Article

Examining the Correlation among Economic Development, Foreign Direct Investment, and CO_2 Emissions by Utilizing the VECM Model—Empirical Study in Vietnam

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Abstract: From 1990 to 2019, Vietnam entered a period of economic growth, attracting foreign investment. However, during this period, CO_2 emissions also increased significantly. This paper will examine the short- and long-term relations of Vietnam's relationship among FDI, economic growth, and CO_2 emissions based on the data on CO_2, GDP, and FDI of Vietnam in 1990–2019. This article uses the VECM model to test the effect among variables. Research results identify an impact and causal correlation among CO_2 emissions and economic growth and foreign direct investment in Vietnam. Research results show a long-term relationship between CO_2 emissions, GDP, and FDI. The authors did not find a short-run relationship between the above variables. Assessing impacts of CO_2 emissions on economic growth and foreign direct investment will help policymakers make reasonable policies to balance the increase in foreign investment capital and economic growth and reduce CO_2 to achieve the commitment in COP26.

Keywords: economic growth; foreign direct investment; CO_2 emission; VECM model; long-term impact

1. Introduction

Recent years have seen an increase in the number of academics interested in the relationship among economic activity and CO_2 emissions. In some developing countries, with technological progress, adaptation to climate change has increased carbon emissions. Rapid economic growth and climate change also make it difficult for many economies to comply with the recommendations of the United Nations. The primary objective of the Intergovernmental Climate Agreement (IPCC) is to constantly control the number of greenhouse gases at a concentration that prevents harmful anthropogenic effects on the climate system in the atmosphere. Reducing CO_2 emissions also needs to be done within a time that will allow habitats to adjust to climate change naturally, protect food security, and support sustainable economic growth. Anthropogenic and biogeographical variables are the main sources of climate change. The amount of greenhouse gas emissions will cause the ozone layer to thin, solar thermal radiation to rise, and the earth's surface to absorb more heat [1]. Carbon Dioxide (CO_2) emissions also include some form of greenhouse gas and thus the environmental consequences of human activities.

In Vietnam, rapid economic development has substantially impacted the environment over the past few decades. Vietnam still exhibits a clear lack of understanding regarding environmental sustainability. Therefore, the promotion of GDP growth and the maintenance of FDI flows must be balanced to maintain the carbon emission toward sustainable development. In the COP26, Vietnam has a strong commitment to reducing the CO_2 Emissions to zero in 2050 [2]. Vietnam's implementation of commitments at COP26, especially the commitment to bring net emissions to "zero" by the middle of the century, is an inevitable and irreversible trend. Therefore, the timely implementation of these commitments will

bring great and long-term benefits to Vietnam. FDI of Vietnam poured into 18 industries, with manufacturing and processing leading the way with US$6.98 billion in total investment capital, or 45.7% of all investment capital. This was followed by the production of energy, which accounted for 35% of the total, and then by the real estate, scientific and technological pursuits, as well as wholesale and retail trade.

One question about the social environment is whether gross domestic income and FDI impact CO_2 emissions in Vietnam and whether the relationship among FDI, CO_2, and GDP is a causal one. Many studies suggest that gross domestic product (GDP) and foreign direct investment (FDI) influence the increase in a country's carbon emissions in the context of economic development. In China, research by Ren et al. [3] has shown that excessive trade surplus and foreign direct investment (FDI) are the basic causes of the rapid increase in CO_2 emissions. In Tunisia and Morocco, Hakimi and Hamdi [4] noticed that the cause for the rise in CO_2 emissions was a lack of green FDI inflows. Zubair et al. [5] recognized the same case for many developing nations.

This paper will conduct an empirical study in Vietnam to test the short-term and long-term causal correlation among FDI, CO_2 emission, and GDP from 1990 to 2019. Indicators from the World Bank suggest that, in 2019, the CO_2 emission intensity in Vietnam in 1990 was 0.315 (tons), but, by 2019, this figure has been 2714 (tons). Is the increase in emissions accompanied by an increase in economic development and FDI in Vietnam? From 1990 to 2019, the total amount of FDI investment in Vietnam always had a steady growth rate every year. In addition, the economic growth rate also increased significantly. However, just looking at the numbers, it is difficult to predict the interactions and trends among FDI, GDP, and CO_2 in the present and the future. Therefore, this study will use the VECM model to verify the short and long-term impact relationship and causal connection among the three variables FDI, GDP, and CO_2 in the period 1990–2019. The VECM model is also relatively suitable for this study as it considers both the presence of homogeneity among variables and the presence of a cointegration relationship.

2. Literature Review

Numerous papers have examined the connection among CO_2 emissions and GDP. Bello et al. [6] suggested that the link among CO_2 and economic prosperity is U-shaped inverted. However, the positive correlation among economic growth and CO_2 emissions will diminish after the economy reaches a certain stage of development. This can reasonably assess because, when the income level increases, the standard of living increases, leading to a higher demand for environmental quality.

The linkages among countries in terms of economic activity and trade have spurred studies investigating hypotheses about pollution and economic growth as well as trade integration. The research of Grossman and Krugger was the initial investigation into how the Carbon Index affected economic growth [7]. The two authors argued that reducing trade barriers and the expansion of economic activities will affect the environment. This study also provides empirical evidence to assess the relative extent of these three effects by applying the process of trade liberalization in Mexico. Naranpanawa [8] used the ARDL model and Johansen cointegration technique to investigate the long-term relationship among economic development and the trade environment. The findings of this study indicate that commerce and CO_2 emissions only have a temporary link. Keho [9] also used the ARDL model to analyze the long-term effects of the environmental impact of global trade in 11 ECOWAS countries between 1970 and 2010 and came to the conclusion that global trade causes environmental degradation. Rahman and Kashem [10] used Toda and Yamamoto's causal model to investigate the connections carbon emissions, energy use, and economic growth in Bangladesh between the 1970s and 2010s. Most of these studies show a long-term association and a pivotal correlation among the variables. In addition, studies also show a positive correlation among GDP growth and the increase in CO_2 during the study period. Esso and Keho [11] have shown causal and long-term relationships among energy usage, CO_2 emissions, and economic development in various African nations.

Balsalobre-Lorente, lvarez-Herranz, and Shahbaz [12] employed the Kuznets curve to evaluate the association among GDP and CO_2 emissions in a set of 16 OECD member countries among 1995 and 2016. The study discovered that, as economies deal with institutional mismatches in the energy development process, environmental sustainability is hampered. The authors proved the Kuznets curve hypothesis and showed that widespread economic growth and the usage of renewable energy decreased environmental pollution between 1990 and 2012 in 17 OECD nations. Sarkodie [13] used a sample of some developing countries and showed a marked decline in energy intensity as FDI increased. The above deterioration can be attributed to the use of modern technologies accompanied by FDI, i.e., a leap forward from the outdated traditional technologies being used in other countries, thereby reducing emissions that pollute the environment.

Numerous studies have also looked into the relation among FDI, capital flows, and environmental damage in various nations or economic blocs. Frankel and Romer [14] has discovered that financial development and deregulation may draw FDI, stimulate the economy, and thus improve environmental performance dynamics. In the UAE, Shahbaz [15] applied the ARDL paradigm for integration to examine the long-term connections among FDI, renewable energy, trade in natural resources, carbon emissions, and GDP in the UAE from 1975 to 2011. The authors affirm that, over time, these variables would have a link. They discovered that trade integration and foreign direct investment both lower greenhouse gas emissions. Economic expansion has a favorable impact on energy use.

Hakimi and Hamdi [4] explored the correlation among trade openness, FDI flows, environmental quality, and GDP in Morocco and Tunisia using the VECM model and cointegration methods. This study argued that both economies have benefited from trade liberalization, which frequently affects CO_2. Michieka [16] examined the effects of energy depletion, trade, and financial improvement on China's economic growth. The findings indicate that, while economic and commercial development has a considerable impact on pollution, it also has long-term implications on CO_2.

Research by Ren et al. has shown that excessive trade surplus along with foreign direct investment (FDI) inflows are the basic causes for the rapid increase in CO_2 emissions in China.

Michieka, Fletcher, and Burnett [16] used a sample of about 20 developing countries and showed a marked decline in energy intensity as foreign direct investment increased. The reason for the above decline can be attributed to the use of modern technologies accompanied by foreign direct investment, i.e., a leap forward from the outdated traditional technologies being used in other countries, thereby reducing emissions that pollute the environment.

Soytas and Sari [17] used a error correction vector model (VECM) to evaluate the relationship between energy consumption and manufacturing sectors in Turkey. The research results show a positive relationship between the variables in the model. In addition, the variables in the model also show a cause-and-effect relationship. In 2009, the two authors conducted another study on the relationship between economic growth, energy consumption, and CO_2 emissions by the linear regression method. The research results also show the co-integration relationship between the parameter variables. In addition, the study also found no long-term association between CO_2 emissions and economic growth. Therefore, the study has come to the conclusion that it is possible to reduce CO_2 emissions without slowing economic growth. The study of Ozturk and Acaravcı [18] also had similar results based on the ARDL model and causality with real data in Turkey. The author used variables including energy, employment rate, and emissions. The results show the opposite of the Kunetz curve.

The study by Begum et al. [19] showed that experimental results from the limited test method ARDL showed that, during the period 1970–1980 in Malaysia, emissions per capita decreased as GDP per capita increased. However, from 1980 to 2009, the amount of CO_2 emissions per capita increased sharply, leading to an increase in GDP per capita. The study came to the conclusion that the EKD hypothesis was not valid in Malaysia during

the study period. The results also show that energy consumption and GDP per capita have a long-term positive relationship with carbon emissions per capita. The study also shows that, in the long term, economic growth can have a negative impact on CO_2 emissions. Therefore, the transition to high-tech machinery and equipment with low emissions and the use of alternative energies will contribute to reducing emissions while maintaining economic growth. Table 1 summarizes the basic research findings, methods and author in relationship between the CO_2 and other variables.

Table 1. Summary of the findings.

Author(s)	Method	Findings
Bello et al. [6]	VECM model	the link among CO_2 and economic prosperity is U-shaped inverted
Grossman and Krugger [7]	linear regression model	reducing trade barriers and the expansion of economic activities will affect the environment
Naranpanawa [8]	ARDL model and Johansen cointegration	Trade and CO_2 emissions only have a temporary relationship
Keho [9]	ARDL model	global trade causes environmental degradation
Rahman & Kashem [10]	Toda and Yamamoto's causal model	long-term association and a pivotal correlation among the variables
Esso and Keho [11]	Causal model	causal and long-term association relationships among energy usage, CO_2 emissions, and economic development in various African nations.
Balsalobre-Lorente [12]	EKC model	economies deal with institutional mismatches in the energy development process, and environmental sustainability is hampered.
Sarkodie [13]	Kuznets curve hypothesis	energy intensity as FDI increased
Frankel & Romer [14]	Regresion model	financial development and deregulation may draw FDI, stimulate the economy, and thus improve environmental performance dynamics
Shahbaz [15]	ARDL model	trade integration and foreign direct investment both lower greenhouse gas emissions and economic expansion has a favorable impact on energy use
Hakimi and Hamdi [4]	VECM model	while both economies have benefited from trade liberalization, which frequently affects CO_2
Michieka [16]	Granger Causality	economic and commercial development has a considerable impact on pollution; it also has long-term implications on CO_2
Soytas and Sari [17]	VECM model	a positive relationship between the variables (CO_2 emissions and economic growth)
Begum et al. [19]	ARDL model	long term, economic growth can have a negative impact on CO_2 emissions

The correlation among foreign direct investment, economic expansion, economic integration, and CO_2 emissions has been examined in numerous empirical research. However, the research results have differences among countries regarding short-term and long-term effects, cointegration relationships, and negative and positive effects of the relationship

among factors. Because of the different results among countries, the author wants to conduct an empirical study to evaluate the correlation among GDP growth rate, CO_2 emissions, and FDI in Vietnam. The empirical results can help policymakers balance reducing CO_2 emissions while increasing FDI attraction and achieving economic growth in the future.

3. Data and Methods Research

3.1. Data

This study is constructed on statistical data from the General Statistics Office of Vietnam and the World Bank (Worldbank) from 1991 to 2019. The extracted data include GDP economic growth rate, the percentage of FDI in GDP in Vietnam, and CO_2 emissions from 1991 to 2019. This study will structure three variables including: economic growth (GDP), Foreign Direct Investment (FDI), and CO_2 emissions (CO_2). To correct for the skewed variance in the data and the strong data variability, the values in each of the three variables were converted to logarithmic.

Figure 1 shows that the share of FDI in the period 1990–2020 has increased unevenly and peaked in two periods, in 1993 and 2008, GDP growth has less volatility and only emissions. CO_2 has a steady increase every year.
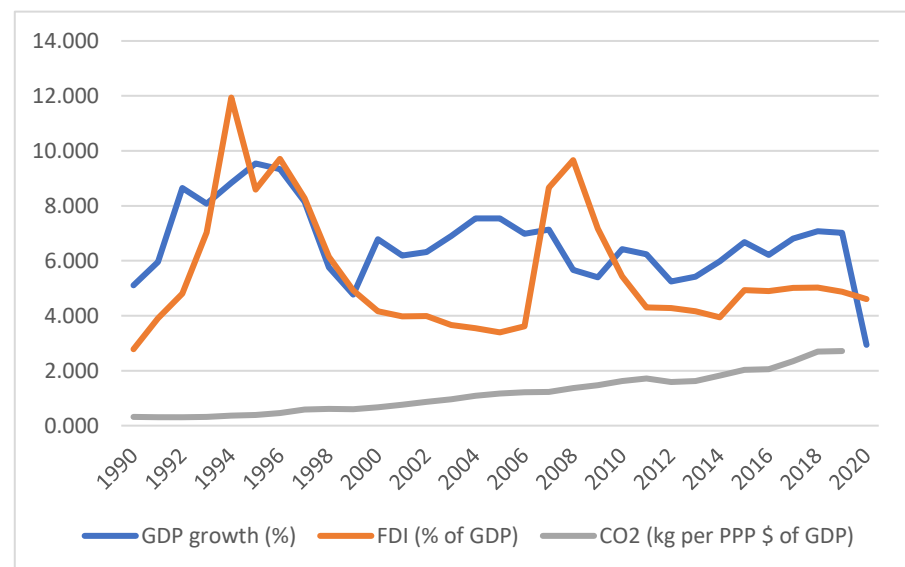

Figure 1. GDP, FDI, and CO_2 growth rates in the period 1990–2020 in Vietnam.

3.2. Research Method

The article will use the VECM model using the OLS method with no constraints. Suppose we have a VAR(p) model:

$$Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + \ldots + A_p Y_{t-p} + u_t$$

The model can be rewritten as follows:

$$Y_t - Y_{t-1} = (A_1 + A_2 + \ldots + A_{p-1})Y_{t-1} - (A_2 + \ldots + A_p)(Y_{t-1} - Y_{t-2}) - (A_3 + \ldots + A_p)(Y_{t-2} - Y_{t-3}) - \ldots - A_p(Y_{t-p+1} - Y_{t-p}) + u_t$$

$$\Delta Y_t = \Pi Y_{t-1} + C_1 \Delta Y_{t-1} + C_2 \Delta Y_{t-2} + \ldots + C_{p-1} \Delta Y_{t-p+1} + u_t$$

in that: $\Pi = -(I - A_1 - A_2 - \ldots A_p)$

$$C_i = -\sum_{j=i+1}^{p} A_j, \ i = 1, 2, \ldots, p-1$$

The model contains the terms ΠY_{t-1}, and this is the error correction part.

Granger also shows that, if the rank of the matrix Π, r(Π) = r < k, then there will be two matrices of order α (level mxr và β (level r × m) so that Π = α β′ and β′Yt is I(0); r is the number of cointegrated relations, and each column of β is a co-integration vector; α is the matrix of correction parameters [20]:

$$C(L)\Delta Y_t = \alpha\beta'Y_{t-1} + d(L)U_t$$

$$C(L) = 1 - C_1L - C_2L_2 + \ldots + C_{p-1}L_{p-1}$$

$$d(L) = 1 + \theta_1L + \theta_2L_2 + \ldots$$

The variance decomposition model to test the impact between three variables of economic growth (GDP), foreign direct investment (FDI), and CO_2 emissions (CO_2) is re-constituted into the following equation:

$$\Delta LNGDP_t = \alpha + \sum_{i-1}^{k} \beta_i \Delta LNGDPi_{t-1} + \sum_{j-1}^{k} \varphi_j \Delta LNFDI_{t-j} + \sum_{m-1}^{k} \varphi_m \Delta LNCO_{2t-m} + \lambda ECT_{m-1} + u1_t$$

4. Research Results and Discussion

4.1. Necessary Tests for Model Stability

4.1.1. Unit Root Test

Table 2 performs some logarithimic table statistics. Skewness measures the asymmetry of the probability distribution around the mean. In the normal distribution, the skewness is equal to the two-sided probability distribution, which is equally symmetric.

Table 2. The descriptive statistics on the data.

	LNCO$_2$	**LNFDI**	**LNGDP**
Mean	−0.053897	8.023565	1.900032
Median	0.122018	7.743200	1.907034
Maximum	0.998424	9.687816	2.255544
Minimum	−1.184170	5.192957	1.563098
Std. Dev.	0.703735	1.198403	0.179098
Skewness	−0.274324	−0.362152	0.221082
Kurtosis	1.807683	2.347846	2.411738
Jarque–Bera	2.153295	1.187400	0.676951
Probability	0.340736	0.552280	0.712856
Sum	−1.616924	240.7069	57.00095
Sum Sq. Dev.	14.36205	41.64891	0.930209
Observations	30	30	30

Kurtosis is a measure of kurtosis or a probability distribution. The kurtosis of a normal distribution is around 3.

The stationarity of the data must be examined when analyzing time series. The stationarity test will avoid the situation of the pseudo-regression series [21]. However, if a linear combination among nonstationary series is stationary, then the regression is an actual regression, and those nonstationary time series are cointegrated. In other words, if the residual in the model among nonstationary time series is stationary, then the regression result is accurate and represents a long-run equilibrium correlation among the variables [22].

Table 3 shows that all three variables GDP, FDI, and CO_2 are nonstationary variables. However, when taking the 1st difference, all the above variables are stationary. The variables in the model all stop at the first difference, which is a necessary condition for the VAR model and the VECM model.

Table 3. Stationarity test of data series.

Variables	ADF Test	t-Statistic	*p*-Value	Difference
$LNCO_2$	−4.808585	−3.699871 −2.976263 −2.627420	0.0007	1
LNFDI	−3.997124	−3.689194 −2.971853 −2.625121	0.0048	1
LNGDP	−4.828096	−3.689194 −2.971853 −2.625121	0.0006	1

4.1.2. Establish the Model's Ideal Lag

Selecting the proper lag for the model is crucial in the VAR model (Table 4).

Table 4. Lag test for the model.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	−28.62203	NA	0.002286	2.432464	2.577629	2.474266
1	58.42389	147.3085 *	5.69×10^{-6}	−3.571068	−2.990409 *	−3.403859 *
2	67.94212	13.91127	5.65×10^{-6} *	−3.610933 *	−2.594778	−3.318317
3	73.38958	6.704561	8.08×10^{-6}	−3.337660	−1.886010	−2.919637
4	85.89314	12.50356	7.32×10^{-6}	−3.607165	−1.720020	−3.063735

Source: Data processing results on Eviews. The * represents the suggested lag of each criterion.

The SC and HQ standards give a lag of 1, FPE and AIC give a lag of 2, and LR gives a lag of 1 (Table 4). Using the 1st lag can lead to an ordering of correlation in the residuals, and the model cannot be generalized satisfactorily. Using too many lag orders in the model can lead to many pushbacks, with strong time oscillations because it may not satisfy the stability conditions for the VAR model. Therefore, the author considers the optimal lag 2 to be appropriate according to the AIC criteria. In addition, lag two also satisfies the necessary conditions better.

4.1.3. Check Model Stability

The estimated model is stable since all of the root values are contained within the unit circle (Figure 2).

4.2. *Estimating the VAR Model*

With lag 2, we have the following VAR model results (Table 5):

Table 5. VAR model estimation results.

	$LNCO_2$	LNFDI	LNGDP
$LNCO_2(-1)$	1.138612 (0.24183) [4.70822]	−2.307572 (0.75764) [−3.04576]	−0.235031 (0.47326) [−0.49662]
$LNCO_2(-2)$	−0.209612 (0.24386) [−0.85956]	2.732359 (0.76398) [3.57649]	0.174816 (0.47722) [0.36632]
$LNFDI(-1)$	0.022396 (0.05253) [0.42635]	0.898591 (0.16457) [5.46029]	0.052043 (0.10280) [0.50626]

Table 5. *Cont.*

	LNCO$_2$	LNFDI	LNGDP
LNFDI(−2)	0.014091	−0.127110	−0.065437
	(0.04976)	(0.15588)	(0.09737)
	[0.28320]	[−0.81542]	[−0.67203]
LNGDP(−1)	0.056832	1.060253	0.656848
	(0.11696)	(0.36641)	(0.22888)
	[0.48592]	[2.89366]	[2.86988]
LNGDP(−2)	−0.055242	0.073040	−0.279153
	(0.09818)	(0.30759)	(0.19214)
	[−0.56265]	[0.23746]	[−1.45288]
C	−0.238008	0.027454	1.297790
	(0.27119)	(0.84962)	(0.53072)
	[−0.87763]	[0.03231]	[2.44536]
R-squared	0.991629	0.966050	0.551697
Adj. R-squared	0.989237	0.956350	0.423610
Sum sq. resids	0.098154	0.963366	0.375898
S.E. equation	0.068367	0.214184	0.133790
F-statistic	414.5955	99.59281	4.307215
Log likelihood	39.41759	7.443088	20.61872
Akaike AIC	−2.315542	−0.031649	−0.972766
Schwarz SC	−1.982491	0.301402	−0.639715
Mean dependent	0.025337	8.199519	1.913797
S.D. dependent	0.658987	1.025165	0.176225
Determinant resid covariance (dof adj.)	3.17×10^{-6}		
Determinant resid covariance	1.34×10^{-6}		
Log likelihood	70.17603		
Akaike information criterion	−3.512573		
Schwarz criterion	−2.513420		

Source: Data processing results on Eviews.

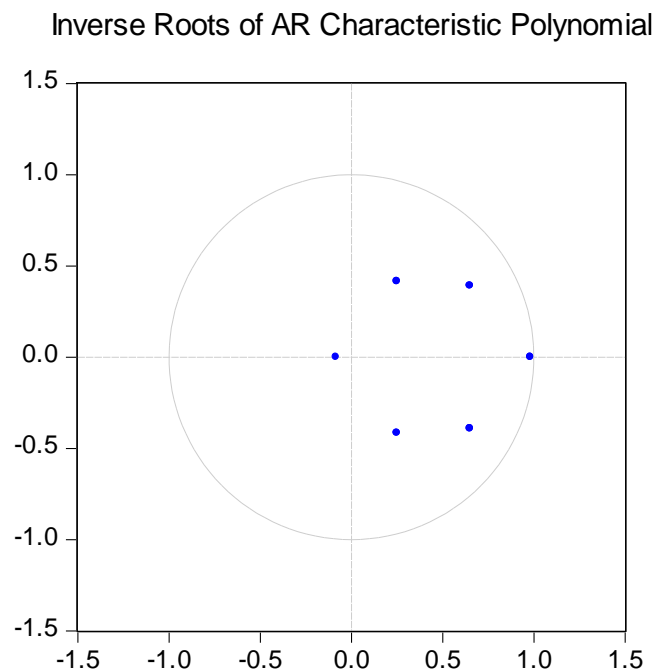Inverse Roots of AR Characteristic Polynomial

Figure 2. AR unit graph. Source: Data processing results on Eviews.

The outcomes of the VAR model suggest that an increase in intensity in FDI capital and GDP growth rate has an impact on increasing CO$_2$ emissions. Conversely, an increase in CO$_2$ also has an impact on increasing FDI and GDP.

If FDI increases by one unit, then at a 1-year lag with other variables constant, CO_2 will increase by 2.2%. At a 2-year lag, an increase in FDI by one unit can increase CO_2 by about 1.4%. With all other variables constant, an increase in GDP by one unit will increase CO_2 by about 5%.

On the other hand, if one unit of CO_2 emissions increases at a lag of 2 years, with all other variables unchanged, the amount of FDI will increase by 27.3%, and GDP will increase by 17.4%. Thus, with a lag of 2 years, it can be concluded that there is evidence of a relationship among GDP and CO_2 emissions and FDI.

Our results are also coherent with the study by Ozturk and Acaravcı [23], reporting that increasing trade results in rising CO_2 emissions. Seker et al. [24] for Turkey reported that FDI has a long-term positive correlation with CO_2 emissions per capita, comparable to [25], who discovered the negative effect of increased FDI on Turkey's clean energy consumption. Our study demonstrates that FDI inflows have a favorable impact on CO_2, increasing emissions by 2.2%. According to an International Energy Agency report (IEA), CO_2 emissions had a sharp increase in the period from 2017–2019, the highest growth rate since 2013, for which the electricity generation sector accounts for two-thirds of total CO_2 emissions [26]. The cause for this sharp increase is that many developing countries produce coal power. China is the largest emitter in Asia, accounting for 30% of total emissions.

Analysis of the Impulse Response Function

The push–response function tests the responses of variables to unexpected shocks. The Cholesky analytical method was used with a reaction time of 10 years. The response function results (Figure 3) are analyzed as follows:
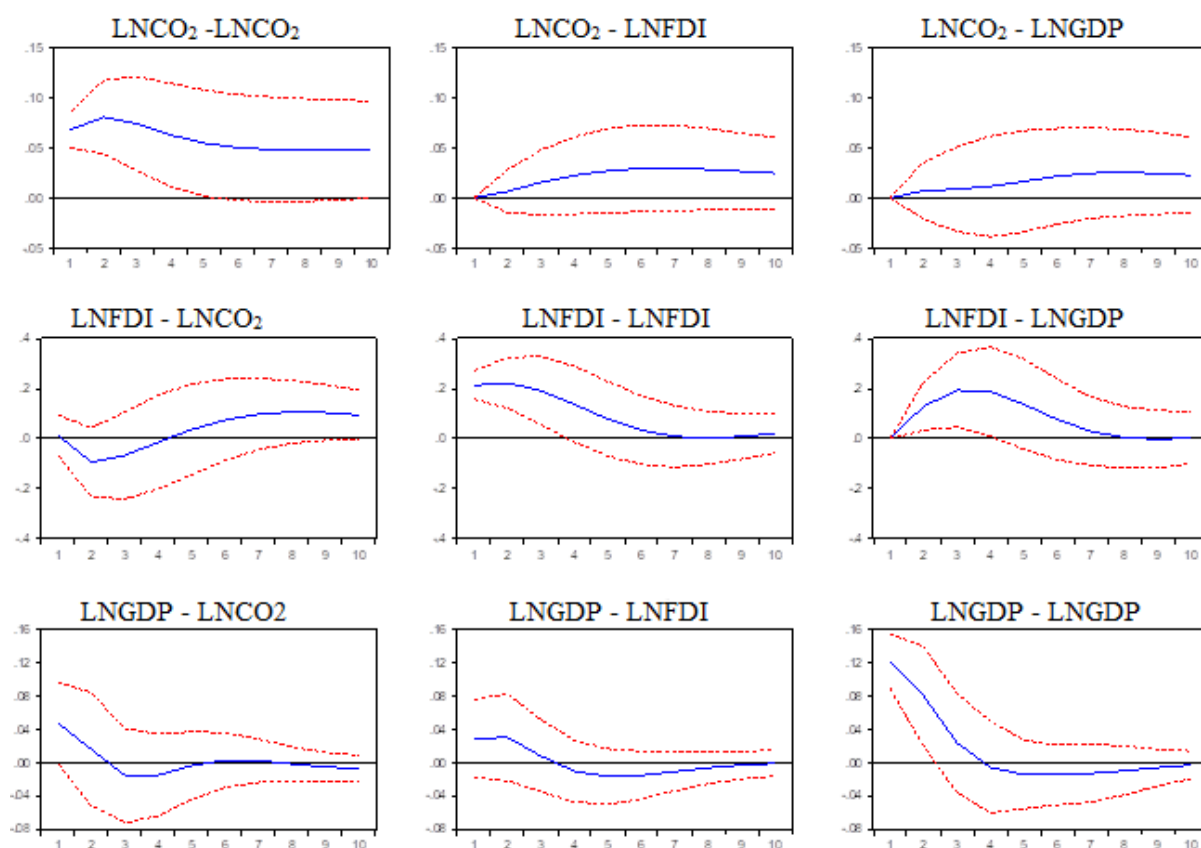

Figure 3. Results of the variable-to-variable impulse response function (In graph, if two red lines touch each other at position 0 (black line), then the independent variable has no effect on the dependent variable. The black line is above the two red lines, then the independent variable has a negative influence on the dependent variable).

Firstly, the impact of CO_2 emissions affects increasing FDI in the long run, with the increase starting in year 3, then decreasing gradually from years 9 and 10.

Second, regarding the impact of FDI on CO_2 emissions, an increase in FDI reduces CO_2 in year 2 and increases CO_2 emissions from year 3 to year 10.

Third, the impact of GDP growth reduces CO_2 emissions from year 1 to year 3. However, CO_2 emissions start to increase again from years 4 and 5 to year 3.

Attracting foreign direct investment associated with sustainable development has become one of the important goals in Vietnam's economic development strategy in recent years. However, besides positive contributions, many FDI projects also have negative impacts on the natural environment. Vietnam has emerged as a potential location for foreign investors due to political stability, an abundance of human resources, and low labor costs since the country's transformation from a centrally planned economy to a model of a market economy that is socialist-oriented, managed, and regulated by the State. However, market opening and economic development increase emissions and contribute to more severe climate change. Therefore, attracting FDI and economic growth must be carefully calculated to avoid damage to the environment and increase emissions.

4.3. Cointegration Test

The trace test shows that there is a co-integration relationship at a 5% significance level. Check with a reasonable ratio:

H0: there are r co-integration relations;
H1: there is r + 1 co-integration relation:

$$\text{Test statistics}: \text{LRmax}(r\,|\,r+1) = -\text{nln}(1 - \lambda r + 1)$$
$$= \text{LRtr}((r + 1\,|\,k) - \text{LRtr}(r\,|\,k)$$

For r = 2, LRmax = 1.008, the 5% critical value equals 3.84, so H1 is accepted. Both tests lead to the conclusion that there are no co-integrated relations (Tables 6 and 7). Based on the conclusion that there is not a co-integration relation, we estimate the error correction model with no co-integrated relation.

Table 6. Trace statistic test. * denotes rejection of the hypothesis at the 0.05 level; ** MacKinnon-Haug-Michelis (1999) *p*-values.

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob. **
None *	0.535530	29.89488	29.89707	0.0487
At most 1	0.232640	8.422855	15.59471	0.4213
At most 2	0.035376	1.008482	3.842466	0.3153

Table 7. Max-Eigen statistic test. * denotes rejection of the hypothesis at the 0.05 level; ** MacKinnon-Haug-Michelis (1999) *p*-values.

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob. **
None *	0.535530	21.47203	21.23162	0.0448
At most 1	0.232640	7.414373	14.36460	0.4413
At most 2	0.035376	1.008482	3.842466	0.3153

The same results with the test of Max-Eigen (Table 7).

The rational function ratio test shows no cointegration relationship at the 5% level of significance. We will estimate the error correction model with two co-integrated relations after determining the number of co-integration relations r = 2 with a 5% significance level. LnGDP is indicated as the independent variable of the model, and signs suggest a long-run correlation.

In the long run, $LNCO_2$ has a co-integrated relationship among GDP, CO_2, and FDI variables. Thus, the hypothesis that there is no co-integration relationship among the variables is rejected. We accept the hypothesis of at least one co-integration relationship among the variables.

The results of the causality test also show that there is a causal relationship among GDP economic growth and CO_2 emissions. Thus, economic growth has the effect of increasing emissions. This finding shows that the government needs to come up with policies to balance emissions reduction and economic growth. At the same time, it is necessary to focus on economic development for people, instead of GDP growth that at all costs can lead to environmental damage.

4.4. Estimating VECM Model by the OLS Method

4.4.1. The Result of the VECM Model

The test results show that there are no cointegration relationships among the three variables. In the long run, for the FDI variable, one unit change in FDI will increase 8.5% of GDP. For the CO_2 variable, a one unit change in CO_2 would result in a 2.2% decrease in GDP (Table 8).

The OLS model that evaluates the long-run effects among variables will have the following form:

$$ETCt-1 = [1.000lnGDPt-1 - 0.085lnFDIt-1 + 0.22lnCO_2t-1 - 1.204]$$

In addition, the OLS model evaluates the short-term impact among variables in the form of a regression equation as follows:

$$\Delta lnGDPt = -0.587ETCt-1 + 0.328\Delta lnGDPt-1 + 0.40\Delta lnFDIt-1 - 0.298\Delta lnCO_2t-1 + 0.018$$

4.4.2. Testing the Long-Term Relationship

In this model, the lambda values of GDP are C1, FDI is C6, and CO_2 is C11. For the GDP variable, C(1) has a negative sign, which is a good sign, it tells us the convergence in the long run, and the T statistic is -2.6 with a *p*-value of 0.01, with a significance level of 0.05; then, we can reject the null hypothesis of causality, and thus there is a long-term causality at a 5% significance level. Thus, at the 5% level of significance, GDP has a long-term correlation with FDI and CO_2. The results are similar to Jalil and Feridun [27] when they analyze the effects of CO_2 emissions on China's economic growth, energy consumption, trade, and financial development from 1953 to 2006.

C(6) has a positive sign of the correction factor, which is not a good sign. However, with a T-statistic of 3.29 and a *p*-value of 0.0016 at the 0.05 level of significance, we can rule out the null hypothesis that FDI and the other two variables do not have any long-term causal relationships and accept the hypothesis of H1 (there was a long-term relationship among variables). There is a cause-and-effect relationship in the long run at the 5% significance level. C(11) also carries a negative adjustment; however, the *p*-value of 0.94 is greater than the 5% significance level. We cannot reject the hypothesis that there is no long-term causal correlation among CO_2 and the remaining variables with the above value (Table 9).

As a result, the correlation among FDI inflows and GDP growth rate is positive and causal, suggesting that an increase in FDI capital boosts GDP growth rate and improves the environment for attracting and retaining FDI into Vietnam. The positive causal correlation between CO_2 emissions and FDI inflows shows that the shift of industrial production chains from developed countries has led to an increase in the environmental pollution in Vietnam as well as in many other developing countries in Asia.

4.4.3. Testing the Short-Term Cointegration Relationship

To evaluate the short-term relations among the variables in the model, the author uses the technique of extracting *p*-values. The table below is the result of the extraction of *p*-values.

Table 8. The results of VECM estimation by the OLS method.

Cointegrating Eq:	CointEq1		
LNGDP(−1)	1.000000		
LNFDI(−1)	−0.085749		
	(0.04744)		
	[−1.80755]		
LNCO$_2$(−1)	0.220420		
	(0.07657)		
	[2.87863]		
C	−1.204893		
Error Correction:	**D(LNGDP)**	**D(LNFDI)**	**D(LNCO$_2$)**
CointEq1	−0.587998	1.193888	−0.008704
	(0.22357)	(0.36235)	(0.11633)
	[−2.63007]	[3.29482]	[−0.07482]
D(LNGDP(−1))	0.327752	0.017433	0.034934
	(0.18704)	(0.30316)	(0.09733)
	[1.75227]	[0.05751]	[0.35893]
D(LNFDI(−1))	0.040200	0.065615	0.014383
	(0.09017)	(0.14615)	(0.04692)
	[0.44581]	[0.44895]	[0.30654]
D(LNCO$_2$(−1))	−0.297987	−2.960779	0.259997
	(0.46422)	(0.75240)	(0.24155)
	[−0.64190]	[−3.93510]	[1.07636]
C	0.018460	0.350787	0.054843
	(0.04954)	(0.08030)	(0.02578)
	[0.37262]	[4.36868]	[2.12750]
R-squared	0.366006	0.518727	0.072547
Adj. R-squared	0.255746	0.435028	−0.088749
Sum sq. resids	0.405934	1.066354	0.109907
S.E. equation	0.132851	0.215321	0.069127
F-statistic	3.319483	6.197489	0.449778
Log likelihood	19.54250	6.021154	37.83428
Akaike AIC	−1.038750	−0.072940	−2.345306
Schwarz SC	−0.800857	0.164954	−2.107412
Mean dependent	0.005828	0.134298	0.077486
S.D. dependent	0.153994	0.286466	0.066250
Determinant resid covariance (dof adj.)	3.26×10^{-6}		
Determinant resid covariance	1.80×10^{-6}		
Log likelihood	65.96460		
Akaike information criterion	−3.426043		
Schwarz criterion	−2.569626		

Table 9. Extract the *p*-values in the model.

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	−0.587998	0.223567	−2.630068	0.0105
C(6)	1.193888	0.362353	3.294820	0.0016
C(11)	−0.008704	0.116331	−0.074820	0.9406
Determinant residual covariance	1.80×10^{-6}			

The short-term causality among GDP, FDI, and CO$_2$ is shown through two coefficients C(3) and C(4). Both coefficients have *p*-values greater than a 10% significance level, so that there is no short-term positive correlation between GDP and FDI and CO$_2$. The short-term causality among FDI and GDP and CO$_2$ is shown in C(7) and C(9). C(7) has a value of 0.95, more significant than the 10% significance level. There is no short-term causal relationship among FDI and GDP. The coefficient C(9) has a value of 0.0002, which is less than the 5%

significance level, so it can be seen that there is a short-term causal correlation between the variable FDI and CO_2 at the 5% significance level. The short-term causalities between CO_2 and FDI and GDP are C(13) and C(12), respectively. Both coefficients C(13) and C(12) have values of 0.7601 and 0.7207, respectively, greater than the 10% significance level, so it can be concluded that there is no causal relationship among CO_2 and FDI and GDP (Table 10). Thus, in the short run, there is no causal relationship among the variables in the model. However, according to the impulse response, from the 3rd, and 4th year onwards, i.e., in the long run, the variables FDI and GDP have a significant influence on CO_2 emissions. These findings are also consistent with the experimental results of Akbostanci [28] examining data for the period 1968–2003 and 1992–2001 in Turkey or the findings Fodha and Zaghdoud [29] in Tunisia.

Table 10. Extract the *p*-values in the model.

	Coefficient	Std. Error	t-Statistic	Prob.
C(3)	0.040200	0.090173	0.445813	0.6571
C(4)	−0.297987	0.464224	−0.641903	0.5231
C(7)	0.017433	0.303157	0.057506	0.9543
C(9)	−2.960779	0.752403	−3.935098	0.0002
C(12)	0.034934	0.097326	0.358935	0.7207
C(13)	0.014383	0.046920	0.306545	0.7601
Determinant residual covariance	1.80×10^{-6}			

5. Conclusions and Policy Recommendations

Many developed and developing economies, particularly developing nations like Vietnam, are still engaged in a discussion about how FDI and economic expansion affect carbon emissions. In international trade, production is heavily concentrated in developing countries, and consumption occurs in developed countries. Therefore, the increase in CO_2 emissions in developing countries can be considered as a transfer from developed countries due to strategies of outsourcing or linking production in production lines. International trade has displaced many highly polluting industries from some developed countries to developing countries. The increase in FDI can be offset by high energy consumption and polluting sectors. The process of industrialization is increasingly strong, and the demand for product consumption is increasing. Therefore, the continuous increase in product production leads to high energy consumption and contributes to an increase in CO_2 emissions.

This paper uses the VAR and VECM models to evaluate the relationship between FDI, GDP, and CO_2 in Vietnam in the long term and the short term. The VAR model and VECM are built stably and with a delay that is consistent with reality. Testing the VAR model shows that CO_2 emissions impact the total amount of FDI invested in Vietnam and economic growth and vice versa. The impact of foreign direct investment on CO_2 emissions is negative, meaning that an increase in FDI and economic growth by one unit will increase CO_2 emissions by 4.2 and 4.8%, respectively. In addition, the amount of CO_2 also impacts the amount of FDI investment and GDP economic growth with an impact ratio of 27.3% and 17.4%, respectively.

The study also found a long-term causal relationship among GDP, FDI, and CO_2 variables. In the long run and at a 5% significance level, GDP has a causal relationship with FDI and CO_2. However, no causal relationship was found among the CO_2 variable and the other two variables in the long run. In the short-term causality, only a causal relationship among FDI and CO_2 is found at a 5% significance level. As such, the factors affecting FDI inflows need to be seriously considered because its increase will affect the reduction of CO_2 emissions. This study is also consistent with the study of Ren et al. [3], which shows that excessive trade surplus along with foreign direct investment inflows are the underlying causes for the rapid increase in CO_2 emissions in China.

Based on the obtained results, the study has shown that FDI plays a considerable role in the development of Vietnam's economy. Environmental protection standards are often set lower than usual to prioritize economic development and attract foreign investment. Thus, foreign direct investment also affects the environment, so the Government of Vietnam needs strategies to change the national environment comprehensively. Governance systems are being changed continuously through the process of public administration reform. Membership in international trade organizations and signing agreements are also additional factors in the scale and dynamics of change in the Vietnamese economy. Each new law passed by the National Assembly is a substantial reform of the Government and industries to promote domestic progress, in line with international standards, such as the Law on Environmental Protection, Land, and Resource Management. This shows that the relationship between the Government, businesses, and the community has been adjusted. However, despite the Government's efforts in administrative reform, environmental pollution is still increasing.

Based on the research results, in the future, the Vietnamese Government needs to come up with appropriate policies to grow the economy, and increase trade openness, but still have to reduce CO_2 emissions according to the government's commitments to environmental protection. It is necessary to implement sustainable growth strategies closely linked with environmental protection policies to achieve both goals of reducing CO_2 emissions and economic growth as well as increasing trade openness.

With the growth strategy of attracting FDI and the combination of import and export strategies, the trade openness of the Vietnamese economy is increasing rapidly. The increased trade openness reflects the deepening international integration trend but also has negative impacts on the Vietnamese economy. Therefore, policies are necessary to strengthen environmental management to attract investment capital and FDI enterprises.

In addition, the increased pollutant emissions due to the participation of multinational corporations need to be offset by the transfer of green technology and towards sustainable development. Policymakers should implement policies that encourage the production and use of environmentally friendly energy and green technologies to reduce carbon emissions and promote balanced economic growth.

The limitation of this study is the lack of sector-specific data. Therefore, in future studies, we will try to use data from industries to examine symmetry in econometric models or use disaggregated data. In addition, we also wanted to conduct studies on other growth drivers that have not been performed in this study.

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