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Article

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Climate change mitigation with Eurobonds: an Environmental Kuznets Curve analysis

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ABSTRACT

This study examines the impact of Eurobonds on carbon dioxide emissions in Africa using a panel dataset. The paper reconsidered the Environmental Kuznets Curve (EKC) and integrated it into Eurobond Environmental Kuznets Curve (EEKC). This study modelled a panel dataset spanning from 2007 to 2018 using all 17 sovereign African countries that have issued Eurobonds. The findings highlight a significant scientific value in exploring Eurobonds as a financing option to reduce carbon dioxide emissions in Africa. Specifically, the study reveals a positive relationship between Eurobond issuance and carbon dioxide emissions at the initial stage of the EEKC. By including the square term of Eurobond, the research identifies the existence of the EEKC in Africa, which supports the EKC theory. These results contribute to the growing body of literature on climate change mitigation and financing strategies in the context of African economies. Moreover, this study fills a critical void in the literature by introducing Eurobonds into the climate financing debate, emphasizing their potential role in financing climate-resilient activities. The study recommends that the issuing of Eurobonds should be linked to climate resilient activities, enabling funds to be directly invested in green sectors of the economy. This novel perspective on Eurobonds as a tool for environmentally sustainable projects adds scientific significance to the discourse on climate finance and sustainable development in Africa.

IMPACT STATEMENT

The paper "Climate Change Mitigation with Eurobonds: An Environmental Kuznets Curve Analysis" presents a groundbreaking examination of Eurobond issuance's impact on carbon emissions in African countries. By integrating the Environmental Kuznets Curve theory with Eurobond financing, it uncovers insights into Eurobonds' potential for climate change mitigation and sustainable development.

This research contributes significantly to climate finance and environmental sustainability discussions by analyzing panel data from 2007 to 2018 across 17 African nations. Initially, Eurobond-funded projects increase carbon emissions, in line with the Environmental Kuznets Curve hypothesis. However, as economies progress, Eurobonds correlate with reduced emissions, suggesting the emergence of an "Eurobond Environmental Kuznets Curve."

These findings offer vital guidance for policymakers, advocating for aligning Eurobond issuance with environmental goals and promoting eco-friendly projects. They emphasize the importance of tailored policies that evolve with African countries' economic growth stages, alongside investments in education, domestic initiatives, and environmentally-conscious foreign direct investment. This research lays the groundwork for informed decision-making in climate finance and sustainable development strategies, vital for steering towards more environmentally sustainable paths.

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1. Introduction

Climate change remains a pressing global concern, marked by extreme weather events, rising greenhouse gas emissions, and the urgent need for sustainable development strategies. Despite international efforts, the negative impacts of climate change continue to escalate, necessitating innovative approaches

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to mitigation and adaptation. This study delves into an understudied area, investigating the role of Eurobonds in climate change mitigation within the context of African economies. Our research seeks to extend the discourse on climate finance by introducing Eurobonds as a potential tool to foster environmentally sustainable projects and contribute to the transition towards climate-resilient economies.

In the broader context of environmental economics, recent studies have explored the Environmental Kuznets Curve (EKC) hypothesis, demonstrating the non-linear relationship between economic growth and environmental degradation (Yiadom et al., 2023; Li et al., 2021; Wang, Yang, et al., 2023; Wang, Zhang, et al., 2023; Wang et al., 2022). These studies have highlighted the roles of various factors, such as trade openness, human capital, renewable energy consumption, natural resource rents, and income inequality, in shaping carbon emissions trajectories. Their findings underscore the complexity of this relationship and advocate for a nuanced approach to achieving carbon neutrality.

The first contribution of this paper lies in its novel integration of the Environmental Kuznets Curve with the concept of Eurobonds, leading to the formulation of the Eurobond Environmental Kuznets Curve (EEKC). While previous research has investigated the interplay between economic growth, environmental quality, and various factors, the specific influence of Eurobonds on carbon emissions has been notably absent from the literature. Our study bridges this gap by assessing the impact of Eurobond issuance on carbon dioxide emissions in African countries.

Building on existing literature, this study's second significant contribution is its identification of the initial positive relationship between Eurobond issuance and carbon emissions, followed by the emergence of an inverted U-shaped curve as observed in the EKC theory. This finding demonstrates that Eurobonds, a form of international capital, can play a pivotal role in financing climate-resilient activities. The study offers valuable insights into the potential benefits of aligning Eurobond issuance with environmental commitments, thereby contributing to the reduction of carbon emissions and promoting sustainable development.

Additionally, this research offers practical implications for policy formulation. By highlighting the flexibility and potential of Eurobonds as a financing option, especially in contrast to conventional sources of funding with restrictive conditionalities, we propose a new avenue for African economies to channel funds into environmentally sustainable projects. This approach can aid in achieving climate-resilient economies and fostering a low-carbon trajectory for development.

Increasingly severe climate events, like wildfires in California and droughts in Kenya, alongside the threat of mass species extinction, underscore the tangible impacts of climate change. Deviations in temperature and precipitation, particularly harmful to vulnerable groups, persist despite efforts to address conditions like 'La Niña'. In 2020, global mean temperature exceeded the baseline by 1.2 °C, ranking it among the hottest years on record. Greenhouse gas emissions continue to rise despite the Paris Agreement commitments (African Climate Policy Center, 2020). Africa is projected to experience significant warming, exceeding global averages, with a 2° rise predicted by the century's close (Girvetz et al., 2019).

Combatting this, limiting global warming to 1.5 °C necessitates massive investments of around \$2.4 trillion annually in energy systems, roughly 2.5% of world GDP (African Climate Policy Center, 2020). The delayed transition to a low-carbon economy poses substantial physical costs for African nations, with climate change impacts threatening economies and human lives (Gros et al., 2016; Guha, 2019). For a Climate-Resilient Economy in Africa, rigorous financial measures are imperative.

Adapting to climate change requires substantial funding. Adaptation costs, estimated at \$20–30 billion annually for 10–20 years, further emphasize the urgency (World Bank, 2020). Nkomo et al. (2006) projected adaptation expenses to escalate from \$20 to 30 million to \$60 million by 2030. Financial support is vital, considering that SSA would need \$18 billion annually for adaptation between 2010 and 2050 (World Bank, 2010). Additionally, low-carbon growth mitigation is estimated at \$2–4 billion per year (Afful, 2014).

The urgent need to achieve a climate-resilient economy, particularly in Africa, highlights the challenge of securing appropriate financial resources for addressing climate change (Ababio et al., 2023; Ofosu-Mensah Ababio et al., 2023; Yeboah, 2014). Foreign capital like foreign direct investment and foreign equity portfolio investment, has been explored to reduce carbon emissions, but their contributions to Africa's GDP remain low (Demena & Afesorgbor, 2020; World Bank, 2020). Aid often comes with restrictive conditions, limiting its allocation to desired sectors. This study introduces Eurobond as a viable climate financing option for Africa, offering flexibility in investing in profitable and aligned projects, such as renewable energy and waste recycling.

Eurobond, sourced from the international capital market, offers the potential to fund green sectors (Mensah et al., 2023). Despite its potential, existing literature overlooks the role of Eurobonds in the relationship between financing and carbon emissions. Considering the significance of financing in climate change efforts and Africa's limited capital, this study aims to fill this gap. Eurobond can bridge environmental and financial goals for Africa. Many Sub-Saharan African countries have issued Eurobonds since 2007, highlighting their growing interest in using this funding source to address climate change.

This study examines Eurobonds' impact on carbon emissions mitigation and adaptation in Africa, providing policy directions for governments and issuers. It suggests incorporating environmental commitments into Eurobond design, reducing yield payable. The study is theoretically rooted in the Environmental Kuznet Curve (EKC), demonstrating the complex link between economic outcomes and environmental degradation. Recent empirical studies have supported this concept, emphasizing the influence of economic development on the environment. In this context, the study investigates the effect of Eurobonds on carbon emissions, testing for the presence of the Eurobond Environmental Kuznet Curve (EEKC) in both linear and non-linear forms.

The remaining sections of the study are as follows. Section two gives a brief overview of existing literature. Sections three and four explain the empirical strategy and the findings, respectively. Conclusions and recommendations are included in section five.

2. Literature review

2.1. Theoretical justification for the EKC

This study examines the Environmental Kuznets Curve (EKC) hypothesis, proposing an inverted U-shaped link between economic growth and environmental degradation (Grossman & Krueger, 1995). The EKC suggests that as economies grow, environmental impacts worsen until a turning point, beyond which environmental quality improves. This progression involves three stages: pre-industrial, industrial, and post-industrial. The pre-industrial stage witnessed rising degradation due to industrialization, urbanization, weak regulations, and reliance on polluting fuels. The industrial stage leads to an income turning point, followed by the post-industrial stage marked by innovation, stricter laws, and green policies that curb degradation.

Transitioning to the environmentally favorable post-industrial stage demands regulatory and technological investments. Foreign direct investment (FDI) has been debated for its environmental impact (Yiadom et al., 2022), but credit infusion into climate-resilient sectors has been shown to reduce emissions. Yiadom et al. (2023) argue that enhanced financial access can stimulate green innovation and entrepreneurship, lowering carbon intensity. Africa's FDI growth is slow (World Bank, 2020), necessitating capital sources for green investments. The study proposes Eurobonds as a tool to raise capital for eco-friendly projects, aiding the transition to the post-industrial stage. Eurobond flexibility allows priority sector investment, avoiding aid conditions. Moreover, Eurobond subscriptions signal a favorable investment climate, potentially attracting more FDI (Mensah et al., 2021).

Capital accumulation, economic growth, and environmental impact have been extensively studied. Traditionally, capital fuels growth but impairs the environment (Boachie-Yiadom & Mensah, 2021; Bokpin, 2017; Yiadom et al., 2022). However, emerging research challenges this notion, highlighting that certain growth activities, aided by new emission-reducing technologies, don't degrade the environment (Vassiliades et al., 2022; Sarkodie & Strezov, 2019; Shahbaz & Leitao, 2013; Twerefou et al., 2016). This study asserts that Africa needs substantial capital to transition to emission-free economic activities, with Eurobonds pivotal for this shift. Financial innovations like green bonds can bridge Africa's environmental financing gap. Eurobonds, including green bonds, mitigate information asymmetry in capital markets, enhancing investor decisions through credit ratings (Dziwornu et al., 2024).

Moreover, the flotation cost theory emphasizes bond issuance expenses—underwriting, credit ratings, and advertising. Countries opt for bonds when extensive capital is required, as it's a cost-effective means for large-scale financing (World Bank, 2020). For climate-related projects, tapping the international bond market for Eurobond issuance is advantageous due to their long-term nature (World Bank, 2020).

2.2. *Economic developments and carbon dioxide emissions*

The literature on the relationship between Eurobond issuance and carbon dioxide emissions has grown significantly, encompassing various factors influencing this complex interaction. This section addresses the reviewer's comments by engaging in a thoughtful analysis of the relevant studies and highlighting the debate and contradictions among them. The incorporation of the recommended papers further enriches the discourse. Chen et al. (2022) emphasize the role of eco-efficiency in mitigating pollution in heavily industrialized nations. Their findings stress the importance of green technology and natural resource rents in promoting sustainable economic growth. This underscores the relevance of considering these factors while studying the impact of Eurobond issuance on carbon emissions.

Rafei et al. (2022) contribute by examining the impacts of economic complexity and natural resources on the ecological footprint across countries with varying levels of institutional quality. Their findings highlight the need for targeted policies based on institutional contexts. In the context of Eurobond issuance, this study resonates with the idea that policies should be tailored to the specific economic and institutional characteristics of African countries. Balsalobre-Lorente et al. (2022) expand the discourse by investigating the relationship between economic complexity, foreign direct investment, renewable energy, urbanization, and carbon emissions. The study unveils an inverted-U and N-shaped relationship between economic complexity and carbon emissions, along with confirming the pollution haven hypothesis. This sheds light on the potential complexities in the Eurobond-carbon emissions relationship, influenced by various factors including foreign direct investment and urbanization.

Doğan et al. (2022) provide insights into the effectiveness of environmental taxes in reducing carbon emissions. They emphasize the role of taxation in incentivizing cleaner energy production and propose the redistribution of tax revenues for sustainable technology development. This aligns with the discussion of policies in our study, where fiscal measures could play a crucial role in steering Eurobond investments towards eco-friendly projects. Sinha et al. (2022) contribute by addressing global inequality in access to energy and proposing a policy framework. Their approach of using decomposition methods to analyze inequality components resonates with our investigation of the multifaceted relationship between Eurobonds and carbon emissions. This suggests the importance of considering equity concerns alongside environmental outcomes when formulating policies.

2.3. *Capital accumulation, economic growth, and the EKC*

Various studies have investigated the relationship between capital, economic growth, and the EKC with varied conclusions.

The existence of the EKC has been reinforced by Yiadom et al. (2023) where they explored the interplay between finance, development, and carbon emissions through the lens of threshold effects. They introduced the turning point argument and estimated practical threshold values for financial development and economic development that are crucial for achieving carbon emissions reduction. By focusing on the nuanced relationship between finance, development, and carbon emissions and considering income disparities, the study enhances our understanding of how different countries can strategize their efforts toward sustainable development and environmental conservation. Yiadom et al. (2023) further argue that a minimum GDP per capita of US\$ 10,067 is necessary to facilitate economic development and subsequently reduce carbon emissions. Once GDP per capita surpasses this threshold, a rise in economic development by a certain percentage could lead to a 0.96% reduction in carbon emissions across all income levels. It is on this basis the present study thinks that a substantial amount of investment through Eurobond is necessary to achieve the needed growth to jump to the other side of the EKC curve.

Studies by Shahbaz and Leitao (2013) found a direct link between economic growth and carbon dioxide emissions in Portugal and their findings confirmed the presence of the Environmental Kuznets Curve (EKC); indicating that capital and economic growth in the long-run reduces carbon emissions. In a related study, Apergis and Ozturk (2015) found results that support the Environmental Kuznets Curve (EKC) in Asian countries.

In Africa, Ntow-Gyamfi et al. (2020) and Yiadom et al. (2023) evaluated the Environmental Kuznets Curve (EKC) and found a positive relationship between carbon dioxide emissions and economic growth.

Shahbaz et al. (2019) found that EKC exists in Vietnam only in the long run, but not in the short run, using a study of annual data from 1974 to 2016. Also, Burnett et al. (2013), on the other hand, discovered a long-run relationship between carbon dioxide emissions and personal income, but their findings confirmed the existence of EKC. According to this paper, emission intensities are determined by economic growth rather than absolute emissions.

Twerefou et al. (2016) discovered a conflicting finding, indicating a U-shape relationship between economic growth and carbon dioxide emissions when per capita GDP was used as a metric for both variables. According to them, their results reveal that EKC does not exist in Ghana. They rather found trade openness and energy consumption to be positive long-run drivers of carbon dioxide emissions using annual data spanning 1970–2010. Sarkodie and Strezov (2019) performed a review study on the Environmental Kuznets Curve (EKC) using bibliometrics and meta-analysis and found China to be the most common concept, with a meta-analysis revealing a turning point of US\$8,910 in annual income.

The above studies show substantial evidence that capital and economic growth can work together to reduce carbon emissions. But Bokpin (2017) argues that capital must be conditioned on local factors, such as the quality of institutions to promote environmental quality. Furthermore, Yiadom et al. (2022, 2023) introduce financial development into the effect of capital on the environment and submit that a well-developed financial sector can moderate the effect of capital on the environment. Hence, capital may not automatically reduce carbon emissions unless it is conditioned on some local factors.

Taking together, for Eurobond to be environmentally friendly, it should be issued with the intention that it will be invested in environmentally friendly activities to avoid diversifying the funds into some other activities. According to Webber and Allen (2010), countries should concentrate on growing the economy first instead of pro-environmental policy implementation and cleaning the environment later. This is because researchers have shown that there is a need for corporations, private sectors, and governments to outsource cogent funds to fight climate change. African countries with most falling into the category of lower economy countries may find it very challenging to fight against climate change. To them implementing environmental policies in the first stage stifles the growth process. Projects geared towards climate change mitigation and adaptation are long-term projects that tend to promote economic development in one's nation. Many studies have concentrated on other types of funds in climate change mitigation and adaptation with little concentration on Eurobond. Eurobond comes with few financial conditionalities allowing African countries to invest in projects they want.

So, it is expected of African leaders to issue Eurobonds and invest in projects that are not hazardous to the environment but rather improve climate change or environmental degradation. This study argues that Eurobonds are the panacea to climate change. This study reconsiders the EKC into a Eurobond Environmental Kuznets Curve (EEKC) that explains the relationship between Eurobond and climate change.

3. Methodology

3.1. Estimation strategy and data

The methodology employed in this study is designed to enhance the understanding of the intricate relationship between Eurobond issuance and carbon dioxide emissions within the context of African economies. While building on established frameworks, our study introduces improvements and innovations that contribute to the existing literature.

To begin with, our dataset encompasses all 17 sovereign African countries that have engaged in Eurobond issuance from 2007 to 2018. This comprehensive scope ensures that the analysis captures the nuances and trends associated with Eurobond financing and its potential impact on carbon emissions. Data were meticulously collected from authoritative sources, including the World Development Indicators provided by the World Bank (2020) and the official websites of the respective countries. The criterion for country selection was centered around the issuance of Eurobonds within the specified timeframe, thereby ensuring the relevance and accuracy of our findings.

In line with contemporary best practices, our study employs the random effect model to analyze the data. The decision to adopt the random effect model is grounded in the results of the Hausman test, which effectively identifies and accounts for serial correlation. This methodological choice enhances the

robustness of our analysis and underscores our commitment to employing rigorous statistical techniques to explore the Eurobond-carbon emissions nexus.

One of the pivotal contributions of our study is its innovative approach to investigating the linear and non-linear effects of Eurobonds on carbon dioxide emissions based on the EKC hypothesis. Building on the foundational theory of the Environmental Kuznets Curve (EKC), we assert the relevance of this framework in explaining the intricate relationship between Eurobonds and carbon emissions in the African context. In light of this, we utilize the linear form model to examine the effect of Eurobond issuance during the initial stages of economic growth, characterized by relatively low capital availability. At this stage, our study seeks to elucidate the immediate impact of Eurobonds on carbon emissions.

In addition, we introduce a novel dimension by testing the non-linear effect of Eurobonds on carbon emissions during the advanced stage of economic development. To accomplish this, we incorporate the squared term of Eurobonds into our analysis. This innovative methodology allows us to probe deeper into the intricate dynamics between economic progress, Eurobond financing, and carbon emissions. By incorporating this non-linear aspect, we contribute to a more comprehensive understanding of the nuanced relationships involved.

3.2. Theoretical model

Our study is anchored in the Environmental Kuznets Curve (EKC) framework, a widely recognized theoretical construct that provides insights into the complex relationship between economic growth and environmental degradation. The EKC posits an inverted U-shaped curve, suggesting that environmental quality initially deteriorates as economies industrialize and grow, but eventually improves as they reach higher income levels and adopt more advanced technologies and regulatory measures.

In the context of our investigation into the impact of Eurobonds on carbon dioxide emissions in African economies, we derive an empirical model that builds upon the principles of the EKC. The theoretical underpinning of our model is based on the interplay between economic growth, capital availability, and environmental considerations, particularly carbon emissions.

The core equation of our empirical model is as follows:

$$CO_2 = f(Bond, Bond^2, X')$$

Where: CO_2 represents carbon dioxide emissions, $Bond$ signifies the level of Eurobond issuance, $Bond^2$ represents the squared term of Eurobond issuance, X' denotes a set of exogenous factors that influence carbon dioxide emissions.

Our theoretical model posits that the linear effect of Eurobond issuance on carbon emissions can be captured by the coefficient of Eurobonds. In the initial stages of economic growth, characterized by relatively lower levels of capital availability, an increase in Eurobond issuance may lead to higher carbon emissions. This can be attributed to the potential allocation of funds to industries with higher emission intensities.

At the same time, we hypothesize a non-linear effect of Eurobonds on carbon emissions, which is reflected by the coefficient of $Bond^2$. As economies progress and income levels rise, the squared term introduces a turning point in the relationship. Beyond this point, increased Eurobond financing may contribute to the adoption of cleaner technologies, mitigation strategies, and environmentally conscious investments, thereby leading to a reduction in carbon emissions.

The coefficients of X' in our model encapsulates the role of economic growth factors and developments in shaping carbon emissions. As economies expand, the environmental impact of growth may vary. Initially, economic expansion might lead to higher emissions as industries prioritize output and resource extraction. However, as countries advance along their development trajectory, greater affluence can facilitate investments in cleaner technologies, regulatory frameworks, and sustainable practices.

In essence, our empirical model is a manifestation of the Environmental Kuznets Curve adapted to explore the specific relationship between Eurobond issuance, economic growth, and carbon emissions in the African context. By combining the linear and non-linear terms of Eurobonds, our model accommodates both the immediate and cumulative effects of this financing mechanism on environmental outcomes, shedding light on potential inflection points and contributing to a nuanced understanding of the complex interactions at play.

3.3. Empirical model

This study uses standard estimation techniques which are widely used in the literature.

Equation (1) specified below assesses the effect of Eurobonds on carbon dioxide emissions.

$$\text{CO}_2\text{gdp}_{it} = \delta_0 + \delta_1 \text{LNBOND}_{it} + \delta_2 \text{LNURBAN}_{it} + \delta_3 \text{LNTRADE}_{it} + \delta_4 \text{LNTRADE}_{it} + \delta_5 \text{LNGDP}_{it} + \delta_6 \text{LNEDU}_{it} + \delta_7 \text{LNRULE}_{it} + \delta_8 \text{FDI}_{it} + \epsilon_{it} \quad (1)$$

Where 'i' represents a country at time 't'. CO_2gdp is carbon dioxide emissions as a proxy for carbon dioxide emissions. Carbon dioxide emissions are those coming from the burning of fossil fuels, dirtier coals, and the manufacture of cement. Carbon dioxide emission is used severally in the literature (Twerefou et al., 2016). LNBOND is the natural logarithm of Eurobonds value. Issuing Eurobonds will lead to a rise in capital accumulation, hence increasing the GDP of an economy. We expect a positive sign at the initial stage of the EEKC and a negative beyond a certain threshold—leading to an inverted 'U' curvature.

LNURBAN is the natural logarithm of urbanization. Urbanization is measured as the total percentage of the urban population. Urbanization is found to hurt carbon dioxide emissions because rural-urban migration exerts pressure on social amenities, such as roads, schools, hospitals, and basic sanitation services in urban places. Chapman et al. (2017) evidenced that urban growth has a large effect on carbon dioxide emissions, which comes from local temperatures. A positive coefficient of urbanization is expected because population growth increases emissions. Urbanization is used as a control variable for carbon dioxide emissions.

LNTRADE is the natural logarithm of trade openness, which measures the total transactions of exports and imports as a percentage of GDP. Trade in African countries is dominated by importation, and many of these imports are avenues for dumping by the exporting countries (Ntow-Gyamfi et al., 2020). An increase in trade openness is hazardous to environmental quality and is a positive long-run driver of carbon dioxide emissions and it is detrimental to environmental quality (Twerefou et al., 2016). LNDINVESTMENT is the natural logarithm of domestic investment. It is measured by gross fixed capital formation as a percentage of GDP. Empirical findings by Ullah et al. (2014) revealed that there is a long-run relationship between domestic investment and economic growth. Kaya (2010) revealed that domestic investment enhances the industrialization of developing countries, which in the end leads to economic growth. LNGDP is the natural logarithm of economic growth. Economic growth is being used as a control variable for carbon dioxide emissions and Eurobond. Economic growth is measured by the percentage of GDP growth of a country. There is an inverted-U relationship between economic growth and environmental degradation according to Environmental Kuznets Curve (EKC) hypothesis (Grossman & Krueger, 1995). This study expects a positive sign for the coefficient of economic growth.

LNEDU is the natural logarithm of education which measures total public spending on education as a percentage of GDP.

LNRULE is the natural logarithm of the rule of law which measures regulation and government intervention. The role of regulation and government interventions must be controlled for in the models for carbon dioxide emissions. A negative relationship is expected between regulation and carbon dioxide emissions. This study expects that effective government interventions and regulations should have a positive effect on carbon dioxide emissions. FDI is Foreign Direct Investment which is measured as net inflows as a percentage of GDP since FDI is widely regarded as a primary medium for boosting economic growth in developing economies, including the African region.

ϵ_{it} denotes the error term.

As indicated by the Environmental Kuznets Curve (EKC) after the economy reaches a certain point called the 'industrial stage', the economy experiences a turning point, which is the post-industrial stage. This means, there is the need to introduce a square term to the explanatory variable (Eurobonds) to denote that turning point. Carbon dioxide emissions and Eurobond were log-transformed in Equation (2). A squared term (LNBOND^2) is introduced to Equation (1), so we obtain Equation (2). The introduction is well documented in the literature, therefore we follow a consistent approach from prior studies (Yiadom et al., 2022, Mensah et al., 2021, Ntow-Gyamfi et al., 2020, Mensah et al., 2018).

$$\text{CO}_2\text{gdp}_{it} = \delta_0 + \beta \text{LNBOND}_{it}^2 + \omega X'_{it} + \epsilon_{it} \quad (2)$$

From model 2, X' indicates all the control variables as specified in Equation (1).

4. Results and discussion

The results of the study are presented and discussed in this section.

Table 1 reports the descriptive statistics. Eurobond (Bond) recorded an average of 1.58% and a standard deviation of 3.06%. The minimum and maximum values are 0 and 1.89%, respectively. The wide variations can be attributed to data not available for some countries in some specific years. Even though domestic investment (lninv) had observations of 204 but there are some variations considering the mean, standard deviation, minimum, and maximum values. The variable domestic investment (lninv) had an average of 7.169% and a standard deviation of 3.669%. The minimum and maximum values are 0 and 11.166%, respectively.

Table 2 reports the pairwise correlation matrix analysis for the variables. The correlation coefficients do not give any concern for multicollinearity.

4.1. Empirical model results

In the empirical results, the relationship between Eurobond and carbon dioxide emissions without including the square term of Eurobond. **Equation (1)** estimation is the baseline equation that examines the relationship between Eurobond and carbon dioxide emissions. The square term of Eurobond was included in **Equation (2)** to test for the presence of Eurobond Environmental Kuznets Curve (EEKC) or the quadratic relationship between Eurobond and carbon dioxide emissions to indicate the turning point at which the relationship between Eurobond and carbon dioxide emissions has an inverted 'U' shape.

4.2. Pooled OLS, fixed effect, and random effect

The pooled OLS assumes no differences among the countries under study and time effect. However, the fixed effect (FE) and random effect (RE) model assumes differences in the countries and differences in time. A Breusch-Pagan Lagrange multiplier (LM) test was conducted to decide whether there exist differences among countries and time effects in the model. The null hypothesis states that there are no differences in time in the pooled OLS model. The alternative states that there are differences in time in the pooled OLS model. **Table 3** reports the output generated for Breusch and Pagan Lagrange multiplier test for random effects.

Table 1. Descriptive statistics of variables.

Variable	Observations	Mean	Std. Dev	Min	Max
CO ₂ gdp	204	1.235	1.319	0.063	5
Bond	137	9.074	0.474	8.301	10.276
Urban	204	38.043	13.767	15.873	89.37
Dinv	204	7.169	3.669	0	11.166
Fdi	204	5.710	8.768	-6.396	57.838
Edu	204	47.651	17.989	18.408	109.444
Gdp	204	5.109	3.295	-4.387	14.047
Rule	204	2.647	0.700	0.895	4.314
Trade	204	-0.458	1.829	-7.048	3.480

Sources: Authors' computation.

Table 2. Pairwise correlational matrix.

Variable	CO ₂ gdp	Bond	Urban	Dinv	Fdi	Edu	Gdp	Rule	trade
CO ₂ gdp	1.000								
Bond	-0.2771*	1.0000							
urban	-0.1551*	0.1328*	1.0000						
dinv	-0.2267*	-0.3439*	0.1279*	1.0000					
fdi	-0.0300	-0.3061*	0.0813	0.1474*	1.0000				
edu	-0.1830*	0.0296	0.0413	-0.3750*	0.0849	1.0000			
gdp	0.0441	-0.0354	0.0143	-0.0021	-0.0863	0.3140*	1.0000		
rule	0.0868	0.1235	-0.1293*	-0.2095*	0.0506	0.1384*	0.2010*	1.0000	
trade	-0.0689	0.4562*	-0.0593	0.0640	-0.3323*	-0.3982*	-0.1956*	-0.2430*	1.0000

Source: Author's computation.

Significant level: (***) indicates 1%, (**) indicates 5%, (*) indicates 10%, respectively.

From Table 3, the p -value of 0.0000, which is <0.05 , indicates that we reject the null hypothesis and accept the alternative, which says there are differences in time in the pooled OLS model. This means there are random effects among the countries. The output generated suggests that Generalized Least Squares (GLS) panel regression analysis is appropriate since there are significant differences among the countries under study.

Furthermore, the Hausman test is conducted to determine whether the random effects or fixed effects model is the most appropriate model for the estimation. Table 4 reports the output of the Hausman test.

From the output generated in Table 4, it is confirmed that the random-effects model is the most appropriate model for the estimation. Thus, the explanatory variables are not correlating with the individual effects at the 5% level of significance. Therefore, we fail to reject the null hypothesis, which says the random effect is the most appropriate model meaning there is the presence of heterogeneity. If the output generated had a significant p -value, then it would have implied that the fixed effect model is the most appropriate for the estimation. However, the test results show an insignificant p -value, and Prob $>$ χ^2 value of 0.1941 which is more than 0.05 meaning the random-effects model is preferred.

Moreover, we employed the Breusch-Pagan and Cook-Weisberg test for heteroscedasticity. Table 5 reports the results of the Breusch-Pagan and Cook-Weisberg test for heteroscedasticity.

From the results in Table 5, the p -value is 0.0000, which indicates 5% significance. Therefore, means we reject the null and accept the alternative hypothesis, which says the variance is not constant. This means there is the presence of heteroscedasticity. The heteroscedasticity was controlled for by using the robust standard errors in our regression models.

4.3. Regression results

The regression results for objectives one and two are reported in Tables 6 and 7, respectively.

From Table 6, the coefficient of the Eurobond (bond) is 0.3682. This means holding all other factors fixed, an additional increase in Eurobonds will cause carbon dioxide emissions to be increased by 0.368. Now, the p -value of the bond is 0.019 and it has at-statistics of 2.35. At a 5% percentage level of significance, we reject the null hypothesis and accept the alternative, which says Eurobonds improve carbon dioxide emissions in Africa.

A similar positive relationship between economic growth and environmental degradation exists in the original Environmental Kuznets Curve (EKC) hypothesis derived by Grossman and Krueger (1995), where the relationship between economic growth and environmental degradation has been studied. The relationship between Eurobond and carbon dioxide emissions is primarily driven by African leaders issuing Eurobond and investing in industrial projects that are not eco-friendly, such as energy consumption projects, but rather are harmful to the environment. From literature, carbon dioxide emissions stem from

Table 3. Test for a panel effect.

Breusch and Pagan Lagrange multiplier test for random effects	
Chi-square value	60.60
p -Value and Prob $>$ χ^2	0.0000

Source: Author's computation.

Table 4. Hausman test for fixed effects vs. random effects.

Hausman test between fixed effects and random effects	
Chi-square value	12.35
p -Value and Prob $>$ χ^2	0.1941

Sources: Author's computation.

Table 5. Test for heteroscedasticity.

Breusch-Pagan and Cook-Weisberg test for heteroscedasticity	
Chi-squared value	101.38
Prob $>$ chi-squared or p -value	0.0000

Source: Author's computation.

Table 6. Regression results of the impact of Eurobond on carbon dioxide emissions random-effects GLS regression results (robust).

Variable	Coefficient	Standard error	T-statistics	p-Value
Constant	6.130235	5.220312	1.17	0.240
Bond	0.3681808	0.1565068	2.35	0.019**
Lnurban	-1.098445	1.143615	-0.96	0.337
Lnrule	0.3946785	1.25316	0.31	0.753
Lndinvestment	-0.7789483	0.4727957	-1.65	0.099*
Lngdp	-0.6670848	0.7715005	-0.86	0.387
Fdi	0.0061419	0.0035321	1.74	0.082*
Lnedu	-1.067673	0.5115278	-2.09	0.037**
Trade	-0.8988038	0.6995636	-1.28	0.240
R-squared	0.521			
Prob > chi ²	0.0243			
Wald Chi ²	11.54			

Significant level: (***) indicates 1% (**) indicates 5% (*) indicates 10%.

Sources: Author's computation.

Table 7. Regression results of the impact of Eurobond on carbon dioxide emissions random-effects GLS regression results (robust).

Variable	Coefficient	Standard error	T-statistics	p-Value
Constant	81.34543	36.43951	2.23	0.026
Bond	4.614807	1.995895	2.31	0.021**
Lnbondsq	-90.41627	41.65861	-2.17	0.030**
Lnurban	-1.471977	1.124834	-1.31	0.191
Lnrule	0.9779048	1.358036	0.72	0.471
Lndinvestment	-0.8506463	0.4703511	-1.81	0.071*
Lngdp	-0.6685678	0.5140034	-1.30	0.193
Fdi	0.0058047	0.4703511	1.72	0.085*
Lnedu	-0.8626921	0.4897429	-1.76	0.078*
Trade	-0.8419738	0.6608089	-1.27	0.203
R-squared	0.2239			
Prob > Chi ²	0.0241			
Wald Chi ²	13.40			

Significant level: (***) indicates 1% (**) indicates 5% (*) indicates 10%.

Sources: Author's computation.

manufacturing industries and construction, transport activity, electricity and heat production and residential buildings, and public services, which produce the combustion of fuel.

Adzawla et al. (2019) in their study that looked at the nexus between greenhouse gas emissions and economic growth in Sub-Saharan Africa (SSA), found out that energy consumption and production are the major cause of carbon dioxide emissions. The findings of this study are consistent with the findings of Shahbaz and Leitao (2013), who found that there is a direct link between economic growth and carbon dioxide emissions in Portugal with time series data spanning 1970–2009, using the ordinary least squares (OLS) estimation and autoregressive moving average model. More so, Burnett et al. (2013) found that economic growth drives carbon dioxide emission intensities in the U.S.A.

Again, Apergis and Ozturk (2015) revealed a positive relationship between emissions and per capita income, which measures economic growth, using a panel dataset from 1990 to 2011 in 14 Asian countries using the generalized method of moments methodology. However, Stefanski (2013) had contradictory results by arguing that growth does not hurt the environment. The results suggest that the real effect of Eurobond on carbon dioxide emissions is an empirical issue. This result is consistent with the findings of Boachie-Yiadom and Mensah (2021), who found in their study that foreign direct investment (FDI) worsens the environment. This means, that as the net inflows increase, African countries will be able to engage in manufacturing and construction projects that require fuel combustion which increases carbon dioxide emissions. An increase in carbon dioxide emissions will cause the carbon dioxide emissions situation to be worsened.

From Table 7, the coefficient of the value of Eurobond squared (Lnbondsq) being -0.9042 means carbon dioxide emissions will be decreased by 0.9042, holding all other factors fixed. Now, the p-value of the value of Eurobond squared is 0.030 with at-statistics of 2.17. At the 5% level of significance, we reject the null hypothesis and accept the alternative, which says that there is a presence of the Eurobond Environmental Kuznets curve (EEKC) supporting the EKC hypothesis.

From Table 7, the coefficient of the logarithm of education ($\ln edu$) being -0.0086 means carbon dioxide emissions will be decreased by 0.0086 , holding all other factors fixed. These results support the findings of Ohene-Asante (2015), who revealed in his study that, as the level of education increases, people begin critically analyzing environmental activities that are very risky to human lives. Again, the p -value of the logarithm of education is 0.078 with t -statistics of 1.76 . This means education has a significant effect on the issuance of Eurobonds in Africa at the 10% significance level.

The coefficient of domestic investment ($\ln investment$) being -0.0085 means holding all other factors fixed, carbon dioxide emissions will be decreased by 0.0085 . Again, the p -value of the logarithm of domestic investment is 0.071 with t -statistics of 1.81 . Hence, at the 5% level of significance, we accept the null hypothesis that domestic investment does not affect carbon dioxide emissions in Africa. However, domestic investment is significant at 10%, which means the domestic investment will reduce carbon dioxide emissions in Africa in the short run.

The coefficient of foreign direct investment (FDI) is 0.0058 and it is positive. This means an additional increase in FDI will cause carbon dioxide emissions to be increased by 0.0058 holding other factors constant. This FDI and carbon dioxide emissions have a positive relationship. Now, the p -value of FDI is 0.085 with a statistic of 1.72 . At a 5% percentage level of significance, we fail to reject the null hypothesis, which says FDI has a significant effect on carbon dioxide emissions in Africa. However, FDI is significant at 10%, which means the foreign direct investment will increase carbon dioxide emissions in Africa in the short run. This finding is well-established in the literature (Bokpin, 2017; Yiadom et al., 2022). Yiadom et al. (2022) studied the effect of FDI on carbon emissions and reported that the unmitigated effect of capital on the environment is detrimental. Thus, FDI increases carbon dioxide emissions in Africa.

The value of the adjusted R -squared indicates that in considering homogeneity across countries and over time, 20.24% of the variability in carbon dioxide emissions was explained by the explanatory variables. The goodness of fit is determined by the R -squared and $\text{prob} > \chi^2$, however, the R -squared is very low due to heterogeneity in the cross-sections in the panel data.

After finding a positive relationship between Eurobond and carbon dioxide emissions, the square term of the logarithm of the value of Eurobond was included in Equation (2) to test for the presence of Eurobond Environmental Kuznets Curve (EEKC). The results after the inclusion of the square term of the value of Eurobond indicate that Eurobond has an inverse relationship with carbon dioxide emissions. In explaining the two results from Equations (1) and (2) together, the study reveals a nonlinear relationship between Eurobond and carbon dioxide emissions. Empirical evidence in the original Environmental Kuznets Curve (EKC) hypothesis suggests an inverted 'U' relationship between economic development and environmental degradation.

From the two regression results, the study finds a similar inverted 'U' relationship between Eurobond and carbon dioxide emissions. The EEKC hypothesis states that an increase in Eurobond leads to an increase in carbon dioxide emissions or worsens carbon dioxide emissions, but at a turning point, as Eurobond increases, carbon dioxide emissions are reduced in Africa. These findings indicate that Environmental Kuznets Curve (EKC) exists in Angola, Cote d'Ivoire, Cameroon, Kenya, Namibia, Nigeria, Senegal, South Africa, Ghana, Gabon, Mozambique, Rwanda, Tanzania, Seychelles, Ethiopia, Congo Republic, and Zambia. This result is consistent with the findings by Apergis and Ozturk (2015), Ntow-Gyamfi et al. (2020), and Shahbaz et al. (2019) who found in their studies that the EKC hypothesis exists in Asian and African countries. Additionally, Shahbaz and Leita (2013) also tested for EKC and found out that Environmental Kuznets Curve (EKC) exists in Portugal. Again, Burnett et al. (2013) found the existence of the Environmental Kuznets Curve (EKC) in the U.S.A., which holds for the relationship between carbon dioxide emissions and personal income. By implication, the study means that at the first stage when Eurobond is issued, African countries are interested in their economic development or growth. The countries will issue Eurobonds and use the proceeds to invest and embark on capital and manufacturing projects no matter the consequences it may bring to the environment. At this stage, environmental protection and a green environment are not their priority.

However, in the post-industrial stage, the issue of environmental protection and eco-friendliness becomes paramount and the proceeds from the issuance of Eurobond are used to invest in projects that are not harmful to the environment. Additionally, at this stage, there is a high rate of innovation,

stringent environmental laws, government policy interventions, change in the structure of GDP, the emergence of policies to promote smart urbanization and public education from the mass media, and environmental research department, which tends to reduce environmental degradation. Using annual data spanning 1970 to 2010, Twerefou et al. (2016) found a contradictory result showing that there is a U-shape relationship between economic growth and carbon dioxide emissions using per capita GDP as a measure for both variables. According to them, their results reveal that EKC does not exist in Ghana. They rather found trade openness and energy consumption to be positive long-run drivers of carbon dioxide emissions.

The inverted 'U' relationship between Eurobond and carbon dioxide emissions is the result of the following reasons. First, from the results, an increase in cash flow will cause carbon dioxide emissions to increase, which indicates that carbon dioxide emissions stifle economic growth. This means the nonlinear relationship between Eurobond and carbon dioxide emissions is established already. Hence, the inverted 'U' relationship evidenced between Eurobond and carbon dioxide emissions may have a direct link with economic growth and Eurobond. Secondly, when African leaders issue Eurobond and use the proceeds to invest in eco-friendly projects, there is a reduction in global warming. This indicates that as African leaders issue Eurobonds and invest in projects that are not harmful to the environment, the significant threats posed by carbon dioxide emissions on communities, livelihoods, and the economy will reduce. In furtherance, as governments embark on projects to fight carbon dioxide emissions, it will create employment for the people in the country. As employment increases, savings and investments also increase leading to an increase in economic growth according to the national income accounting equation. Again, the results show that there is a positive relationship between foreign direct investment and carbon dioxide emissions and an inverse relationship between domestic investment and carbon dioxide emissions. This implies that as African leaders issue more Eurobonds, investments will increase, which will give the country the capacity to embark on energy-consuming projects. This will increase carbon dioxide emissions according to the Environmental Kuznets Curve (EKC) at the pre-industrial stage, but after the country reaches a certain level of economic development, carbon dioxide emissions reduce as the results have indicated that a rise in domestic investment causes carbon dioxide emissions to decrease.

4.4. Computation of turning point using random effect regression results from Table 6

A partial derivative of carbon dioxide emission (CO_2gdp) is taken concerning Eurobond (bond) to estimate how much an increase in the bond will help reduce carbon dioxide emissions. This is specified below:

$$CO_2gdp = 81.34 + 4.61bond - 90.42lnbondsq - 1.47lnurban + 0.98lnrule - 0.85lninvestment - 0.67lngdp + 0.01lninfl - 0.86lnedu - 0.84trade \quad (3)$$

$$\frac{dCO_2gdp}{dbond} = 4.61 - 180.84lnbond \quad (4)$$

$$\frac{d^2 CO_2gdp}{dbond^2} = -180.84 < 0 \dots \quad (5)$$

Hence, the curve has one turning point with the bond coordinate equal to -180.84% , which is the local maximum. This means as more Eurobonds are issued at the turning point, carbon dioxide emissions will reduce by 180.84% . We find that our results extend the existing literature by revealing distinctive insights specific to the relationship between Eurobond issuance and carbon dioxide emissions in African countries. Unlike previous works that focused on broader economic and environmental factors, our study delves into the direct impact of Eurobonds, offering a more nuanced understanding of how this financing mechanism affects carbon emissions. By isolating the effects of Eurobond issuance and examining them within the context of economic growth and development, we contribute a deeper layer of understanding to the existing body of research.

4.5. Policy insights and theoretical advancements

We emphasize that our results provide substantial implications for environmental policies in African economies that utilize Eurobond financing. Specifically, the positive relationship between Eurobond issuance and carbon emissions at the initial stage of economic development underscores the potential environmental trade-offs associated with capital-intensive projects funded by Eurobonds. This highlights the need for careful project selection and management to ensure that economic growth does not come at the expense of increased carbon emissions.

Moreover, our identification of an inverted U-shaped relationship between Eurobond issuance and carbon emissions suggests the presence of an 'Eurobond Environmental Kuznets Curve' (EEKC) in Africa. This finding signifies that as economies mature and attain higher levels of income, the environmental impact of Eurobond-funded projects tends to decrease. This insight holds significant policy implications, encouraging countries to adopt eco-friendly and sustainable projects as they advance along their development trajectories.

Our results also underline the importance of education and domestic investment as potential mitigating factors for carbon emissions. These findings support the notion that investing in education and promoting domestic investment could help African countries transition toward more environmentally sustainable development paths.

Furthermore, the observed positive association between foreign direct investment (FDI) and carbon emissions reinforces the need for environmentally-conscious investment strategies. Policymakers should consider incorporating environmental safeguards and regulations to ensure that FDI contributes to economic growth without exacerbating environmental degradation.

To summarize, our study's results offer a comprehensive framework to guide policy discussions and strategic decision-making. By highlighting the nuanced relationship between Eurobond issuance, economic growth, and carbon emissions, we contribute novel insights that can guide policymakers in shaping environmentally sustainable development strategies in African economies.

5. Conclusion

In this study, we investigated the relationship between Eurobond issuance and carbon dioxide emissions in 17 African countries from 2007 to 2018. Our findings contribute to the existing literature by demonstrating a nuanced relationship between Eurobonds and carbon emissions. Specifically, we found that Eurobond issuance initially leads to increased carbon emissions due to investments in energy-intensive projects, supporting the traditional Environmental Kuznets Curve (EKC) hypothesis. However, at a more advanced stage of economic development, Eurobonds become associated with decreased carbon emissions, indicating the presence of an Eurobond Environmental Kuznets Curve (EEKC). This complex relationship underscores the need for targeted policies that evolve with the economic growth stages of African countries.

While our study adds value to the understanding of the Eurobond-carbon emissions nexus, it has certain limitations. The analysis is based on cross-sectional data, and the applicability of findings may vary across different contexts. Furthermore, the policies outlined in our discussion are derived directly from the empirical results, offering a more grounded approach towards addressing environmental concerns related to Eurobond issuance.

In the future, further research could extend this analysis to consider additional factors and regions, enhancing the generalizability of findings. Additionally, a deeper investigation into the mechanisms driving the observed relationships could provide valuable insights for formulating targeted environmental policies that align with the economic development stages of African countries. By untangling these complexities, policy-makers can make informed decisions that balance economic growth with environmental sustainability.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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References

- Ababio, J. O. M., Yiadom, E. B., Mawutor, J. K. M., Tuffour, J. K., & Attah-Botchwey, E. (2023). Sustainable energy for all: the link between financial inclusion, renewable energy, and environmental sustainability in developing economies.
- Adzawla, W., Sawaneh, M., & Yusuf, A. M. (2019). Greenhouse gasses emission and economic growth nexus of sub-Saharan Africa. *Scientific African*, 3, e00065. <https://doi.org/10.1016/j.sciaf.2019.e00065>
- Afful, K., T. (2014). The Green Climate Fund in Africa: What should be different? *Climate and Development*, 7(4), 367–379.
- African Climate Policy Center (2020). *Climate change and development in Africa post COVID-19: Some critical reflections*. United Nations-Economic Commission for Africa. Retrieved December 19, 2020.
- Apergis, N., & Ozturk, I. (2015). Testing environmental Kuznets curve hypothesis in Asian countries. *Ecological Indicators*, 52, 16–22. <https://doi.org/10.1016/j.ecolind.2014.11.026>
- Balsalobre-Lorente, D., Driha, O. M., Halkos, G., & Mishra, S. (2022). Influence of growth and urbanization on CO₂ emissions: The moderating effect of foreign direct investment on energy use in BRICS. *Sustainable Development*, 30(1), 227–240. <https://doi.org/10.1002/sd.2240>
- Boachie-Yiadom, E., & Mensah, L. (2021). Environmental risk, FDI and tax reforms: Why we must worry. *African Journal of Economic and Management Studies*, 12(2), 269–284. <https://doi.org/10.1108/AJEMS-08-2020-0399>
- Bokpin, G. A. (2017). Foreign direct investment and environmental sustainability in Africa: The role of institutions and governance. *Research in International Business and Finance*, 39, 239–247. <https://doi.org/10.1016/j.ribaf.2016.07.038>
- Burnett, J. W., Bergstrom, J. C., & Wetzstein, M. E. (2013). Carbon dioxide emissions and economic growth in the US. *Journal of Policy Modeling*, 35(6), 1014–1028. <https://doi.org/10.1016/j.jpolmod.2013.08.001>
- Chapman, S., Watson, J. E., Salazar, A., Thatcher, M., & McAlpine, C. A. (2017). The impact of urbanization and climate change on urban temperatures: A systematic review. *Landscape Ecology*, 32(10), 1921–1935. <https://doi.org/10.1007/s10980-017-0561-4>
- Chen, F., Ahmad, S., Arshad, S., Ali, S., Rizwan, M., Hamzah Saleem, M., Driha, O. M., & Balsalobre-Lorente, D. (2022). Towards achieving eco-efficiency in top 10 polluted countries: The role of green technology and natural resource rents. *Gondwana Research*, 110, 114–127. <https://doi.org/10.1016/j.gr.2022.06.010>
- Demena, B. A., & Afesorgbor, S. K. (2020). The effect of FDI on environmental emissions: Evidence from a meta-analysis. *Energy Policy*, 138, 111192. <https://doi.org/10.1016/j.enpol.2019.111192>
- Doğan, B., Chu, L. K., Ghosh, S., Truong, H. H. D., & Balsalobre-Lorente, D. (2022). How environmental taxes and carbon emissions are related in the G7 economies? *Renewable Energy*, 187, 645–656. <https://doi.org/10.1016/j.renene.2022.01.077>
- Dziwornu, R. K., Yiadom, E. B., & Narteh-Yoe, S. B. (2024). Agricultural loan pricing by banks in Ghana: a panel data analysis. *African Journal of Economic and Management Studies*, 15(1), 145–158. <https://doi.org/10.1108/AJEMS-12-2022-0504>
- Girvetz, E., Ramirez-Villegas, J., Claessens, L., Lamanna, C., Navarro-Racines, C., Nowak, A., & Rosenstock, T. S. (2019). Future climate projections in Africa: Where are we headed? In *The climate-smart agriculture papers* (pp. 15–27). Springer.
- Gros, D., Lane, P. R., Langfield, S., Matikainen, S., Pagano, M., Schoenmaker, D., & Suarez, J. (2016). *Too late, too sudden: Transition to a low-carbon economy and systemic risk*. No. Reports of the Advisory Scientific Committee.
- Grossman, G. M., & Krueger, A. B. (1995). Does the Environmental Kuznets Curve describe how individual countries behave? *The Quarterly Journal of Economics*, 110(2), 353–377. <https://doi.org/10.2307/2118443>

- Guha, A. (2019). Green bonds: Key to fighting climate change? *ORF Issue Brief*, 321.
- Kaya, Y. (2010). Globalization and industrialization in 64 developing countries, 1980–2003. *Social Forces*, 88(3), 1153–1182. <https://doi.org/10.1353/sof.0.0300>
- Li, R., Wang, Q., Liu, Y., & Jiang, R. (2021). Per-capita carbon emissions in 147 countries: The effect of economic, energy, social, and trade structural changes. *Sustainable Production and Consumption*, 27, 1149–1164. <https://doi.org/10.1016/j.spc.2021.02.031>
- Mensah, L., Andoh, C., Kuttu, S., & Boachie-Yiadom, E. (2023). The level of African forex markets integration and Eurobond issue. *Journal of Economics and Finance*, 47(1), 232–250. <https://doi.org/10.1007/s12197-022-09596-6>
- Mensah, L., Bokpin, G., & Boachie-Yiadom, E. (2018). External debts, institutions and growth in SSA. *Journal of African Business*, 19(4), 475–490. <https://doi.org/10.1080/15228916.2018.1452466>
- Mensah, L., Yiadom, E. B., & Dziwornu, R. (2021). Does Eurobond issuance influence FDI location? Evidence from sub-Saharan Africa. *African Journal of Economic and Management Studies*, 12(2), 336–355. <https://doi.org/10.1108/AJEMS-03-2021-0094>
- Nkomo, J. C., Nyong, A. O., & Kulindwa, K. (2006). *The impacts of climate change in Africa*. Final draft submitted to the Stern Review on the Economics of Climate Change, 51.
- Ntow-Gyamfi, M., Bokpin, G. A., Aboagye, A. Q., & Ackah, C. G. (2020). Environmental sustainability and financial development in Africa; Does institutional quality play any role? *Development Studies Research*, 7(1), 93–118. <https://doi.org/10.1080/21665095.2020.1798261>
- Ofori-Mensah Ababio, J., Yiadom, E. B., Sarpong-Kumankoma, E., & Boadi, I. (2023). Financial inclusion: a catalyst for financial system development in emerging and frontier markets. *Journal of Financial Economic Policy*, 15(6), 530–550. <https://doi.org/10.1108/JFEP-06-2023-0155>
- Ohene-Asante, S. N. (2015). *Climate change awareness and risk perception in Ghana: A case study of communities around the Muni-Pomadze Ramsar Site* [Doctoral dissertation]. University of Ghana.
- Rafei, M., Esmaeili, P., & Balsalobre-Lorente, D. (2022). A step towards environmental mitigation: How do economic complexity and natural resources matter? Focusing on different institutional quality level countries. *Resources Policy*, 78, 102848. <https://doi.org/10.1016/j.resourpol.2022.102848>
- Sarkodie, S. A., & Strezov, V. (2019). A review on Environmental Kuznets Curve hypothesis using bibliometric and meta-analysis. *Science of the Total Environment*, 649, 128–145. <https://doi.org/10.1016/j.scitotenv.2018.08.276>
- Shahbaz, M., & Leitao, N. C. (2013). Portuguese carbon dioxide emissions and economic growth: A time series analysis. *Bulletin of Energy Economics (BEE)*, 1(1), 1–7.
- Shahbaz, M., Haouas, I., & Van Hoang, T. H. (2019). Economic growth and environmental degradation in Vietnam: Is the environmental Kuznets curve a complete picture? *Emerging Markets Review*, 38, 197–218. <https://doi.org/10.1016/j.ememar.2018.12.006>
- Sinha, A., Balsalobre-Lorente, D., Zafar, M. W., & Saleem, M. M. (2022). Analyzing global inequality in access to energy: Developing policy framework by inequality decomposition. *Journal of Environmental Management*, 304, 114299. <https://doi.org/10.1016/j.jenvman.2021.114299>
- Stefanski, R. (2013). On the mechanics of the Green Solow Model. *OxCarre Research Paper*, 47.
- Twerefou, D. K., Adusah-Poku, F., & Bekoe, W. (2016). An empirical examination of the Environmental Kuznets Curve hypothesis for carbon dioxide emissions in Ghana: An ARDL approach. *Environmental & Socio-Economic Studies*, 4(4), 1–12. <https://doi.org/10.1515/enviro-2016-0019>
- Ullah, I., Shah, M., & Khan, F. U. (2014). Domestic investment, foreign direct investment, and economic growth nexus: A case of Pakistan. *Economics Research International*, 2014, 1–5. <https://doi.org/10.1155/2014/592719>
- Vassiliades, C., Diemuodeke, O. E., Yiadom, E. B., Prasad, R. D., & Dbouk, W. (2022). Policy pathways for mapping clean energy access for cooking in the global south—A case for rural communities. *Sustainability*, 14(20), 13577. <https://doi.org/10.3390/su142013577>
- Wang, Q., Wang, X., & Li, R. (2022). Does urbanization redefine the Environmental Kuznets Curve? An empirical analysis of 134 Countries. *Sustainable Cities and Society*, 76, 103382. <https://doi.org/10.1016/j.scs.2021.103382>
- Wang, Q., Yang, T., & Li, R. (2023). Does income inequality reshape the environmental Kuznets curve (EKC) hypothesis? A nonlinear panel data analysis. *Environmental Research*, 216(Pt 2), 114575. <https://doi.org/10.1016/j.envres.2022.114575>
- Wang, Q., Zhang, F., & Li, R. (2023). Revisiting the Environmental Kuznets Curve hypothesis in 208 counties: The roles of trade openness, human capital, renewable energy and natural resource rent. *Environmental Research*, 216(Pt 3), 114637. <https://doi.org/10.1016/j.envres.2022.114637>
- Webber, D. J., & Allen, D. O. (2010). Environmental Kuznets Curves: Mess or meaning? *International Journal of Sustainable Development & World Ecology*, 17(3), 198–207. <https://doi.org/10.1080/13504501003787638>
- World Bank (2010). *World development report: Climate change and development*. Author.
- World Bank (2020). *World development indicators data*. Author.
- Yeboah, S. A. (2014). *Financing capital projects in Ghana: The choice of Eurobonds over loans from international development partners* [Doctoral dissertation].
- Yiadom, E. B., Dziwornu, R. K., Mawutor, J. K., & Amankwah, R. F. (2023). Exploring the relationship between extreme weather events, urbanization, and food insecurity: Institutional quality perspective. *Environmental Challenges*, 13, 100775. <https://doi.org/10.1016/j.envc.2023.100775>

- Yiadom, E. B., Mensah, L., & Bokpin, G. A. (2022). Environmental risk and foreign direct investment: The role of financial sector development. *Environmental Challenges*, 9, 100611. <https://doi.org/10.1016/j.envc.2022.100611>
- Yiadom, E. B., Mensah, L., & Bokpin, G. A. (2023). Environmental risk and foreign direct investment: The role of financial deepening, access and efficiency. *Sustainability Accounting, Management and Policy Journal*, 14(2), 369–395. <https://doi.org/10.1108/SAMPJ-12-2021-0552>
- Yiadom, E. B., Mensah, L., Bokpin, G. A., & Dziwornu, K. R. (2023). Analyzing financial and economic development thresholds for carbon emission reduction: A dynamic panel regime-switching study across income levels. *Management of Environmental Quality*, 35(1), 18–37. <https://doi.org/10.1108/MEQ-12-2022-0338>