Narayan	**Value**	**Significance Level**	**Bounds Critical values**	
F-Statistics	5.299641		I(0)	I(1)
		1%	5.17	6.36

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K	3	5%	4.01	5.07
		10%	3.47	4.45
Note: Null hypothesis: No level relationship.				

From the result, F statistics (5.299) is greater than the upper bound critical value (5.070), and thus cointegration or long-run relationship is present. The study proceeded to check for long-run and short-run effects.

4.3Estimation Result

ARDL estimation was applied to investigate the long-run and short-run relationship between target variables based on the Akaike information criterion (AIC) (3, 4, 3, 4). Table 4representsthe ARDL regression result.

Table4. ARDL Result

Long run results				*Short run results*			
Variable	Coefficient	t-statistics	P-value	Variable	Coefficient	t-Statistic	P-value
TECH	-0.079	-3.032**	0.0126	ΔTECH	-0.032	-4.145***	0.0020
ECG	0.654	4.097***	0.0022	ΔECG	-1.226	-2.023*	0.0706
FDI	0.109	7.313***	0.0000	ΔFDI	0.020	2.032*	0.0695
Cons	-2.525	-2.204*	0.0520	Cons	-2.525	-5.250***	0.0004
				ECT(-1)	-0.975	-5.249***	0.0004
Goodness of fit		R-Squared			0.708097		
Econometrics Problems		Test Statistic			F-statistics		P-Value
Serial Correlation		Breusch-Godfrey LM			0.343513		0.7192
Heteroscedasticity		Breusch-Pagan-Godfrey			0.470490		0.9213
*Note: * p < 0.1, ** p < 0.05, *** p < 0.01 are significance levels, in which the null hypothesis is rejected. Dependent variable: CO2*							

Based on Table 4 result, an increase in technology development will reduce carbon emissions in Kenya, in the long run. Specifically, an increase in technology and innovation by 1 % will reduce carbon emissions by 0.079%. Technology can enhance the efficiency of carbon emissions and as such reduce carbon emissions. Improved technology can significantly reduce carbon emission intensity and improve carbon emission efficiency. This means that technological innovation can increase labor productivity and utilization of resources, thereby reducing carbon emissions.Furthermore, additional energy consumption pollution is offset by the improvement of technological innovations. Also, software technology reduces the number of physical resources and thus uses less energy. Hence, enhancing technological innovations can help resolve environmental degradation issues and achieve sustainable development (Gao & Fan, 2023). The findings agree with research by Gao and Fan (2023) and Nawaz et al. (2023) empirical studies. The short-run findings agree with long-run findings that an increase in technology development will translate to a reduction in carbon dioxide emissions and improve environmental quality.

An increase in GDP will increase carbon emissions in Kenya. In Kenya increase in GDP by 1% will increase CO_2 emission by 0.654%. Economic growth has been found to have a significant influence on CO_2 emissions in several studies. Carbon emission increases as

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energy consumption and economic activities are enhanced in the economy. Increased labour force and capital formation will increase further carbon emissions. These findings support the Environmental Kuznets Curve (EKC) hypothesis. The study finding is similar to Nawaz et al. (2023) empirical study. In the EU countries, economic growth was found to have a statistically significant effect on CO2 emissions, with a 1% change in GDP leading to a 0.072 change in CO2 emissions on average (Madaleno & Nogueira, 2023). A study on Indonesia also found a positive relationship between economic growth and CO2 emissions in the long run (Taufiq et al., 2022). In the Beijing-Tianjin-Hebei region, economic growth was found to reduce CO2 emissions, while CO2 emissions also contributed to economic growth to some extent.Economic growth can improve CO2 emissions by increasing carbon dioxide emissions levels. The studies conducted in China, Indonesia, Nepal, and the EU member states (Taufiq et al., 2022) supported positive results.In contrast, the short-run result indicates a negative relationship between economic growth and CO2 emissions.This is possible with enhanced GDP the economy may adopt better technology and cleaner sources of energy and thus reduce carbon emissions. Economic growth facilitated industrial structure upgrading, and the advanced industrial structure promoted economic growth, but the rationalization of the industrial structure had a limiting effect on economic growth (Néjib & Guenichi, 2023).

An increase in foreign direct investment (FDI) inflow will increase carbon emissions in Kenya. The result indicates FDI inflow is positively related to carbon emission. Specifically, increase in FDI level by 1 will increase carbon emission by 0.109 %. FDI will expand the production capacity of the host country via new investment, which results in carbon emission in the production unit involved and as such increases the carbon dioxide level (Kipchirchir & Mose, 2024). The findings agree with Serge et al. (2023) research. Studies have shown that FDI can lead to increased carbon emissions in some cases, particularly in developing countries with low levels of education (Serge et al., 2023), which suggests that countries with weaker environmental regulations and lower environmental quality attract more FDI, leading to increased pollution levels (Xie & Zhang, 2023; Chiriluş & Costea, 2023; Zhang et al., 2023). However, in other cases, FDI has been found to harm carbon emissions, especially when combined with effective environmental management systems and higher levels of education (Wang et al., 2023; Khan et al., 2023). The findings agree with short-run results.

The coefficient of error term (ECT) was significant and negative in Kenya, implying a long-run relationship exists between carbon emissions and technology. It also impliesthat 0.957 will be corrected in case of any disequilibrium in Kenya in the current year; disequilibrium will exist for a short time. Having confirmed long-run causality using ECT, the study proceeded to check for short-run causality using a pairwise causality test.The coefficient of determination is 0.708, implying about 70 % of the variation in carbon emission is explained in the model.The study also conducted diagnostic tests and controlled for the effect. Based on the diagnostic result, serial correlation and heteroscedasticity were not a problem in the regression model.

4.4 Causality Test

A pairwise causality test was applied to confirm the association between technology and carbon emission in the short run. Table 5 shows the pairwise causality result.

Table5. Pairwise Causality Results

Direction	F-Statistic	P-Value	Status
$TECH \rightarrow CO2$	3.18451	0.0354	

$CO2 \rightarrow TECH$	0.37815	0.8215	One way causality

The study result has identified one-way causation runs from technology development to carbon emission. This means technological progress has a relationship with carbon emissions. Technology can enhance the efficiency of carbon emissions and as such reduce carbon emissions.

5 CONCLUSION

African economies specifically Kenya are currently threatened with more carbon dioxide (CO2) emissions for which proper strategies need to be adopted to reduce and mitigate this situation. To achieve this objective, the study employed advanced econometric methods to investigate the role of technology on carbon emissions. The study usedthe Phillips Peron unit root test, F-bound cointegration test, ARDL estimation approach, and causality test. Secondary data for Kenya for the period 1990 to 2022 was obtained from the World Bank database. The results indicate a negative relationship between technology and carbon emissions. This means that technological innovation can increase labor productivity and utilization of resources, thereby reducing carbon emissions. In contrast, economic growth and FDI inflow have a positive sign on carbon emissions.Technology, economic growth and FDI have been identified as the main drivers of carbon emissions in Kenya. The study has also established a causal relationship running from technology to carbon emissions. Based on the result, various strategies have been proposed, including using different technologies to produce renewable fuels. The use of green and clean technologies can help mitigate the negative impact of technological progress on the environment. Additionally, technological progress, particularly in the information and communication technology (ICT) sector, will reduce greenhouse gas emissions. Policymakers and stakeholders should emphasize research and development for updated production technology while raising economic growth helps to reduce CO2 emissions. Additionally, environmental policies should aim to minimize emissions, FDI should be environmentally friendly, and incentives needed to redirect private credits toward green projects and renewable energy development.

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REFERENCES

Adam, S., Delestre, I., Levell, P., & Miller, H. (2022). Tax Policies to Reduce Carbon Emissions. *Fiscal Studies*, *43*(3). https://doi.org/10.1111/1475-5890.12308.

Akhter, P., Farkhondehfal, M. A., Hernández, S., Hussain, M., Fina, A., Saracco, G., Khan, A. U., & Russo, N. (2016). Environmental issues regarding CO2 and recent strategies for alternative fuels through photocatalytic reduction with titania-based materials. *Journal of Environmental Chemical Engineering*, *4*(4), 3934–3953. https://doi.org/10.1016/j.jece.2016.09.004.

Aysun,K., &Bayar.Y. (2022). Impact of Information and Communication Technology on CO2 Emissions. *Practice, Progress, and Proficiency in Sustainability*, 1–11. https://doi.org/10.4018/978-1-7998-9648-7.ch001.

Basumatary, J., Mucheri, T., Nyoni, T., Mose, N., & Waweru, D. (2021). Linking the environment, SDGS and economic growth: Are we doing enough? Journal of Research in Environmental and Earth Sciences, 7(7), 69-75

Boudinar, I. (2022). The theoretical framework of Environmental degradation, Energy consumption, and Globalization and the relationship between them. *Science and Knowledge Horizons Journal*, *2*(01), 684–701. https://doi.org/10.34118/jskp.v2i01.2143

Chaudhry, A., & Chandni. (2023). The Impact of Innovation Technology on Carbon

Emissions in India. *Journal of Asian Energy Studies*, *7*, 1–19. https://doi.org/10.24112/jaes.070001
Chiriluş, A. I., & Costea, A. (2023). *The Effect of FDI on Environmental Degradation in Romania: Testing the Pollution Haven Hypothesis*. *15*(13), 10733–10733. https://doi.org/10.3390/su151310733
Dai, H., Sun, T., Zhang, K., & Guo, W. (2015). Research on Rural Nonpoint Source Pollution in the Process of Urban-Rural Integration in the Economically-Developed Area in China Based on the Improved STIRPAT Model. *Sustainability*, *7*(1), 782–793. https://doi.org/10.3390/su7010782
Dehdar, F., Silva, N., Fuinhas, J. A., Koengkan, M., & Nazeer, N. (2022). The Impact of Technology and Government Policies on OECD Carbon Dioxide Emissions. *Energies*, *15*(22), 8486. https://doi.org/10.3390/en15228486
Dong, Y. (2023). How Does FDI Affect Carbon Emissions?—Heterogeneity Analysis Based on Spatial Econometric Models. *Environmental Science and Engineering*, 447–454. https://doi.org/10.1007/978-3-031-25284-6_48
Fang, H., Zhang, X., Lei, T., & Baya Lydia Houadi. (2023). FDI Quality, Green Technology Innovation and Urban Carbon Emissions: Empirical Evidence from China. *Sustainability*, *15*(12), 9657–9657. https://doi.org/10.3390/su15129657
Gao, X., & Fan, M. (2023). The role of quality institutions and technological innovations in environmental sustainability: Panel data analysis of BRI countries. *PLOS ONE*, *18*(6), e0287543–e0287543. https://doi.org/10.1371/journal.pone.0287543
Gisore, M. (2017). Renewable energy and nonrenewable energy consumption, CO2 emissions and economic expansion nexus: Further evidence from Kenya. *Energy Economics Letters*, 4(4), 36-48
Grossman, G. M., & Krueger, A. B. (1995). Economic Growth and the Environment. *The Quarterly Journal of Economics*, *110*(2), 353–377. https://doi.org/10.2307/2118443
Ifelunini, I., Ekpo, U., Adzugbele, S., Agbutun, O., Arazu, C. Ugwu,S., Osademe, N., & Asogwa, F. (2023). Economic Growth, Governance And CO_2 Emissions In West Africa. *Chinese Journal Of Urban And Environmental Studies*, *11*(01). Https://Doi.Org/10.1142/S2345748123500021
Khan, M., Rana, A., & Wafa, G. (2023). FDI and CO2 emissions in developing countries: the role of human capital. *Natural Hazards*, *117*(1), 1125–1155. https://doi.org/10.1007/s11069-023-05949-4
Kim, S. (2022). The Effects of Information and Communication Technology, Economic Growth, Trade Openness, and Renewable Energy on CO2 Emissions in OECD Countries. *Energies*, *15*(7), 2517. https://doi.org/10.3390/en15072517.
Kipchirchir, E., & Mose, N. (2024). Foreign Direct Investment and Economic Growth in Kenya: A Comprehensive Analysis. *Asian Journal of Economics, Business and Accounting*, 24(2), 1–13. https://doi.org/10.9734/ajeba/2024/v24i21215
Lawn, P. (2006). A theoretical investigation into the likely existence of the Environmental Kuznets Curve. *International Journal of Green Economics*, *1*(1/2), 121. https://doi.org/10.1504/ijge.2006.009340
Madaleno, M., & Nogueira, M. C. (2023). How Renewable Energy and CO2 Emissions Contribute to Economic Growth and Sustainability—An Extensive Analysis. *Sustainability*, *15*(5), 4089. https://doi.org/10.3390/su15054089.
Maranzano, P., Cedeira, B, & Manera, M. (2021). The role of education and income inequality in environmental quality. A panel data analysis of the EKC hypothesis on OECD countries. *Social Science Research Network*. https://doi.org/10.22004/ag.econ.310225.
Milindi, C. B., & Inglesi-Lotz, R. (2022). Impact of technological progress on carbon

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emissions in different country income groups. *Energy & Environment*, 0958305X2210875. https://doi.org/10.1177/0958305x221087507
Muganyi, T., Yan, L., & Sun, H. (2021). Green finance, fintech and environmental protection: Evidence from China. *Environmental Science and Ecotechnology, 7*, 100107. https://doi.org/10.1016/j.ese.2021.100107.
Nawaz, A., Saif Ur Rahman, Zafar, M., & Ghaffar, M. (2023). Technology Innovation-institutional Quality on Environmental Pollution Nexus From E-7 Nations: Evidence From Panel Ardl Cointegration Approach. *Review of Applied Management and Social Sciences*, *6*(2), 307–323. https://doi.org/10.47067/ramss.v6i2.329
Néjib,C.,& Guenichi, H. (2023). The effects of economic growth, energy consumption and financial development on CO_2 emissions in Tunisia: ARDL bounds testing approach to cointegration. *Natural Resources Conservation and Research*, *6*(1), 2037–2037. https://doi.org/10.24294/nrcr.v6i1.2037
Ozpolat, A., &Özsoy, F. (2022). The Effect of Technological Innovations on Environmental Quality in Selected OECD Countries. *Sosyoekonomi*, 11–31. https://doi.org/10.17233/sosyoekonomi.2022.01.01.
Pesaran, M., Shin, Y., & Smith, R. (2001). Bounds Testing Approaches to the Analysis of Level Relationships. *Journal of Applied Econometrics*, 16(3), 289 – 326.
Serge,P., Puatwoe,J., Tabi, P., Nghogekeh,R.,&Foundjem-Tita , D. (2023). Foreign direct investment and carbon emissions from land use, land-use change, and forestry (LULUCF): empirical evidence from tropical forest countries. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-023-03267-0
Taufiq,M, Bashir, A., Pratama A.,, Hamidi, I., Mukhlis, M., &Sukanto, S. (2022). The Link between Economic Growth, Electricity Consumption, and CO_2 Emissions: Evidence from Indonesia. *Signifikan*, *11*(2), 253–272. https://doi.org/10.15408/sjie.v11i2.26286
Wang, C., Liu, T., Zhu, Y., Wang, H., Zhao, S., & Liu, N. (2023). The impact of foreign direct investment on China's industrial carbon emissions based on the Threshold Model. *Research Square (Research Square)*. https://doi.org/10.21203/rs.3.rs-2489521/v1
Waweru D., & Mose, N. (2022). Household fuel choice in urban Kenya: a multinomial logit analysis. Financial Internet Quarterly 18 (2), 30-41
Wen, H., & Dai, J. (2021). The Change of Sources of Growth and Sustainable Development in China: Based on the Extended EKC Explanation. *Sustainability, 13*(5), 2803–2803. https://doi.org/10.3390/su13052803
Xie, R., & Zhang, S. (2023). *Re‐ examining the impact of global foreign direct investment (FDI) inflows on haze pollution—considering the moderating mechanism of environmental regulation*. 0958305X2311646–0958305X2311646. https://doi.org/10.1177/0958305x231164679
Yilmaz, R. (2022). Endüstriyel Kalkinma Ve Çevresel Kuznets Eğrisi: Ergene Havzasi Üzerine Bir Vaka Çalişmasi. *Sosyal Bilimler Metinleri*. Https://Doi.Org/10.56337/Sbm.1158780
Zargar, R. & Rather, M. I. (2022). Emerging Issues of Climate Change. *CRC Press EBooks*, 215–230. https://doi.org/10.1201/9781003220824-16
Zhang, J., Han, R., Song, Z., & Zhang, L. (2023). Evaluation of the triangle-relationship of industrial pollution, foreign direct investment, and economic growth in China's transformation. *Frontiers in Environmental Science*, *11*. https://doi.org/10.3389/fenvs.2023.1123068
Zheng, J., Assad, U., Kamal, M. A., & Wang, H. (2022). Foreign direct investment and carbon emissions in China: "Pollution Haven" or "Pollution Halo"? Evidence from the NARDL model. *Journal of Environmental Planning and Management*, 1–26.

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https://doi.org/10.1080/09640568.2022.2130194

Zhu, Y., Yu, J., Fan, Z., & Zhang, Z. (2021). 2D Materials for electrochemical carbon dioxide reduction. *Elsevier EBooks*, 183–196. https://doi.org/10.1016/b978-0-12-822894-4.00006-x

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