CHAPTER TWO

Impact of Macroeconomic Determinants on Carbon Emission in Developing Countries

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Abstract

The primary purpose of the research is to examine the macroeconomic variables that influence environmental quality in developing countries. First, this study employs a dynamic panel data model to address the endogeneity problem and utilises a system-generalised method of moments estimator to examine the impact of macroeconomic determinants on environmental quality, using panel data from 113 developing countries from 2013 to 2022. Based on the income level, the sample is categorised into four groups. The analysis focuses on seven macroeconomic determinants: foreign direct investment, renewable energy consumption, economic growth, trade openness, natural resources, information and communication technology, and financial development. Robustness tests were conducted using the general term of the lagged independent variable approach, while the primary data analysis employed econometric estimation methods, including ordinary least squares, fixed effects, and the dynamic generalised methods of moments approach, to select the model for the dynamic panel. The results show that foreign direct investment, financial development, and economic growth have a significantly positive impact on carbon emissions. On the other hand, information and communication technology, as well as renewable energy consumption, have an insignificant negative impact. All other remaining variables showed an insignificant positive effect. This study's findings suggest green macroeconomic initiatives as an eco-friendly approach to achieving both environmental and economic sustainability.

Keywords: *Carbon Emission, Developing Countries, Environmental Quality, Generalised Methods of Moments (GMM), Macroeconomic Variables.*

1. Introduction

Global warming and climate change have become urgent environmental concerns that are causing alarm among economists, legislators, and academics everywhere. The primary cause of these issues is the excessive release of greenhouse gas emissions, particularly carbon dioxide (CO_2), which accelerates environmental degradation and disrupts climate stability (Onuonga, 2020). By promoting energy consumption and trade, rapid industrialisation and globalisation have exacerbated these consequences and increased ecological stress in emerging nations (Ahmed & Long, 2013). Since the start of industrialisation in the 1970s, energy consumption has risen steadily, contributing to the growth of international trade while also leading to significant environmental concerns. Globalisation has benefited developing countries by lowering investment and trade obstacles, facilitating the flow of technology, labour, and mobilising capital. However, it has also contributed to rising environmental degradation, partly due to increased energy consumption. The ongoing industrialisation process in developing countries remains highly vulnerable to the adverse impact of global climate change.

Developing countries frequently struggle to strike a balance between economic growth and emissions, which are widely recognised as a major contributor to climate change, as they utilise their advantages and resources to achieve economic parity. Developing countries face significant challenges in reducing carbon emissions and meeting global reduction objectives at various stages of development. Additionally, it is noteworthy that around 80% of the world's carbon dioxide (CO_2) emissions come from the top 20 emitting nations (UN trade & development, 2021). On a worldwide scale, global warming currently poses a serious threat to environmental health. Thus, by implementing various policies, all nations are attempting to reduce CO2 emissions. This is supported by Figure 1.1. The CO2 emission pathway is displayed by income category. The majority of countries are implementing net-zero emission targets, which is encouraging because they aim to reduce around 63% of global emissions (IEA, 2021). However, to remain viable and credible, these goals must be quickly integrated into both short-term policies and considerably more ambitious Nationally Determined Contributions (NDCs) for the period up to 2030. Severe weather events and other climatic phenomena that show signs of human-caused climate change have been reported in 2021. Interestingly, extreme heat in North America and widespread flooding in Western Europe have been recognised as important examples of this phenomenon (United Nations Climate Change, 2021).

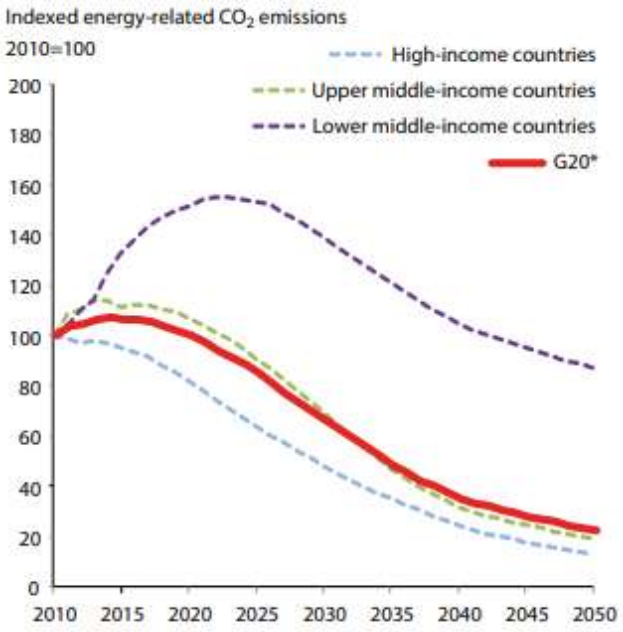

Figure 1.1: Emissions pathway by income group

Source: IEA (2017) and OECD calculations

Global economies are increasingly adopting sustainable energy sources and exploring strategies to mitigate CO2 emissions in response to the escalating environmental challenges associated with climate change. Existing empirical data suggest that rapid economic expansion and rising energy consumption in developing nations account for a substantial portion of global carbon emissions (Ahmed & Long, 2013).

One aspect of the relationship between economic activity and carbon emissions that has been examined extensively and whose data is no longer controversial is the association between economic growth and carbon emissions. The list of factors influencing carbon emissions has not yet been determined. Therefore, by investigating the factors that influence carbon emissions in emerging nations, the author aims to contribute to the existing body of literature. To the best of the researcher's knowledge, no study has examined the factors that influence carbon emissions in developing nations both across income levels and as a whole. The current research examines how macroeconomic parameters affect carbon emissions in the developing world, both overall and by socioeconomic class, with the goal of addressing this gap.

This study's primary concern is the growing harm to the environment caused by carbon emissions worldwide, primarily due to the exponential increase since the Industrial Revolution. Environmental pollution is increasing due to greenhouse gas emissions (Pelickis, 2016). One of the primary causes of environmental deterioration, climate change, and global warming has been identified as the release of greenhouse gases, specifically carbon dioxide (CO_2) (Onuonga, 2020). All such environmental harms have led to a worsening of ecological

quality and pose a significant risk to achieving high levels of sustainability. The relationship between macroeconomic indicators and ecological quality, particularly CO_2 emissions, is multifaceted and complex. Although economic growth and industrialisation increase emissions, the implementation of efficient environmental policies, innovation, and sustainable practices can decouple environmental degradation from economic growth. Building successful international plans to lower CO2 emissions requires addressing these problems.

According to this research, several factors, including population, trade, energy usage, and economic development, influence CO2 emissions (Kwakwa et al., 2020). Most studies have investigated individual factors affecting CO2 emissions, as well as combinations of two or three factors. However, an agreed-upon list of macroeconomic factors influencing a decrease in environmental quality still needs to be fully discovered (Tsaurai, 2020). Therefore, by conducting a thorough investigation into the factors affecting carbon emissions in developing nations, this study aims to bridge the existing gap in the literature.

Industrialised nations have increasingly directed their investments to developing countries or established production facilities in resource-rich regions, leveraging skilled human capital, raw materials, vast land resources, and financial resources. This development has resulted in pollution-intensive industries transferring from developed to developing economies, while developing countries pursue economic advancement through such industrialisation. As a result, the increased carbon emissions and environmental pollution in the developing world have become a significant factor contributing to global warming. Climate change is becoming a major worry as a result of the phenomenon of industry transferring from developed to developing nations due to cheap labour, an abundance of natural resources, and lax environmental rules (Nawaz et al., 2021; Apergis et al., 2023; Nyeadi, 2023; Song et al., 2021; Aghasafari et al., 2021).

According to the Intergovernmental Panel on Climate Change (IPCC) reports, all economies must adopt steps to help keep global temperatures below 2˚C (Gunarto, 2020). According to Rukikaire & Nullis (2021), the occurrence and severity of various weather and climate extremes are being amplified in all geographical regions worldwide due to global climate change. Developing countries have generally emphasised efforts to promote and enhance their industrial activity, substantially expanding their energy consumption to generate more goods and services. The economic growth of developing countries drives extensive energy use, and as a result, waste is often disposed of in the environment, leading to environmental degradation. Hence, the level of environmental contamination in developing countries has increased significantly in the 21st century.

1.1. Research Objectives

1. To determine the relationship between macroeconomic variables and carbon emissions in developing countries.
2. To examine the impact of macroeconomic determinants on carbon emissions in developing countries.
3. To explore the impact of macroeconomic determinants on carbon emissions based on the developing countries' income levels.

2. Literature Review

2.1. Theoretical Review

In the theoretical review, the researcher outlines the fundamental theories employed in the research. The theoretical review section encompasses the examination of the EKC model hypothesis and the Pollutant Haven Hypothesis. The researcher used these theories to develop the proposed study by defining the variables and providing supporting arguments.

The Environmental Kuznets Curve (EKC) theory was initially proposed by Simeon Kuznets in 1955. The term "inverted-U relationship" is derived from the research conducted by Kuznets (1955), who proposed a comparable association between income disparity and economic development. The concept of the Environmental Kuznets Curve (EKC) was first introduced in the early 1990s through the influential research conducted by Grossman and Krueger (1991) on the potential effects of NAFTA, as well as the background study conducted by Shafik and Bandyopadhyay (1992) for the 1992 World Development Report. Nevertheless, the notion that the preservation or enhancement of environmental quality is contingent upon economic growth constitutes a fundamental component of the sustainable development discourse advocated by the World Commission on Environment and Development (1987) in their seminal publication, "Our Common Future" (Ekins, 1997)

Two alternative theories associate FDI and the environment, namely, the "pollution-haven" and "pollution-halo" theories. The pollution-halo hypothesis posits that foreign companies, particularly those originating from developed economies, bring with them advanced and environmentally friendly technologies, as well as superior management techniques, that have the potential to enhance the host country's environmental quality. The pollution-halo concept gains particular significance when examining the pollution intensity of local businesses in relation to foreign standards.

The concept of the Pollution Haven Hypothesis (PHH) was initially proposed by Copeland and Taylor (1994) within the framework of North-South trade facilitated by NAFTA. Under the North American Free Trade Agreement (NAFTA), companies based in heavily regulated countries, such as the United States and Canada, found themselves in direct competition with companies operating in economically disadvantaged countries like Mexico, which had less stringent environmental regulations. According to the predictions made by Copeland and Taylor (1994), NAFTA was anticipated to have detrimental environmental consequences for Mexico and result in a significant loss of jobs for the United States. Within the context of trade liberalisation, companies producing environmentally harmful items would relocate from affluent nations with stringent environmental regulations to developing countries with relatively weak environmental regulations. Hence, under the context of free and liberalised commerce, it is plausible that developing countries may assume the role of pollution havens, accommodating the environmentally detrimental businesses of developed countries.

2.2. Empirical Review

Many studies have examined the causal relationships between various environmental deterioration and economic variables, as well as pollution in terms of carbon emissions. Various empirical studies have yielded different results due to methodological contrasts and study contexts (Khan & Ahmad, 2021). The literature has extensively modelled the connection between economic growth and environmental quality using the emissions–income link.

Based on the factors highlighted, it is evident that Asian economies have exhibited a more commendable performance in terms of carbon emissions compared to developed countries on a global scale (Gunarto, 2020). The majority of developing countries are located in Asian regions. Currently, many developing countries are implementing innovative strategies to mitigate environmental degradation and reduce carbon emissions associated with their developmental activities (Gunarto, 2020).

To determine long-term correlations between variables, Onuonga (2020) employed the ARDL bounds testing approach to examine the relationship between environmental quality, financial development, and economic growth in Kenya. The study, which utilised time series data from 1970 to 2019, confirmed that environmental quality is negatively impacted by trade openness, population growth, energy consumption, financial development, and foreign direct investment. In Kenya, it was also discovered that the use of natural resources increased air pollution. Regarding the relationship between income and air pollution, the study questioned the EKC hypothesis but concluded that it was more pertinent when considering financial development.

Fitriyah (2019) used the EKC model for Indonesia to investigate the relationship between energy consumption, financial development, economic growth, and carbon emissions. A long-term and statistically significant association between these factors was empirically demonstrated using the ARDL bounds testing technique. Research has shown that financial development, energy consumption, and economic expansion all have a positive and statistically significant impact on CO2 emissions over the long and short terms.

(2021) pointed out that because developing countries have more lax environmental regulations, they are pollution havens; hence, FDI inflows from developed to developing countries are likely to raise emissions. FDI can, however, also be beneficial in enhancing managerial efficiency and introducing new technologies, both of which may lead to a reduction in emissions. GDP per capita, energy consumption, trade openness, urban population, and renewable energy utilisation were their control variables. Recent research on the Pollution Halo Effect (PHE) and the Pollution Haven Hypothesis (PHH) suggests that the impact of foreign direct investment (FDI) on CO_2 emissions may not be uniform across all Chinese regions. PHH or PHE has been proven in numerous regions of China, confirming the prevalence of aggregation bias (Apergis et al., 2023), as cited in Ahmad et al.. The empirical data, as cited in Apergis et al. (2023) and Cai et al. (2018), hypothesise that China serves as a pollution refuge for 22 industrialised countries and 19 developing countries, confirming the PHH in the case of China.

Similarly, Nyeadi investigated how FDI inflows and financial growth affected the use of clean energy and carbon dioxide emissions in Sub-Saharan Africa (SSA). FDI did not significantly affect the use of clean energy in SSA, according to the study, which also controlled for economic growth. However, when the sample was divided according to income, a strong correlation was found: FDI had a negative impact on middle-income economies but a positive impact on clean energy use in low-income nations. FDI has a positive correlation with CO_2 emissions across the board, especially in low-income economies.

On a global scale, countries are achieving sustainable development by obtaining environmentally friendly FDI as well as strengthening technology capabilities. However, this is not always the case with South Asia and other emerging nations, where record CO_2 emissions have been reached. This is partly due to the fact that a significant number of growing economies are located in Asia, where excessive expansion, foreign investment, and lax environmental regulations all contribute to environmental degradation. Nawaz et al. (2021) present empirical results that contradict the conventional EKC hypothesis, which posits an inverse U-shaped relationship between CO2 emissions and per capita GDP. Instead,

a U-shaped relationship is observed between FDI and CO_2 emissions, suggesting that further FDI inflows may lower emissions beyond a certain point. However, most South Asian nations face a dire challenge in attaining sustainable economic development, as FDI remains a key driver of environmental deterioration (Nawaz et al., 2021).

A considerable number of empirical studies have examined the impact of different variables on CO2 emissions, both individually and in combination with two or three variables. There is a considerable body of literature that investigates factors such as renewable energy consumption, FDI, and economic growth as determinants of CO2 emissions pollution. However, those studies investigated each factor separately. Therefore, the present study aims to examine the impact of seven macroeconomic determinants on CO2 emissions in a single study, thereby filling this gap.

In addition, most empirical studies have centred on single countries or regions. This study, in contrast, encompasses all available developing countries and aggregates them into four income groups to see how the effect of macroeconomic determinants on carbon emissions varies across different income levels. Several methodological limitations have been identified in existing empirical studies, including the failure to capture the dynamic characteristics of CO2 emissions data, the inability to address issues of endogeneity, autocorrelation, and heteroskedasticity, which results in biased and inconsistent results. The present study addresses all these issues using a system-generalised method of moments (GMM) estimator. Ultimately, this study fills a gap in the literature by providing unique insights to the global community.

3. Methodology

3.1. Conceptual Framework

The study developed the conceptual model using evidence from previous researchers to address the research objectives. The independent variables of the study are foreign direct investment, Renewable energy consumption, economic growth, Trade openness, Natural resources, Information and Communication Technology, and Financial development. The study examined how these independent variables impact carbon emissions.

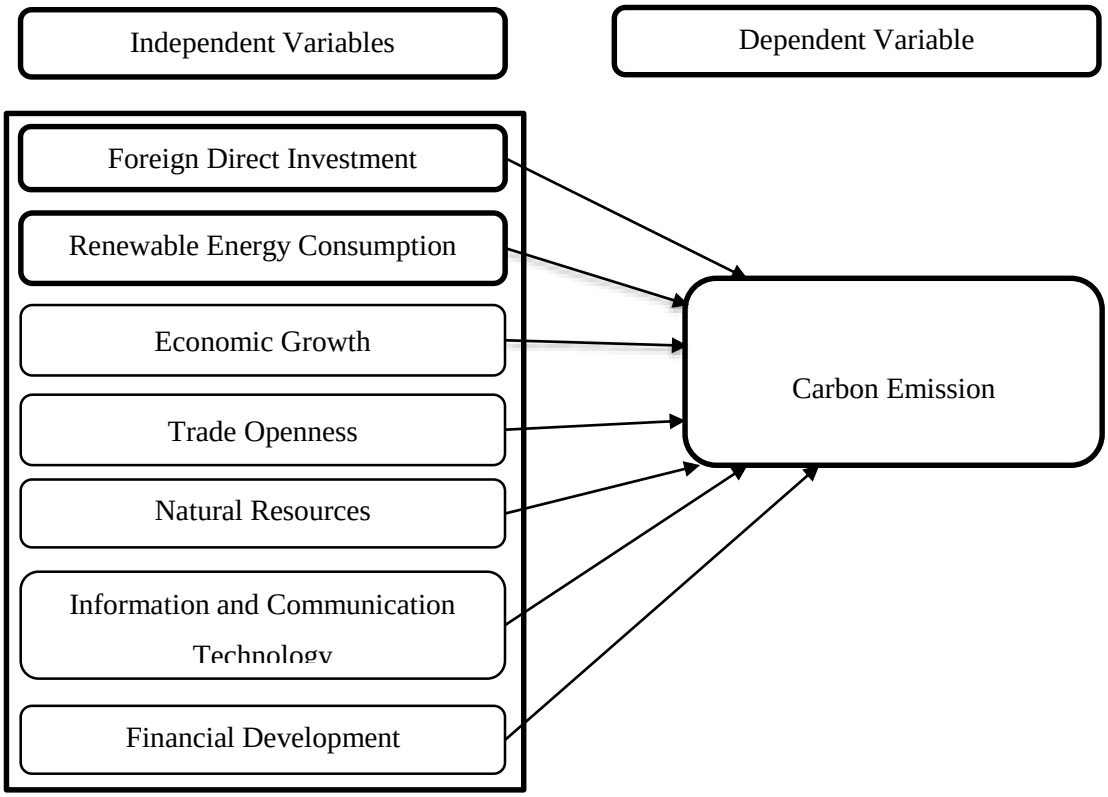

Figure 3.1: Conceptual Framework

Source: Developed by the researcher

The following hypotheses are developed based on the conceptual framework.

H_1: There is a significant impact of foreign direct investments on carbon emissions in developing countries.

H_2: There is a significant impact of renewable energy consumption on carbon emissions in developing countries.

H_3: There is a significant impact of economic growth on carbon emissions in developing countries.

H_4: There is a significant impact of trade openness on carbon emissions in developing countries.

H_5: There is a significant impact of natural resources on carbon emissions in developing countries.

H_6: There is a significant impact of information and communication technology on carbon emissions in developing countries.

H_7: There is a significant impact of financial development on carbon emissions in developing countries.

3.2. Operationalisation of the study

Table 3.1: Measurement of Variables

Variables	Indicator	Reference	Source
Carbon Dioxide Emission	Carbon emissions (metric tons per capita)	(Khan & Ahmad, 2021)	World Bank Indicators
Foreign Direct Investment (FDI)	Net inflows as a percentage of GDP	(Khan & Ahmad, 2021)	
Renewable energy consumption (REC)	Renewable energy consumption (% of total final energy consumption)	(Khan & Ahmad, 2021)	
Economic growth (EG)	Gross Domestic Product Growth (annual %)	(Nyeadi, 2023)	
Trade openness (TO)	Total trade (% of GDP)	(Marques & Caetano, 2020)	
Natural Resources (NR)	Total natural resources rents (% of GDP)	(Adjei et al., 2018)	
Information and communication technology (ICT)	Individuals using the Internet (% of the population)	(Tsaurai, 2020)	
Financial Development (FD)	Domestic credit issued to the private sector (% of GDP)	(Nyeadi, 2023)	

Source: Previous Literature

3.3. The Data and Sample

This study adopts a quantitative research approach and aims to address the research questions through the analysis of data collected from secondary sources. The study used the following sampling criteria. Considering the availability of the data, the researcher chose 113 developing countries. The data was collected for 10 years, from 2013 to 2022. The 113 developing countries were categorised into four categories according to income level: high-income, upper-middle-income, lower-middle-income, and low-income developing countries.

Table 3.2: Sample Size

Income Level	Number of Countries
High-Income Antigua and Barbuda, Bahamas, Bahrain, Barbados, Chile, Kuwait, Oman, Panama, Poland, Qatar, Romania, Saudi Arabia, Seychelles, Uruguay	14
Upper-middle Income Albania, Argentina, Armenia, Azerbaijan, Belarus, Belize, Bosnia and Herzegovina, Botswana, Brazil, Bulgaria, China, Colombia, Costa Rica, Dominica, Ecuador, El Salvador, Equatorial Guinea, Fiji, Gabon, Georgia, Guatemala, Indonesia, Iraq, Jamaica, Kazakhstan, Malaysia, Maldives, Mauritius, Mexico, Moldova, Montenegro, Namibia, North Macedonia, Paraguay, Peru, Russia, Serbia, South Africa, Thailand, Tonga,	40
Lower-middle Income Algeria, Angola, Bangladesh, Benin, Bhutan, Bolivia, Cambodia, Cameroon, Comoros, Djibouti, Egypt, Eswatini, Ghana, Guinea, Haiti, Honduras, India, Iran, Jordan, Kenya, Kyrgyzstan, Lebanon, Lesotho, Mauritania, Mongolia, Morocco, Myanmar, Nepal, Nicaragua, Nigeria, Pakistan, Philippines, Samoa, Senegal, Solomon Islands, Sri Lanka, Tajikistan, Tanzania, Tunisia, Ukraine, Uzbekistan, Vanuatu, Vietnam, Zambia, Zimbabwe	45
Low-Income Burkina Faso, Burundi, Central African Republic, Chad, Gambia, Guinea-Bissau, Madagascar, Mali, Mozambique, Niger, Rwanda, Sudan, Togo, Uganda	14

Source: World Bank Classification

3.4. Data analysis

The study used a two-step system GMM to address the research objectives and obtain precise conclusions. Several previous studies failed to address the potential issue of endogeneity. This study employs a system-generalised method of moments (GMM) estimator to investigate the impact of macroeconomic variables on environmental quality, utilising panel data from various developing countries. The present research has extensively explored the study of dynamic specification with a lagged dependent variable. Researchers used CO_2 emissions as a proxy for assessing the dependent variable. Given the cumulative nature of CO_2 emissions

over time, it is essential to incorporate a dynamic panel data model that includes the lagged dependent variable, as this allows for an analysis of the relationship between current emissions and those of the previous year. Moreover, the GMM is a more suitable approach for estimating a dynamic panel data model. This is because GMM is well-suited for addressing issues such as endogeneity, heteroskedasticity, and autocorrelation that may arise in the variables being examined.

4. Results and Discussion

The two-step system GMM is the most suitable estimating method for this investigation, as indicated by the data in Table 4.1. When using traditional panel estimating techniques, the endogeneity of right-hand side regressors may result in biased and inconsistent estimation, primarily because the error term and the lagged effect of CO2 emissions are correlated. An alternative approach is provided by Arellano & Bond (1991), who use the first-difference GMM estimator. The first-difference GMM employs moment conditions as tools to deal with the endogeneity issue, assuming that there is no serial correlation in the error terms and that the exogenous explanatory factors are weak. Furthermore, fixed effects are eliminated by the model's first differencing, and theoretically, the two-step GMM estimator produces more accurate estimates.

Table 4.1: Model selection

	Pool OLS	**Fixed Effect**	**1st Difference GMM**
L.COE	0.9730	0.6852	0.4659
Conclusion: The value of δ in the Difference GMM (0.4659) is lower than that of the FE model (0.6852); hence, System GMM is appropriate for this data.			
pval in parentheses *** p<0.01, ** p<0.05, * p<0.1			

Source: STATA Output

However, as mentioned in Arellano & Bover (1995) and Blundell & Bond, the lagged levels are not good tools for the two-step GMM estimator when the autoregressive process is sufficiently persistent. Blundell & Bond (2023) proposed the system-GMM estimator, which combines moment conditions for the level and differenced equations, as a way to circumvent this restriction. Therefore, the primary estimate method used in this study is the two-step system-GMM estimator. The Arellano-Bond GMM estimator might be a better choice if the coefficient on lagged levels is highly persistent. Post-estimation diagnostics such as the Sargan test and the Arellano-Bond serial correlation tests are used to assess the validity of the instruments and any serial correlation in the residuals.

4.1. Dynamic panel-data Estimation, Two-step System GMM

Table 4.2: Model selection

Prob > chi2 = 0.000		
Variable	**Coef.**	**P>|z|**
COE L1.	0.9361	0.0000***
FDI	0.0227	0.0220**
REC	-0.0012	0.2080
EG	0.0246	0.0000***
TO	0.0013	0.4400
NR	0.0090	0.1020
ICT	-0.0038	0.1010
FD	0.0012	0.0490**
_cons	-0.1556	0.1760
Arellano-Bond test for AR(1) in first differences: z = -2.88 Pr > z = 0.004		
Arellano-Bond test for AR(2) in first differences: z = -0.62 Pr > z = 0.532		
Sargan test = Prob > chi2 = 0.084		
Hansen test = Prob > chi2 = 0.388		
pval in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		

Source: STATA Output

Here, the number of instruments is lower than the number of groups, as 15 < 117; the researcher has met the reasonable requirement. Although the chi-square value is 0.000, the model is correctly specified due to its significant p-value. The lag value of the dependent variable is crucial, as it impacts the current value of CO_2.

The AB test for AR (1) in the first difference says that the p-value (0.004 < 0.05) is less than the significance level, so there is first-order serial correlation since it needs the dynamic panel data modelling. However, second-order serial correlation says by the AB test AR(2) results (0.532>0.05), so due to the use of L for instrumental variables, we do not need to reject the null hypothesis.

To meet the over-identification restrictions, the researcher used a set of instruments that are valid if the p-value is greater than the results. According to the result, Hansen is robust, as the p-value (0.084) is greater than 0.05. The difference in Sargan tests of exogeneity of the instrument subset (0.388 > 0.05) meets the required threshold for exogenous instruments, as it is greater than 0.05.

The results also show that CO2 emissions in the previous year, FDI, EG and FD significantly impacted the environmental quality at the 95% confidence level. The results indicate that the increase in these three variables, including LCOE, is associated with an increase in CO2 emissions. On the other hand, REC, TO, NR, and ICT do not have a significant impact on

environmental quality. The increase in the REC and ICT leads to a decrease in CO2 emissions. These results demonstrate that high-income developing countries employed some sustainable methods while engaging in REC and ICT-related activities. The rise of the TO and NR leads to an increase in CO2 emissions.

Two-step system GMM can be written as follows;

$$\mathbf{COE_t = -0.1556 + 0.9361COE_{t-1} + 0.0227FDI_t + 0.0246EG_t + 0.0012FD_t + \varepsilon_t}$$

According to Table 4.2, economic growth had a significant positive impact on carbon emissions. This finding aligns with that of Tsaurai (2020), Aye & Edoja (2017), and Ye et al. (2021), who argue that economic growth is associated with a high level of economic activity, resulting in significant energy usage and increased pollution and carbon emissions. Additionally, this result is inconsistent with those of Sepehrdoust et al. (2023) and Aye & Edoja (2017). Natural resources had an insignificant positive effect on carbon emissions. The results do not align with those of Tsaurai (2020) and Kwakwa et al. (2020). The study noted that the extraction of natural resources is done using heavy equipment and machinery, which emit CO_2. Trade openness had an insignificant positive effect on CO_2 emissions. This result is similar to those of Tsaurai (2020) and Ali et al. (2021), but differs from Huo et al. (2022). FDI was found to have a significant negative impact on carbon emissions, with results in line with those of Jijian et al. (2021) and Cheng & Yang (2016). However, this result differs from that of Nyeadi (2023). A significant positive relationship exists between financial development and carbon emissions across developing countries, as observed by Aye & Edoja (2017), Fitriyah (2019), and Ye et al. (2021). This finding is consistent with the work of Aye & Edoja (2017), Fitriyah (2019), and Ye et al. (2021). In contrast, Nyeadi (2023) and Ali et al. (2021) report inconsistent results. ICT had an insignificant negative influence on carbon emissions, in line with Lee & Brahmasrene (2014) and not in line with Lee & Brahmasrene (2014), Tsaurai (2020) and Nyeadi (2023). REC had an insignificant positive influence on carbon emissions, in line with Tsaurai (2020), but not in line with Ali et al. (2021) and Sepehrdoust et al. (2023).

This research examines the impact of selected macroeconomic variables on carbon emissions in developing countries. In addition to the above, this study analyses how those macroeconomic variables impact CO2 emissions based on the income levels of developing countries.

4.2. Dynamic Panel-Data Estimation, Two-Step System GMM for High-Income Developing Countries

Table 4.3: Dynamic panel-data Estimation, Two-step System GMM for High-Income Developing Countries

Prob > chi2 = 0.000		
Variable	**Coef.**	**P>|z|**
COE L1.	0.8950	0.0000***
FDI	-0.4068	0.0670*
REC	0.0017	0.8630
EG	0.1499	0.0920*
TO	0.0158	0.0910*
NR	-0.0211	0.5060
ICT	0.0037	0.9360
FD	0.0195	0.0600*
_cons	-0.7125	0.8350
Arellano-Bond test for AR(1) in first differences: z = -1.31 Pr > z = 0.192		
Arellano-Bond test for AR(2) in first differences: z = 0.98 Pr > z = 0.327		
Sargan test = Prob > chi2 = 0.738		
Hansen test = Prob > chi2 = 0.599		
pval in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		

Source: STATA Output

According to the results, the number of instruments is the same as the number of groups, which is 14=14. Although the Chi-square value is 0.000, the model is correctly specified due to its significant p-value. The lag value of the dependent variable is crucial, as it impacts the current value of COE.

AB test AR (1) for first-order serial correlation (0.192 >0.05) accepts the null hypothesis; this is not significant. So, there is no first-order serial correlation with residual values. In the AB test, AR (2) second-order correlation (0.327>0.05), as set by the fact that there is no second-order serial correlation, the researcher has used L2 as an instrument, and the results showed estimation to be correct.

To meet the over-identification restrictions, the researcher used the set instruments, which are valid if the p-value is greater than the reported results. According to the result, Hansen is robust as the p-value (0.599) is greater than 0.05. The results of the Sargan tests for the difference in exogeneity of the instrument subset (0.738 > 0.05) meet the requirement for exogenous instruments, as they exceed the 0.05 threshold.

The results also indicate that CO2 emissions in the previous year had a significant impact on environmental quality at the 95% confidence level. The results suggest that an increase in

LCOE leads to an increase in CO2 emissions. On the other hand, FDI, REC, EG, TO, NR, ICT and FD do not significantly impact environmental quality. The increase in FDI and REC leads to a decrease in CO2 emissions. These results demonstrate that high-income developing countries employed some sustainable methods while engaging in FDI and REC-related activities. However, the rise of EG, TO, NR, FD, and ICT leads to increased CO2 emissions.

4.3. Dynamic Panel-Data Estimation, Two-Step System GMM for Upper-Middle Income Developing Countries

Table 4.4: Dynamic panel-data estimation, two-step system GMM for upper-middle-income developing countries

Prob > chi2 = 0.000		
Variable	**Coef.**	**P>|z|**
COE L1.	0.83095	0.0000***
FDI	-0.02467	0.2230
REC	-0.00510	0.0520*
EG	0.06196	0.0000***
TO	0.00124	0.3400
NR	0.01689	0.0040***
ICT	0.01502	0.0010***
FD	0.00319	0.1280
_cons	-0.56877	0.0040
Arellano-Bond test for AR(1) in first differences: z = -3.23 Pr > z = 0.001		
Arellano-Bond test for AR(2) in first differences: z = -0.03 Pr > z = 0.977		
Sargan test = Prob > chi2 = 0.000		
Hansen test = Prob > chi2 = 0.200		
pval in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		

Source: STATA Output

Here, the number of instruments is lower than the number of groups, as 16 < 41; the researcher has met the requirement. That is good. Although the Chi-square value is 0.000, the model is correctly specified due to its significant p-value. The lag value of the dependent variable is crucial, as it impacts the current value of COE.

AB test for AR (1) in the first difference says that the p-value (0.001<0.05) is less than the significance level, so there is first-order serial correlation since it needs the dynamic panel data modelling. However, second-order serial correlation says by the AB test AR (2) results, (0.977>0.05), so due to the use of lag 2 for instrumental variables, the study does not need to reject the null hypothesis.

To meet the over-identification restrictions, the researcher used the set instruments, which are valid if the p-value is greater than the reported results. According to the Hansen result, 0.200> 0.05. The results of the Sargan tests for the difference in exogeneity of the instrument subset (0.000 < 0.05) do not meet the required threshold, as they should be greater than 0.05.

The results also show that CO2 emissions in the previous year, as well as EG, NR, and ICT, have a significant impact on environmental quality at the 95% confidence level. The results indicate that the increase in LCOE, EG, NR, and ICT leads to an increase in CO2 emissions. On the other hand, FDI, REC, TO, and FD do not have a significant impact on environmental quality. The increase in FDI and REC leads to a decrease in CO2 emissions. These results prove that upper-middle-income developing countries used some sustainable methods while engaging in FDI and REC-related activities. However, the rise in TO and FD leads to increased CO2 emissions.

4.4. Dynamic Panel-Data Estimation, Two-Step System GMM for Lower-Middle Income Developing Countries

Table 4.5: Dynamic Panel-Data Estimation, Two-Step System GMM for Upper-Middle Income Developing Countries

Prob > chi2 = 0.0000		
Variable	**Coef.**	**P>|z|**
COE L1.	0.8025	0.0000***
FDI	-0.0073	0.8170
REC	-0.0043	0.4260
EG	0.0160	0.0098***
TO	-0.0009	0.4470
NR	0.0175	0.2380
ICT	0.0025	0.2090
FD	0.0030	0.0760*
_cons	0.1791	0.6250
Arellano-Bond test for AR(1) in first differences: z = -1.36 Pr > z = 0.175		
Arellano-Bond test for AR(2) in first differences: z = 0.66 Pr > z = 0.511		
Sargan test = Prob > chi2 = 0.000		
Hansen test = Prob > chi2 = 0.098		
pval in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		

Source: STATA Output

Here, the number of instruments is lower than the number of groups, as 15 < 45; the researcher has met the requirement. Although the Chi-square value is 0.000, the model is correctly specified due to its significant p-value. The lag value of the dependent variable is crucial, as it impacts the current value of COE.

AB test AR (1) for first-order serial correlation (0.175 >0.05) accepts the null hypothesis; this is not significant. So, there is no first-order serial correlation with residual values. In the AB test AR (2) second-order correlation (0.511>0.05), as set by the fact that there is no second-order serial correlation, the researcher has used L as an instrument, and the results showed that the estimation was correct.

To meet the over-identification restrictions, the researcher used the set instruments, which are valid if the p-value is greater than the reported results. According to the Hansen result, 0.098>0.05. The results of the Sargan tests for the difference in exogeneity of the instrument subset (0.000 < 0.05) do not meet the required threshold, as they should be greater than 0.05.

The results shown in Table 4.5 also indicate that CO2 emissions in the previous year and EG have a significant impact on environmental quality at the 95% confidence level. The results indicate that the increase in LCOE and EG leads to an increase in CO2 emissions. On the other hand, FDI, REC, TO, NR, ICT and FD do not significantly impact environmental quality. The increase in FDI, REC, and TO leads to a decrease in CO2 emissions. These results demonstrate that lower-middle-income developing countries employed sustainable methods when engaging in FDI, REC, and TO-related activities. However, raising the NR, ICT, and FD leads to increased CO2 emissions.

4.5. Dynamic panel-data estimation, two-step system GMM for lower-income developing countries

Table 4.6: Dynamic panel-data estimation, two-step system GMM for lower-income developing countries

Prob > chi2 = 0.0000		
Variable	**Coef.**	**P>|z|**
COE L1.	0.5164	0.3030
FDI	0.0011	0.3300
REC	-0.0022	0.2260
EG	0.0022	0.3580
TO	0.0000	0.9450
NR	0.0000	0.9860
ICT	0.0001	0.9390
FD	0.0018	0.4090
_cons	0.2010	0.1790
Arellano-Bond test for AR(1) in first differences: z = -1.06 Pr > z = 0.289		
Arellano-Bond test for AR(2) in first differences: z = 0.45 Pr > z = 0.650		
Sargan test Prob > chi2 = 0.051		
Hansen test Prob > chi2 = 0.700		
pval in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		

Source: STATA Output

According to the results, the number of instruments is lower than the number of groups (15 < 16), so the researcher has met the requirement. Although the Chi-square value is 0.000, the model is correctly specified due to its significant p-value. The lag value of the dependent variable is crucial, as it impacts the current value of COE.

AB test AR (1) for first-order serial correlation (0.289>0.05) accepts the null hypothesis; this is not significant. So, there is no first-order serial correlation with residual values. In the AB test AR (2) second-order correlation (0.650>0.05), as set by the fact that there is no second-order serial correlation, the researcher has used L2 as an instrument, and the results showed estimation was correct.

To meet the over-identification restrictions, the researcher used the set instruments, which are valid if the p-value is greater than the reported results. According to the result, Hansen is robust as the p-value (0.700) is greater than 0.05. In the results of the Sargan tests for the difference in exogeneity of the instrument subset, the p-value (0.051) is greater than 0.05, meeting the requirement for exogenous instruments.

The results in Table 4.5 indicate that no macroeconomic variables have a significant impact on environmental quality at the 95% confidence level. The results indicate that FDI, REC, EG, TO, NR, ICT, and FD do not have a significant impact on environmental quality. These results demonstrate that lower-income developing countries employed some sustainable methods while engaging in related activities. Increases in selected macroeconomic variables, except for REC, result in higher CO2 emissions.

5. Conclusion

The growing global concern over climate change stems from the enduring detrimental effects of greenhouse gas emissions on the ecosystem. The impact of global warming is evident through the manifestation of rising sea levels, increasing ocean temperatures, glacial melting, changing rainfall patterns, a significant decline in biodiversity, reduced agricultural yields, and declining labour force productivity worldwide. There is a pressing need for empirical research on the macroeconomic variables that influence environmental quality, which is crucial for promptly implementing environmental protection policies essential for ensuring a sustainable future in developing countries.

This study demonstrated that economic growth cannot consistently improve environmental quality. Therefore, it is imperative for policymakers to carefully formulate and implement measures that promote economic growth while enhancing environmental quality, thereby achieving sustainable development. Given the evidence suggesting that foreign direct

investment, renewable energy consumption, economic growth, trade openness, natural resources, information and communication technology, and financial development may potentially contribute to economic activities that generate environmental pollution as an unintended consequence, it is recommended that regulatory bodies prioritise the provision of credit for investments in the utilisation and advancement of environmentally friendly technology. This can be achieved by implementing lower interest rates on agreements about environmental protection.

To address the issue of heightened CO_2 emissions in countries with significant industrial sectors, it is essential to implement policies that encourage greater engagement in the tertiary industry, such as the service and finance sectors, or incentivise the adoption of environmentally sustainable technologies and economic practices within the secondary industry. Green macroeconomic activities refer to environmentally friendly methods that can contribute to economic and environmental sustainability.

Governments in high-income developing countries can invest in carbon capture systems and technologies to mitigate climate change. Given the positive effect of the lag-dependent variable, allocate resources and financing to develop and implement sophisticated carbon capture technology to offset last year's emissions. These countries can also initiate green financing programs. They can encourage financial institutions to consider environmental factors when making investment decisions and to promote sustainable projects and businesses. Green technological innovation can be introduced in upper-middle-income developing countries. Researchers can enhance green technology research and development to promote economic growth while minimising environmental impacts. Not only that, but these governments must improve environmental monitoring. The government needs to invest in information and communication technology to enhance environmental monitoring and management, enabling data-driven decision-making for sustainable long-term growth. As natural resource extraction activities weaken the environment in these countries, responsible authorities and departments should not only guide companies that extract natural resources on the importance of afforestation and encourage them to practice land reclamation and afforestation, but also establish laws governing such practices in the country to ensure a safe environment.

The findings from lower-middle-income countries suggest that a comprehensive policy framework is necessary to protect the environment while promoting economic growth. Policymakers can utilise sustainable economic policies to develop and implement measures that support industries with low carbon footprints and sustainable practices, while fostering economic growth. In addition, the study suggests some renewable energy promotions. As a

result, governments can incentivise the use of renewable energy sources to minimise reliance on carbon-intensive energy sources and promote cleaner alternatives. Lower-income developing countries can prioritise projects that provide access to renewable energy sources, particularly in remote areas, to enhance energy access and reduce their reliance on fossil fuels. Additionally, relevant authorities can invest in education and training programs to enhance community knowledge and capacity for sustainable practices. Furthermore, these countries can concentrate on environmentally sustainable agriculture, resource management, and Energy conservation.

The growing global concern over climate change stems from the enduring detrimental effects of greenhouse gas emissions on the ecosystem. The impact of global warming is evident through the manifestation of rising sea levels, increasing ocean temperatures, glacial melting, changing rainfall patterns, a significant decline in biodiversity, reduced agricultural yields, and declining labour force productivity worldwide. There is a pressing need for empirical research on the macroeconomic variables that influence environmental quality, which is crucial for promptly implementing environmental protection policies essential for ensuring a sustainable future in developing countries.

The present study examined the impact of macroeconomic variables on environmental quality in developing countries. Therefore, future research may focus on examining the impact of macroeconomic variables on sectors that significantly contribute to environmental degradation, such as energy, transportation, agriculture, and manufacturing. The analysis of sector-specific data provides valuable insights into the varying impacts of different industries on environmental quality, thereby enabling the identification of appropriate policy actions. The variables included in this study were chosen based on data availability. Future research may consider additional factors, such as infrastructural development, solar radiation, overall biocapacity, and air temperature, to further enhance understanding of the relationship between these variables.

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