UNRAVELING THE NEXUS BETWEEN MACROECONOMIC FACTORS AND CARBON EMISSIONS IN DEVELOPING COUNTRIES: A VECM ANALYSIS MODELS

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ABSTRACT

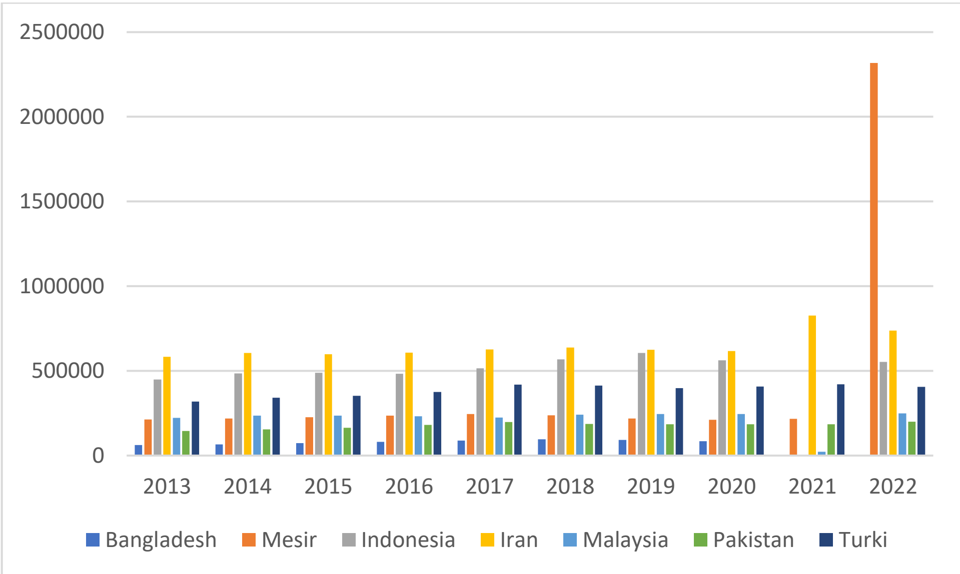
Global efforts to reduce carbon emissions have become a major concern due to growing concerns over global warming and climate change. However, despite these efforts, carbon emissions continue to rise, particularly in developing countries that often prioritize economic growth over environmental sustainability. This study aims to analyze the causal relationship between carbon emissions, interest rates, political stability, trade openness, and foreign direct investment in eight developing countries. A quantitative approach, using regression analysis, is used to examine panel data collected from official sources over the period 2013–2022. The econometric model, the Vector Error Correction Model (VECM), is applied to identify causal relationships and reveal the long-term and short-term effects between the variables analyzed. The findings indicate that there is no relationship between all variables and carbon emissions. While the long-term test results show that exchange rates, political stability, trade openness, and foreign direct investment affect carbon emissions, while the short-term relationship as a whole has no short-term effect, this study emphasizes providing deeper insights into how macroeconomic policies and conditions can affect carbon emission reduction efforts in various countries. These findings play an important role in controlling carbon emissions and can encourage policymakers to integrate environmental considerations into economic policies.

Keywords: *Carbon Emissions, Exchange Rate, Political Stability, Trade Openness, Foreign Direct Investment, Developing countries.*

INTRODUCTION

Global warming and climate change driven by carbon emissions are widely recognized as the most significant threats of the 21st century (Costello et al., 2009). In 2015, 196 nations committed to the Paris Agreement on Climate Change, with the objective of limiting the global temperature increase this century to well below 2°C in order to mitigate the severe consequences of globalization (Gao et al., 2017). The effectiveness of the Paris Agreement, along with other environmental pollution policies, is closely linked to the quality of state institutions. These institutions, which are responsible for the formulation and enforcement of environmental regulations aimed at reducing carbon emissions, vary in form—encompassing political, governmental, and social entities and are shaped by a multitude of factors (Salman et al., 2019).

Graph 1. Carbon Emission Trends in D-8 Countries



Source: Data processed 2024

A look at graph 1 shows that the carbon emissions trend in D-8 countries is stuck in the period observed, namely for 10 years from 2013 to 2022. The highest CO2 occurred in 2022 at 23.17% in Egypt. Iran is the largest CO2 emitter among the D-8 countries, followed by Indonesia and Türkiye. Bangladesh accounts for the smallest share of total CO2 carbon emissions. The problem of environmental degradation has come to the fore in the D-8 countries (Bangladesh, Egypt, Indonesia, Iran, Malaysia, Pakistan, and Turkey) due to a marked increase in total CO2 emissions. From graph 1, there is an increase in carbon emissions from year to year, so there needs to be a solution to overcome this problem considering that C02 is the main factor in global warming.

Global carbon emissions have continued to rise despite international efforts aimed at their reduction (Acheampong & Boateng, 2019). Governments across the globe have been actively implementing various strategies to curb carbon emissions. Nevertheless, the overall level of carbon emissions worldwide has not shown a decline (Micheal, 2019). According to data released by the Global Carbon Project (GCP), in 2018, total CO2 emissions from energy consumption worldwide increased by 1.7% (around 560 million tonnes) and reached an all-time high of 33.1 billion tonnes.(Acheampong & Boateng, 2019; Sun et al., 2020).

The growing concern over global warming and climate change in recent decades has led to extensive research into the underlying causes of environmental degradation. Among the various environmental pollutants, carbon dioxide (CO2) emissions are recognized as a primary contributor to global climate change. Consequently, reducing global CO2 emissions has become a central objective of international policies aimed at mitigating the adverse effects of climate change. Traditionally, factors such as income, demographic variables like population density, urbanization, and political institutions including democracy and corruption have been identified as key determinants of CO2 emissions. Moreover, the increasing globalization of trade and significant structural changes in the global economy—particularly in the manufacturing sector and international trade flows since the 1990s—have prompted a growing body of literature exploring the impact of trade on CO2 emissions (Ansari et al., 2020; Kim et al., 2019).

Numerous countries have introduced trade restrictions, adversely affecting international trade. The recent surge in protectionism has undoubtedly created new obstacles for carbon reduction efforts in both developed and developing nations. In light of the ongoing Paris Agreement initiatives, examining the impact of trade openness on carbon emissions has become increasingly pertinent (Q. Wang & Zhang, 2021). Additionally, one of the contributing factors to the rise in carbon dioxide emissions is the international trade process, where payment transactions occur using agreed-upon currencies between the participating countries (Hermawan & Ramadhan, 2016). Political conflict can influence a government's stance on environmental issues through the formulation and implementation of related policies and regulations. Additionally, it can shape the perspectives of business organizations and citizens regarding environmental quality. The body of literature examining the relationship between environmental degradation and political stability is relatively nascent and limited, with most studies focusing on the impact of corruption and other indicators of institutional quality on pollution (Purcel, 2019).

Developing countries frequently grapple with the challenge of balancing economic growth with the need to reduce emissions, which are often viewed as a significant contributor to climate change, as they utilize their resources and profits to overcome economic underdevelopment. Achieving a reduction in carbon emissions while meeting global reduction targets has consistently posed a substantial challenge for these nations at various stages of development (Y. Wang et al., 2021). In this context, foreign direct investment (FDI) plays a crucial role as a driving force for economic growth and technological advancement (Hong, 2014). More critically, the anticipated environmental degradation due to carbon emissions threatens the sustainability of global socio-economic development, highlighting a serious concern for stakeholders (Gryglewski et al., 2019). Consequently, it is imperative to adopt and effectively implement pertinent environmental policies to address and reduce the rate of carbon emissions.

A significant advancement in ecological macroeconomics is the examination of financial markets, particularly the impact of exchange rates on environmental quality through their effects on economic and technological activities (Karagiannopoulou et al., 2022). The role of the US dollar is particularly crucial for the global economy, as it can affect international trade transactions (Eguren Martin et al., 2017). When a country's exchange rate appreciates or depreciates, it influences the volume of imports and exports. A depreciation of the national currency makes goods and services produced domestically cheaper compared to those from other countries, potentially boosting export volumes while increasing carbon emissions due to higher production and reduced imports. The relationship between exchange rates and environmental pollution supports the hypothesis that companies may relocate to developing countries with less stringent environmental regulations, leading to increased emissions (Adjei-Mantey et al., 2023). Research by Ullah & Ozturk (2020) and Zhang et al. (2017) indicates that, in the short term, exchange rate fluctuations negatively impact carbon emissions. Additionally, Omoke et al. (2020) found that exchange rate depreciation contributes to environmental degradation, specifically through increased carbon emissions.

Stable governments are generally more capable of designing, implementing, and enforcing effective environmental policies. Political stability facilitates the enforcement of stricter regulations on carbon emissions (Smaili & GAM, 2023). For example, countries with stable governments can adopt and enforce stricter emissions standards, provide incentives for green technologies, and support green infrastructure projects. Political instability often disrupts the policy-making process and its implementation. Unstable governments may focus less on environmental issues because they are more involved in resolving political or social conflicts. This can lead to delays or abandonment of carbon emission reduction policies, as well as an increase in environmentally damaging activities without adequate supervision (Ahmad et al., 2022). Political stability plays an important role in determining carbon emission levels through governance mechanisms, investment and infrastructure, economic structure, and public awareness and participation. Stable governments tend to be more capable and committed to implementing effective carbon emission reduction policies, while political instability tends to hinder such efforts and increase carbon emissions. This hypothesis can be further tested through empirical data analysis in the context of a particular country or period.

Trade openness is a crucial factor impacting environmental quality. It has the potential to reduce environmental degradation (Shahbaz et al., 2013). Financial openness and liberalization associated with trade openness can attract increased investment in research and development, fostering technological innovation. Such innovations enhance energy efficiency, thereby contributing to lower carbon emissions (Nur Sahara & Rahadian, 2024). Trade openness, which denotes the degree to which a country engages in international trade, can influence carbon dioxide (CO_2) emissions. While international trade generally boosts economic activity, it also leads to higher energy consumption and emissions. Typically, increased trade openness is associated with rising CO2 emissions. Nevertheless, trade agreements have the potential to mitigate the adverse effects of trade openness on emissions. Dou et al. (2021) found that increasing trade openness has both direct and indirect positive impacts on carbon emissions.

Foreign direct investment (FDI) is a significant driver of economic growth, particularly when domestic savings fall short of meeting investment needs (OECD, 2002). Proponents of FDI argue that it can promote environmental sustainability by facilitating the adoption of cleaner and more advanced technologies. However, recent research underscores the pollution haven hypothesis, which posits that countries with weaker environmental regulations attract FDI, potentially resulting in environmental harm. This research also supports the notion of a positive relationship between FDI and increased CO2 emissions in certain countries or regions (Essandoh et al., 2020).

In the current era of globalization, international trade is becoming increasingly interconnected, with capital moving across national borders to industries and regions offering higher returns. Enhanced foreign direct investment (FDI) provides numerous advantages, including capital infusion, skill development, technology transfer, market access, and export incentives. International trade and unrestricted capital flows are significantly driving FDI into developing countries (He et al., 2020). Hoffmann et al. (2005) found that in low-income countries, CO2 emissions impact FDI inflows, while in middle-income countries, FDI inflows contribute to increased CO2 emissions. Conversely, in high-income countries, no causal relationship between FDI and CO2 emissions is observed. The relationship between CO2 emissions and FDI remains inconclusive due to the pollution halo hypothesis. The pollution halo hypothesis recommends that universal standard environmental regulations transfer a country's green technology to its partners through FDI inflows(Pao & Tsai, 2011).

This research examines significant shifts in economic conditions and environmental policies within developing countries of the D-8 group, an area not fully addressed by previous studies. It is possible that new factors are affecting carbon emission levels. The research's strength lies in its application of the Vector Error Correction Model (VECM) to explore both long-term and short-term relationships between various economic variables and carbon emissions. This approach is particularly relevant in the context of the interplay between carbon emissions and economic policy in D-8 developing countries. These insights are crucial for efforts to mitigate carbon emissions and can help policymakers integrate environmental considerations into economic strategies.

METHODS

This research is research with a quantitative approach using secondary data taken through the official website. The type of data used is panel data with the population, namely countries that are members of the Organization of Islamic Cooperation (OIC). Sampling used a purposive sampling technique with the criterion of availability of variable data related to the research object. The sample in this study was 7 developing countries (D-8), namely Bangladesh, Egypt, Indonesia, Iran, Malaysia, Pakistan and Turkey with a research period of 10 years from 2013-2022. The data used for each variable is as follows:

Table 1. Operational Definition of Variables

Variables	Type of Variables	Proxied by	Source
Carbon Emissions (CO2)	Dependent	CO2 Emissions (kt)	World Bank
Exchange Rate (ER)	Independent	Official Exchange Rate (LCU per US$, Period Average)	World Bank
Political Stability (SP)	Independent	Political Stability and Absence of Violence/Terrorism: Estimate	World Bank
Trade Openness (TO)	Independent	Trade (% of GDP)	World Bank
Foreign Direct Investment (FDI)	Independent	Foreign Direct Investment, Net Inflows (BoP, Current US$)	World Bank

Source: Created by Author

This research uses the Vector Autoregression (VAR) or Vector Error Correction Model (VECM) model, where this model allows regression analysis involving both independent variables and dependent variables.(Princess, 2020). The VAR or VECM method was chosen because often the dependency relationship between the dependent variable and the independent variable is difficult to find in a constant state. In other words, the influence of the independent variable on the dependent variable can fluctuate over time(Sudarmawan, 2023). Can be written as follows:

$$CO2_t = \beta_0 + \beta_1 ER_t + \beta_2 SP_t + \beta_3 TO_t + \beta_4 FDI_t + e_t$$

The Vector Error Correction Model (VECM) approach will be applied through a series of systematic and comprehensive stages in this research. The first stage is a stationarity test using the Augmented Dickey-Fuller (ADF) or Phillips-Perron (PP) method to ensure stability. After that, the optimal lag will be determined using information criteria such as AIC, SIC, or HQ. Next, the Johansen cointegration test will be carried out to detect the existence of a long-term relationship between variables. After cointegration is confirmed, VECM model estimation is carried out to analyze short-term and long-term relationships between variables. The resulting model will then be tested diagnostically through autocorrelation, heteroscedasticity and residual normality tests to ensure conformity with classical assumptions. Advanced analysis includes Impulse Response Function (IRF) to observe variable responses to shocks, as well as Variance Decomposition to measure the contribution of each variable to the variability of other variables. To identify the direction of causality, the Granger Causality test will be applied. All results from this stage will be interpreted comprehensively, with a focus on analysis of long and short term coefficients, evaluation of adjustment speed, as well as interpretation of IRF and Variance Decomposition results. This process will end with model validation through comparison with economic theory and previous empirical studies, as well as robustness testing if necessary. Each stage will be reported in detail to ensure transparency and validity of research results(Sari et al., 2023).

RESULTS AND DISCUSSION

This research investigates the relationship between Exchange Rate, Political Stability, Trade Openness, Foreign Direct Investment and Carbon Emissions in developing countries (D-8). Apart from that, below are descriptive statistics from the time series data presented in table 2 below:

Table 2 Descriptive Statistics Results

	C02	E.R	SP	TO	FDI
Mean	12.20910	4.941069	-1.091660	54.32808	1.561188
Median	12.38719	4.405961	-1.130682	42.95322	1.435611
Maximum	14.65621	10.64542	0.266619	146.6638	5.415570
Minimum	4.671894	0.643835	-2.603302	24.70158	0.355309
Std. Dev	1.669147	3.451521	0.737842	34.07400	1.077899
Skewness	-3.230660	0.550731	0.064404	1.677817	1.128228
kurtosis	14.56885	1.779374	2.500488	4.433096	4.251595
Jarque - Bera	512.1287	7.884176	0.776136	38.83263	19.41941
Probability	0.000000	0.000000	0.678366	0.000000	0.000061
Sum	854.6373	345.8748	-76.41618	3802.966	109.2832
Sum Sq. Dev.	192.2375	821.9968	37.56439	80111.58	80.16875
Observations	70	70	70	70	70

Source: Output

Based on table 2 above, it shows that the average carbon emissions in developing countries (D-8) sampled in this study for 10 years was 12.20 with a standard deviation value of 1.66 and a probability value of 0.00. Furthermore, the ER variable during this period had an average of 4.94 with a standard deviation of 3.45 and a probability of 0.00. The SP variable has an average of -1.09 with a standard deviation value of 0.73 and a probability of 0.67. Furthermore, the TO variable has an average of 54.32 with a standard deviation value of 34.07 and a probability of 0.00. And the last one is FDI which has an average of 1.56 with a standard deviation value of 1.07 and a probability of 0.00.

Stationary Test

The initial step in applying the VECM model is to test the stationarity of the data using the Levin, Lin & Chu (LLC) method). The basic condition that must be met in the VECM model is that the data must be stationary at the level level and at the first difference level (Difference 1). The unit root test results can be found in table 3 as follows:

Table 3 Stationary Results

Variable	Levels		1 Difference	
	Statistics	Prob	Statistics	Prob
CO2	-1.50622	0.0660	-2.31234	0.0104
E.R	-1.64131	0.0504	-3.36607	0.0004
SP	-3.08293	0.0010	-7.61697	0.0000
TO	-2.58983	0.0048	-6.89940	0.0000
FDI	-4.32910	0.0000	-9.25057	0.0000

Source: Eviews 12 Processed

According to the Levin, Lin, and Chu (LLC) test results, the CO2 variable is stationary at the second difference, with a probability value of 0.0104, which is below the 0.05 threshold, indicating stationarity at the first difference level. The Exchange Rate (ER) variable is also stationary at the second difference, with a probability value of 0.0004, confirming its stationarity at the first difference level. For the Political Stability (PS) variable, stationarity is observed at the first difference, with a probability value of 0.0010, meaning it is stationary at the level. The Trade Openness (TO) variable shows stationarity at the first difference, with a probability value of 0.0048, indicating it is stationary at the level. Finally, the Foreign Direct Investment (FDI) variable is stationary at the first difference, with a probability value of 0.0000, confirming its stationarity at the level.

Lag Criteria

After stationarity testing is carried out at the level or first difference level, the next step is to determine the optimal lag using lag order selection criteria. This criterion aims to select the most appropriate number of lags for the model, taking into account the balance between model complexity and prediction accuracy. The results of this lag selection can be seen in table 4 below:

Table 4 Optimal Lag

Lag	LogL	L.R	FPE	AIC	S.C	HQ
0	-400.4183	NA	7922.445	23.16676	23.38896	23.24346
1	-165.8222	388.7593	0.050669	11.18984	12.52300	11.65005
2	-139.6431	35.90279	0.051983	11.12246	13.56658	11.96617
3	-109.9741	32.21207*	0.051395*	10.85566*	14.41074*	12.08288*

Source: Eviews 12 Processed

Based on the determination of the optimal lag, it is based on criteria such as the Akaike Information Criterion (AIC), Schwarz Criterion (SC), and Hannan-Quinn Criterion (HQ), where the lag selected is the one with the highest number of asterisks, namely Lag 3 AIC. which provides guidance regarding the best lag to use in model estimation. Thus, choosing the right lag will increase the reliability and validity of the model in predicting long-term and short-term relationships between the variables studied.

Stability Test

After testing the lag criteria, the next step is to test the stability of the VAR model. This stability test aims to ensure that the VECM model can be used accurately in forecasting using the Impulse Response Function (IRF) and Variance Decomposition (VD) methods. One of the main requirements for a model to be considered stable is that all modulus values must be below 1. The results of this stability test are presented in table 5, which shows whether the model meets the stability criteria. A stable model will provide more reliable forecasting results and support long-term analysis more precisely.

Table 5 Stability Test

Root	Modulus
0.998321	0.998321
0.996440	0.996440
0.944540 – 0.032670i	0.945105
0.944540 + 0.032670i	0.945105
-0.647793	0.647793
0.366758 – 0.251290i	0.444588
0.366758 + 0.251290i	0.444588
-0.121788 – 0.193361i	0.228519
-0.121788 + 0.193361i	0.228519
-0.073015	0.073015

Source: Eviews Processed

Cointegration Test

The cointegration test is carried out to ensure the existence of a stable long-term relationship between two or more non-stationary variables in time series analysis. In this research, cointegration testing uses the Johansen Cointegration Test method. The results of this test show that the model meets the requirements for using the VECM approach, because the probability value obtained is less than 0.05. This shows that there is a cointegration relationship between these variables, as shown in Table 6. Thus, the VECM model can be applied to analyze the dynamics of long-term and short-term relationships between these variables effectively.

Table 6 Cointegration Test Results

Hypothesized No. of CE(s)	Eingenavalue	Trace Statistics	0.05 Critica Value	Prob**
None*	0.857102	122.4176	69.81889	0.0000
At most 1*	0.654755	54.32073	47.85613	0.0110
At most 2	0.300952	17.09816	29.79707	0.6328
At most 3	0.097647	4.566896	15.49471	0.8529
At most 4	0.027352	0.970653	3.841465	0.3245

Source: Eviews Processed

Granger Causality Test

The Granger causality test is carried out to identify one-way or two-way causal relationships between variables in the context of long-term relationships. Table 7 presents the results of the causality test, with the stipulation that the causal relationship is considered significant if the probability value is less than 0.05. Based on these results, it can be concluded that there is a causal relationship between the variables tested.

Table 7 Granger Causality Test Results

Null Hypothesis	Obs	F-Statistics	Prob.
ER does not Granger Cause CO2	49	0.33963	0.7968
CO2 does not Granger Cause ER		0.70342	0.5553
SP does not Granger Cause CO2	49	0.27907	0.8402
CO2 does not Granger Cause SP		0.27406	0.8438
TO does not Granger Cause CO2	49	0.63006	0.5997
CO2 does not Granger Cause TO		1.14215	0.3432
FDI does not Granger Cause CO2	49	0.93803	**0.0430**
CO2 does not Granger Cause FDI		0.06944	0.9759
SP does not Granger Cause ER	49	0.88357	0.4574
ER does not Granger Cause SP		0.83769	0.4809
TO does not Granger Cause ER	49	0.88184	0.4583
ER does not Granger Cause TO		1.31519	0.2821

Source: Eviews Processed

Based on the results of the causality test in table 7 above, it shows that there is a one-way relationship between Foreign Direct Investment and Carbon Emissions. This finding is in line with the research results(Bakhsh et al., 2021)which states that there is a relationship between these two variables.

VECM Model Regression

The results of the VECM test in the long term and short term can be seen in table 8. This research uses a significance level of 5% to assess the variables CO2, exchange rate, political stability, trade openness, and foreign direct investment. In determining the level of significance, the researcher compared the t-statistic with a t-table of 1.99714. Sy The main way the variable is considered to influence is the t-statistic value > t-table value. Therefore, the VECM test results and analysis can be seen in table 8 below.

Table 8 Long Term and Short Term VECM Test

Variable Long Run Results	Coefficient	Std. Error	t-stat	Information
D(ER)	1.675064	0.58159	[2.88017]	Significant
D(SP)	-0.880678	0.25462	[-3.45875]	Significant

D(TO)	-0.103077	0.025462	[-4.92754]	Significant
D(FDI)	1.091123	0.11603	[9.40384]	Significant
Short Run Results				
CointEq1	-2.562468	1.84163	[-1.39142]	Not Significant
D (CO2(-1),2)	1.074156	1.89774	[0.56602]	Not Significant
D (CO2(-2),2)	7.625204	1.89774	[0.83537]	Not Significant
D (CO2(-3),2)	-4.566642	9.27926	[-0.49213]	Not Significant
D (ER(-1),2)	-0.687363	4.98783	[-0.13781]	Not Significant
D (ER(-2),2)	0.959078	3.92450	[0.24438]	Not Significant
D (ER(-3),2)	-1.294553	4.31072	[-0.30031]	Not Significant
D (SP(-1),2)	-0.635826	2.17158	[-0.29279]	Not Significant
D (SP(-2),2)	0.084420	2.08354	[0.04052]	Not Significant
D (SP(-3),2)	-0.149113	1.83272	[-0.08136]	Not Significant
D (TO(-1),2)	-0.073513	0.13754	[-0.53450]	Not Significant
D (TO(-2),2)	-0.052018	0.09499	[-0.54761]	Not Significant
D (TO(-3),2)	0.027539	0.09470	[0.29079]	Not Significant
D (FDI(-1),2)	2.208428	1.61975	[1.36343]	Not Significant
D (FDI(-2),2)	1.097527	1.22641	[0.89491]	Not Significant
D (FDI(-3),2)	0.871464	0.67391	[1.29315]	Not Significant
C	0.757227	1.06105	[0.71366]	Not Significant

Source: Eviews Processed

Exchange Rate affects Carbon Emissions (CO2)

The exchange rate has a positive and significant effect on carbon emissions (CO2) in developing countries (D-8). These findings show that if the exchange rate is 1% it will reduce carbon emissions in the long term by1.675064. This research is in line with research conducted(Ma et al., 2021)that for every 1% the average carbon emission intensity in the region is reduced by 0.528 tons/10,000 yuan. Exchange rate appreciation effectively reduces the intensity of carbon emissions, reduces the level of foreign trade and foreign investment, encourages optimization and improvement of industrial structure. In developing countries (D-8), however, the exchange rate in the short term can have a negative impact on carbon emissions as shown in table 8 because a stronger exchange rate can make fossil fuel imports cheaper. This can increase fossil fuel consumption in a country because energy prices become more affordable. This increase in fossil fuel consumption directly increases carbon emissions.

Political Stability influences Carbon Emissions (CO2)

Furthermore, there is evidence that the political stability variable has a positive impact on carbon emissions in developing countries (D-8). These findings show that with good political stability in the country, companies will be able to reduce carbon emissions by thinking about the environment in the long term by 1.67%. This research is in line with(Fatah & Altaee, 2024)that the presence of good political stability will encourage progress in environmental conditions and efforts to realize sustainable practices. This is in line with research(Adebayo et al., 2022)And(Kirikkaleli & Osmanlı, 2023)that political stability plays an important role in attracting investment from international companies. Thus, maintaining political stability is a crucial factor for increasing foreign investment which can then encourage the government to be more serious in facing the challenge of climate change. Additionally, reform efforts should focus on protecting environmental policies that support the transition to a green economy, while local and international companies are expected to actively allocate their investments into renewable energy and energy efficiency technologies. Political stability refers to the absence of major changes in a country's political structure.

In a stable political system, environmental crises can be managed well and appropriate environmental protection policies can be adopted, thereby contributing to sustainability and preventing environmental degradation(Agheli & Taghvaee, 2022). In developing countries (D-8), however, political stability in the short term can have a negative impact on carbon emissions as shown in table 8 because government priorities tend to focus on economic growth and industrialization which often depend on fossil energy. In an effort to accelerate development, environmental policies are often ignored or postponed, resulting in increased carbon emissions. Reliance on cheap, but highly polluting, technology and energy resources exacerbates this situation, making environmental protection a lower priority compared to the need for economic development.

Trade Openness affects Carbon Emissions (CO2)

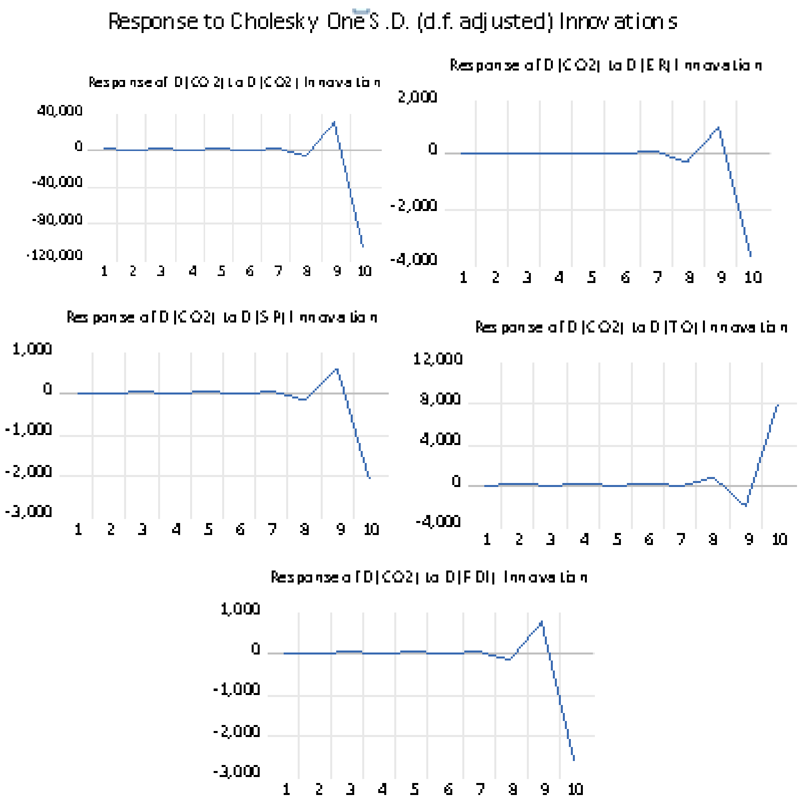
The long-term estimation results presented in Table 8 indicate that trade openness significantly impacts carbon emissions (CO2). Specifically, an increase in trade openness by 1% is associated with a rise in carbon emissions by 0.103077 in the long term within the D-8 region. This suggests that greater trade openness can lead to higher carbon emissions, as it facilitates the transfer of new, more environmentally friendly technologies through international trade (Ali et al., 2020). This finding aligns with previous research by Pata et al. (2023), Li & Haneklaus (2022), and Nasir & Ur Rehman (2011), which supports the notion that increased trade openness significantly boosts carbon emissions (CO2). The expansion of international trade and production capacity often exacerbates negative externalities in the import sector, leading to increased CO2 emissions. In developing countries (D-8), however, trade openness in the short term can have a negative impact on carbon emissions as shown in table 8 because trade openness does not directly contribute to carbon emissions. This means that any fluctuations in international trade reflect energy consumption directly, while energy consumption can stimulate trade openness in the long term.

Foreign Direct Investment affects Carbon Emissions (CO2)

The long-term estimation results in Table 8 reveal that Foreign Direct Investment (FDI) affects carbon emissions (CO2) in the D-8 region. Specifically, a 1% increase in FDI is associated with a rise in carbon emissions by 1.091123 in the long term. FDI can contribute to increased pollution through two main channels. First, foreign investment can boost national output, thereby raising pollution levels, which supports the Pollution Haven Hypothesis (PPH). Second, FDI can also facilitate pollution reduction by introducing more efficient production technologies (Lau et al., 2014). This finding is consistent with research by Rahaman et al. (2022), which shows that foreign investment can exacerbate environmental degradation. However, in the short term, FDI appears to have a mitigating effect on CO2 emissions in developing countries within the D-8 region, as indicated by Table 8.

Impulse Response

The next analysis focuses on impulse response, which aims to evaluate the impact of a shock to one variable on other variables. Through impulse response, a deeper understanding can be obtained regarding the extent of the impact of the shock and how quickly the variable in question reaches stability over time. The results of this analysis can be seen below:



Based on the processing results in the form of the graph above, it shows that shocks to carbon emissions (CO2) only have a temporary impact on themselves, that is, they only last for one period and disappear in the next period. This indicates that CO2 has no resistance to shocks in the past. Meanwhile, shocks to the exchange rate (ER) have a positive and significant impact on CO2 in the long term, with the effect becoming larger in the third and fourth periods before decreasing. Shocks to political stability (SP) and trade openness (TO) also have a negative impact on CO2, although they only last in the short term. Meanwhile, shocks to FDI have a relatively persistent positive impact up to the tenth period on CO2, both in the short and long term.

Variance Decomposition

Variance decomposition is to identify how much influence each variable has on the fluctuation of the dependent variable from time to time. This method helps explain the proportion of forecast error variance that is caused by surprises in other variables in the model. Thus, variance decomposition shows the dominance and contribution of independent variables to the dependent variable, both in the short and long term, thus helping to understand the dynamics between variables and formulate more appropriate policies. The results of the analysis can be seen below:

Table 9 Variance Decomposition CO2

Variance Decomposition of D(CO2):						
Period	S.E	D(CO2)	D(ER)	D(SP)	D(TO)	D(FDI)
1	2.188673	100,0000	0.000000	0.000000	0.000000	0.000000
2	2.541070	94.27418	0.485003	0.115273	4.109737	1.015802
3	15.24501	99.68965	0.062685	0.030452	0.188754	0.028458
4	51.16300	99.18846	0.118823	0.025410	0.588205	0.079099
5	164.4700	99.01051	0.151088	0.053060	0.704297	0.081045
6	656.8359	9934349	0.112264	0.036062	0.461335	0.046847
7	2307.841	99.18528	0.128323	0.039359	0.580958	0.066083
8	8355.684	99.21666	0.126551	0.040970	0.555247	0.060574
9	30632.29	99.23893	0.123405	0.038995	0.539749	0.058922
10	1104983	99.21610	0.125971	0.039904	0.556614	0.061410

Source: Eviews Processed

The next explanation in table 9 is the result of the variance decomposition of Carbon Emissions (CO2), showing a contribution of 2.18% in the first period. Furthermore, if you observe and understand in detail in periods 5 to 10, there are shocks that fluctuate over 10 periods in the long term.

Table 10 Variance Decomposition ER

Variance Decomposition of D(ER):						
Period	S.E	D(CO2)	D(ER)	D(SP)	D(TO)	D(FDI)
1	0.120249	5.195350	94.80465	0.000000	0.000000	0.000000
2	0.145758	9.021864	86.61443	0.643628	1.140943	2.579136
3	0.518788	91.22138	7.919121	0.057641	0.093742	0.708111
4	0.736231	92.38900	3.932892	0.206809	1.870880	1.600415
5	2.679668	98.61256	0.628051	0.099969	0.537778	0.121637
6	12.39533	99.49038	0.090453	0.023594	0.361684	0.033890
7	36.31319	98.84217	0.179292	0.053373	0.823402	0.101763
8	143.8019	99.32227	0.114221	0.040280	0.475126	0.048105

9	521.2210	99.23171	0.123392	0.037160	0.546800	0.060936
10	1851,487	99.19102	0.129003	0.041545	0.574632	0.063805

Source: Eviews Processed

Based on observations in table 10 of the variance decomposition of D(ER) section, it shows that the exchange rate itself experienced a major shock in the initial period of 94% and in the final period experienced a decrease of 0.12%. Meanwhile, the SP, TO and FDI variables have not contributed at all because they have a value of zero. In the 2nd period, ER in the previous period contributed 86.61% of the current exchange rate variable, political stability contributed 0.64%, trade openness 1.14%, and FDI 2.57%. Until the 10th period, SP, TO, and FDI each contributed 0.04%, 0.57%, and 0.06%.

Table 11 Variance Decomposition SP

Variance Decomposition of D(SP):						
Period	S.E	D(CO2)	D(ER)	D(SP)	D(TO)	D(FDI)
1	0.220113	22.98752	0.723993	76.28848	0.000000	0.000000
2	0.272355	24.31573	1.646673	73.09040	0.597175	0.350018
3	3.574975	99.47500	0.037094	0.481352	0.003633	0.002917
4	5.134970	96.05865	0.395645	0.355076	2.619752	0.570876
5	24.69340	99.52886	0.095133	0.040275	0.301933	0.033801
6	94.34581	99.33377	0.106731	0.028998	0.474869	0.055634
7	301.6631	99.01899	0.147589	0.047851	0.703147	0.082418
8	1174.521	99.30982	0.116646	0.038317	0.485190	0.050024
9	4203.222	99.21125	0.125608	0.038586	0.561548	0.063007
10	15127.86	99.20974	0.127102	0.040880	0.560690	0.061589

Source: Eviews Processed

The results of the VD analysis are in table 11. It can be seen that in the 1st period the political stability variable experienced a shock of 76%, the amount of trade openness and FDI did not contribute to the formation of political stability. The difference occurred in the 2nd period where TO contributed 0.59% and FDI 0.35%.

Table 12 Variance Decomposition TO

Variance Decomposition of D(TO):						
Period	S.E	D(CO2)	D(ER)	D(SP)	D(TO)	D(FDI)
1	5.561519	19.65059	4.933416	18.04169	57.37430	0.000000
2	6.185456	20.70282	7.946840	16.38792	54.25005	0.712369
3	14.80769	85.79205	1.419800	2.871895	9.711973	0.204278
4	40.74305	96.90680	0.425690	0.380886	2.237624	0.049001
5	125.4315	98.31703	0.144600	0.178485	1.206950	0.152931
6	517.9738	99.42263	0.106462	0.033539	0.385301	0.052069
7	1807.478	99.17173	0.126224	0.037961	0.597621	0.066468
8	6483.468	99.20092	0.129808	0.041664	0.566020	0.061592
9	23937.69	99.24714	0.122244	0.038965	0.533613	0.058041

10	86154.14	99.21377	0.126194	0.039829	0.558466	0.061738

Source: Eviews Processed

In table 12. regarding the VD analysis of the TO variable, it is known that in the 1st period CO2 contributed 19.65% to the formation of TO. Meanwhile TO itself showed a shock of 57.37% and decreased in the final period to 0.55%. Contributions between variables continue to occur until the 10th period.

Table 13 Variance Decomposition of FDI

Variance Decomposition of D(FDI):						
Period	S.E	D(CO2)	D(ER)	D(SP)	D(TO)	D(FDI)
1	0.720877	4.747560	10.96407	1.530707	46.19432	38.56335
2	0.846959	5.557909	22.13845	4.386736	33.46576	34.45115
3	6.752532	98.14667	0.355545	0.225365	0.730411	0.542006
4	20.72823	98.85880	0.117272	0.077146	0.797038	0.149743
5	75.19601	99.18558	0.122581	0.045752	0.566843	0.079240
6	281.5977	99.28978	0.115322	0.035370	0.495007	0.064522
7	1001,847	99.19907	0.126183	0.039347	0.570377	0.065026
8	3649.005	99.22834	0.124988	0.039809	0.546935	0.059930
9	13270.90	99.22780	0.124686	0.039404	0.547946	0.060164
10	48047.87	99.22077	0.125549	0.039855	0.553058	0.060768

Source: Eviews Processed

The results of the VD analysis are in table 13. It can be seen that in the 1st period the FDI variable contributed 38.56% and experienced a drastic decline in the 3rd period by 0.54%. Then in the following periods, it shows that there were fluctuating shocks until the 10th period.

CONCLUSION

This research succeeded in investigating the relationship between several macroeconomic factors, namely exchange rates, political stability, trade openness, and foreign direct investment (FDI) on carbon emissions in developing countries (D-8). The research uses the VECM analysis model with panel data over a 10 years period, namely 2013-2022. The findings of this research indicate the existence of a long-term cointegration relationship between variables. In general, it can be concluded that exchange rates, political stability, trade openness and FDI have a significant impact on carbon emissions in developing countries in the long term. However, in the short term this relationship was not proven to be significant. These findings provide an important contribution in understanding the factors that influence carbon emissions and their implications for efforts to control and reduce carbon emissions in developing countries. This research can also guide policymakers to better consider environmental aspects in economic and trade policies. Overall, this research succeeded in analyzing the relationships between variables empirically and concluded scientifically reliable results using appropriate methodology. It is hoped that these findings can contribute to the development of further knowledge about the factors causing carbon emissions.

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