Accounting 6 (2020) 365–372

Contents lists available at GrowingScience

Accounting

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Short-and long-term effects of GDP, energy consumption, FDI, and trade openness on CO_2 emissions

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C H R O N I C L E

Article history:
Received November 22 2019
Received in revised format November 28 2019
Accepted January 9 2020
Available online January 9 2020

Keywords:
CO_2 emissions
Energy consumption
GDP
Trade openness

A B S T R A C T

This research applies a Vector error correction model to investigate the long-run and short-run effects of gross domestic product (GDP), energy consumption, foreign direct investment (FDI), and trade openness on CO_2 emissions. The findings indicate that in the long run, GDP growth per capita has a negative influence on CO_2 emission. Energy consumption and trade openness negatively affect CO_2 emission. The foreign direct investment as the percentage of GDP in a long time has a positive relationship with CO_2 emission. Furthermore, the short-run GDP per capita affects CO_2 emission with two-year lags and energy consumption influences CO_2 emission with a one-year lag. These observations have many implications for policy-makers in issuing the FDI policy in Vietnam in recent times and considering the impact of economic development on protecting the sustainable growth in the long-run.

1. Introduction

In recent decades, the foreign direct investment (FDI) inflow has represented the trend to shift from developed countries to developing countries based on the statistics data from the World Bank (Cole et al., 1997; Cole, 2004; Liu, 2005; Mohiuddin et al., 2016; Roca & Alcántara, 2001). The reason causes this issue in the developing countries are to get the advantages of natural resources, labor force, and the nonstrict environmental policy (Ozturk & Acaravci, 2010). In developing countries, FDI plays an important part in enhancing productivity, modernizing the economy and promoting economic growth. The host economy has an opportunity to receive not only direct capital funding but also to transfer to technology, know-how, and managerial skills. Fernandes and Paunov (2012) have shown evidence that FDI has a positive impact on productivity in services and manufacturing industries in host countries, especially in developing countries. Nevertheless, the increase in FDI inflow has led to environmental problems, the exhausted natural resources and the requirement for environmental policy. Many theoretical and empirical studies have highlighted the existence of the inverted-U form relationship between income level and several pollution indicators such as wastewater discharge, sulfur dioxide emissions, carbon monoxide emissions, and suspended particles. These studies have not only been conducted in individual countries but also they have been implemented in different regions. The literature concerned with the relationship between income level and pollution indexes has been mentioned as the Environmental Kuznets Curve (EKC) theory in 1955. Grossman and Krueger (1991) measured the potential environmental impacts on income within North American free trade agreement countries. Coondoo and Dinda (2008) and Pao and Tsai (2011) investigated the panel sample of BRIC countries and found the significant existence of this hypothesis. Omri et al. (2014) have

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doi: 10.5267/j.ac.2020.1.002

investigated the causality effect among CO_2 emissions, foreign direct investment inflows, and economic growth using dynamic simultaneous-equation panel data models for a global panel of 54 countries from 1990 to 2011. The evidence of bidirectional causality between FDI and economic growth for all countries and between FDI and CO_2 for all regions has been indicated, except Europe and North Asia. Lee (2013) has conducted research that measured the contributions of FDI inflows to clean energy use, carbon emissions, and economic growth of 19 nations of the G20 in the period 1971-2009. The final results implied that FDI plays an important role in economic growth for the G20, but did not show any clear impact on the increase in CO_2 emissions in the economies (Holtz-Eakin & Selden, 1995). Moreover, the FDI inflows have been shown the potential factor in obtaining green growth purposes. Lu (2017) has illustrated the co-movement and causality relationships between greenhouse gas emissions, energy consumption and economic growth of 16 Asian nations during the period 1990–2012. The empirical findings concluded that there is a bidirectional relationship between energy consumption, GDP, and greenhouse gas emissions and between GDP, greenhouse gas emissions, and energy consumption in the long-term. Jamel and Maktouf (2017) highlight the bidirectional causality between economic growth, financial development, trade openness, and CO_2 emissions in Eurozone by applying Cobb–Douglas production function during period 1985-2014. Dogan et al. (2017) indicate the long-run dynamic relationship of CO_2 emissions, real GDP and energy consumption through employing dynamic ordinary least squares estimation for Organization for Economic Cooperation and Development member countries.

Chen et al. (2007) and Managi (2008) have employed research on the existence of EKC in the empirical cases of China and India, respectively. Furthermore, Akbostanci et al. (2009) and Özturk and Öz (2016) have examined whether the EKC hypothesis exited by applying the time-series dynamics of income and CO_2 emissions in Turkey. Lau et al. (2014) have indicated the relationship among FDI, trade openness and CO_2 emission in both short- and long-term in a host country and they have shown the empirical evidence of the Malaysian economy. However, an inverted-U shape does not represent in this fast-growing economy. He and Richard (2010) based on the EKC hypothesis, have reported an inverted-U-shaped relationship when looking into the relationship between GDP per capita and pollutant emissions per capita in Canada. The positive relationship between GDP on CO_2 emission has been already found in the research of Mahmood and Alkhateeb in 2017 and investigated the influence of trade and income level on the CO_2 emissions in Saudi Arabia by examining data from 1970 to 2016. Thus, increasing income and economic activities has been responsible for higher CO_2 emission and pollution degradation. The EKC hypothesis also recognized that trade has a strong negative influence on CO_2 emissions, however, trade has a contribution to declining pollution in Saudi Arabia. For emerging economies such as China, India, Malaysia, Turkey and so on, the EKC hypothesis has not represented whereas the developed countries such as Canada, Spain, G20, etc. the existence of EKC has been shown in much practical research.

In Vietnam, some scholars took consideration of the EKC hypothesis and the causality effect among the CO_2 emission and economic indicators. Dinh and Lin (2014) did not find out the existence of EKC while concentrated on the impacts of economic growth, FDI and energy consumption on CO_2 emissions in Vietnam during the period 1980-2009. But this study also revealed the causality relationship between economic growth, FDI, energy consumption and CO_2 emissions. Mạnh (2015) has studied the causality relationship between GDP per capita and CO_2 emissions in both the short-run and long-run during the period 1985-2011 in Vietnam. In recent time, Vietnam has strategy to attract foreign direct investment flow in order to not only improve the quality of FDI but also enlarge the scale of FDI. Furthermore, increasing the scale of FDI inflow must parallel with environmental protection. Therefore, studying the short-term and long-term effects of GDP, energy consumption, FDI, and trade openness on CO_2 emissions would be meaningful for policy-makers.

The objective of this research is to examine whether the long-run relationship between economic growth and the environmental pollution level exists. Therefore, this relationship is determined by performing the vector autoregression model. In this article, the dependent variable uses CO_2 emission in the relationship with the independent variables are GDP per capita, energy consumption, foreign direct investment, and trade openness in context of Vietnam. Based on the short-run and long-run relationship between the economic indicators and CO_2 emission might be helpful for policy-makers to attract FDI inflow, protect the environment and use energy efficiently. To the best of our knowledge no other authors has collected the data since the time Vietnam economy transfered from subsidized economy to market economy until the new period of attracting FDI. The longer time series, the more clearly evidence in relationship between these variables.

This article is structured into four parts: Firstly, the paper focuses on the introduction. The data collection and variable form are provided in part 2. Part 3 explained the empirical results. We concluded and suggest recommendation in part 4.

2. Data collection and variable form

This study uses the regression model to evaluate the effect of economic growth on the environmental pollution level from 1980 (the time Vietnam economy transfer from subsidized economy to market economy) to 2014. Therefore, the dependent variable CO_2 in this article is representative of the level of environmental pollution, which is CO_2 emission per capita. In terms of the explanatory variable, the research authors employed gross domestic product per capita representing the economic growth denoted as GDP. According to previous studies, foreign direct investment (FDI) as the percentage of gross domestic product, energy consumption per capita (EC), and trade openness (TO, calculated by the sum of the import and export of Vietnam divided by gross domestic product) can affect CO_2 emission; therefore, the authors apply these variables as control variables denoted as FDI, EC, and TO. The database of these variables is obtained from World Bank Indicator and UNCTAD statistics. The units measuring the energy consumption and the CO_2 emission are a kilogram of oil equivalent per capita and metric tons per capita, respectively. GDP and EC have a logarithm form ($LnCO_2$, LnGDP, LnEC); while FDI and TO have remained their forms because they are ratios.

The purpose of this research is to examine whether the long-run relationship between economic growth and the environmental pollution level exists. Hence, this relationship is determined by performing the Vector autoregression model. In this article, the dependent variable is $LnCO_2$, the independent variables are LnGDP, LnEC, FDI, and TO.

3. Empirical Results

Unit root test

As can be seen, those variables employed in this article have time-series data. The authors used a unit root test to examine whether a time series variable is stationary or not, applying the common test with a small sample - Augment Dickey and Fuller (ADF). The result of this test is presented in Table 1:

Table 1

Unit root test results

	Level		1st difference	
	t-stat	P_value	t-stat	P_value
$LnCO_2$	0.48965	0.98380	-4.90966***	0.00040
LnGDP	-0.49025	0.88050	-5.15507***	0.00020
LnEC	1.83724	0.99960	-3.55559**	0.01270
FDI	-1.81319	0.36800	-5.32416***	0.00010
TO	-2.42540	0.14490	-5.70314***	0.00010

*, **, and *** denote 10%, 5%, and 1% level of significance, respectively.

Table 1 shows that all variables are non-stationary at their levels but stationary at their first differences. To be specific, $LnCO_2$, LnGDP, FDI, and TO are stationary at the first difference at 1% significance level; whilst LnEC is stationary at the first difference at 5% significant level. Based on these results, the vector error correction model is applied to estimate the regression model. Besides, criterion commonly used to select an optimal lag length is AIC (Akaike information criterion), SC (Schwart Bayesian criterion) and HQ (Hannan Quinn Information Criterion). According to the results of AIC and HQ in Table 2, the optimal lag length is 3 lags.

Table 2

Optimal lag length results

Lag	LogL	LR	FPE	AIC	SC	HQ
0	112.35990	NA	0.00000	-8.58879	-8.34502	-8.52118
1	237.51710	190.23910	0.00000	-16.60137	-15.13872*	-16.19569
2	276.56130	43.72941*	0.00000	-17.72490	-15.04337	-16.98116
3	313.48350	26.58400	1.73e-14*	-18.67868*	-14.77828	-17.59687*

** Indicates lag order selected by the criterion.*

Johansen cointegration test

Johansen cointegration test is employed to examine whether the cointegration exists in the non-stationary time-series variables. The study used the Trace test and Maximum Eigenvalue Test to identify the number of cointegration vectors. Results of two tests in Table 3 indicated that two cointegration equations exist at the 0.05 level among time series variables. Hence, the authors determine that variables in this research study have a long-run relationship.

Table 3

Results of the Johansen cointegration test

Method 1: Unrestricted Cointegration Rank Test (Trace)				
Hypothesized		Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.
None *	0.9773	162.0702	69.8189	0.0000
At most 1 *	0.8125	67.4011	47.8561	0.0003
At most 2	0.4495	25.5472	29.7971	0.1428
At most 3	0.3418	10.6249	15.4947	0.2356
At most 4	0.0067	0.1674	3.8415	0.6825

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

Table 3

Results of the Johansen cointegration test (Continued)

Method 2: Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized		Max-Eigen	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.
None *	0.9773	94.6691	33.8769	0.0000
At most 1 *	0.8125	41.8539	27.5843	0.0004
At most 2	0.4495	14.9223	21.1316	0.2944
At most 3	0.3418	10.4575	14.2646	0.1836
At most 4	0.0067	0.1674	3.8415	0.6825

Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

Vector Error Correction Model

After discovering all variables are non-stationary and the cointegration vectors exist, this study employs a Vector error correction model to analyze the long-run and short-run relationships among $LnCO_2$, LnGDP, LnEC, FDI, and TO. The optimal lag length in the model is 3 lags, selected based on AIC and HQ criterion. According to Johansen (1988), the Vector error correction model (VECM) is defined as:

$$\Delta X_t = \mu + \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-k} + \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \Pi X_{t-k} + \varepsilon_t$$

where t = 1, 2, …, X_t is a *n*_dimensional vector which consists of *n* time series that are integrated of order one and have cointegration equations among them, Δ is the difference operator, μ *is the n x 1 vector of constants, k is a lag structure.* Γ_1, Γ_2, …, Γ_{k-1} *are the coefficient matrices of short-run dynamics,* Π is the matrix of long-run coefficients. The application of VECM has shown in previous studies such as Ang (2007).

Table 4

Cointegration equation

Cointegration equation		Log-likelihood	279.7829	
Dependent variable: $LnCO_2$				
$LNCO_2$	LNGDP	LNEC	FDI	TO
1.0000	-0.2135***	-0.1865**	2.6260***	-0.9915***
	(0.0487)	(0.0884)	(0.3433)	(0.0618)
	[-4.3839]	[-2.1093]	[7.6486]	[-16.0315]

The values in () and [] are standard errors and t-statistics, respectively.

, **, and * denotes significance at 10%, 5%, and 1% level, respectively.*

The results in Table 4 have indicated that most of the coefficients in the cointegration test are significant at 1% level, only the coefficient of LnEC is significant at 5% level. As a result, in the long run, the changes in variables influence CO_2 emission. To be specific, in the long run, GDP growth per capita has a negative influence on CO_2 emission. According to the Kuznets curve for the relationship between carbon dioxide emission and economic growth, the environment pollution represented by CO_2 emission has risen at the early stages of economic growth; however, CO_2 emission began to reduce after GDP per capita reached a certain point on the Kuznets curve. The result of the cointegration equation is appropriate with the Kuznets curve in the long term. Whereby, the GDP of Vietnam accumulated to a certain level would enable Vietnam to pay more attention to environmental issues, which could decrease the CO_2 emission. Moreover, in the long term, energy consumption and trade openness negatively affect CO_2 emission. The foreign direct investment as the percentage of GDP in a long time has a positive relationship with CO_2 emission. Dinh and Lin (2014) have found evidence of a positive relationship between GDP and CO_2 emission in the previous period. This result supports for conclusions of Esteve and Tamarit (2012) while focusing on the Kuznets Curve in Spain, Fodha and Zaghdoud (2010) in Tunisia, Govindaraju and Tang (2013), Magazzino (2016), and Jamel and Maktouf (2017). The estimated results of the Vector error correction model in Table 5 specified that the error correction term of the equation, in the long-run, is -0.6116 and significant at 1% level. The error correction term is the speed of adjustment of any disequilibrium that exists towards long-run equilibrium state per year. The CO_2 emission will converge towards its long-run equilibrium level by 61.16%. Tests apply to diagnose the model indicated that the series correlation and heteroskedasticity do not appear in the model. Furthermore, in the vector error correction model, the coefficient of $\Delta LnGDP_{t-2}$ is significant at the 10% level, which means that in the short-run GDP per capita affects CO_2 emission with two-year lags.

Table 5
The estimated results of Vector error correction model

Dependent variable: $LnCO_2$		
	Coeficient	P_value
Error Correction	-0.6116***	0.0026
$\Delta LnCO_{2t-1}$	-0.0544	0.8091
$\Delta LnCO_{2t-2}$	0.2097	0.3791
$\Delta LnGDP_{t-1}$	-0.3863	0.2647
$\Delta LnGDP_{t-2}$	0.5057*	0.0840
$\Delta LnEC_{t-1}$	1.2945*	0.0531
$\Delta LnEC_{t-2}$	0.2075	0.7574
ΔFDI_{t-1}	-0.1278	0.8897
ΔFDI_{t-2}	0.7147	0.5175
ΔTO_{t-1}	0.1518	0.4463
ΔTO_{t-2}	-0.1338	0.4444
Constant	-0.0160	0.7489
R-squared	0.6810	

, **, and * denotes significance at 10%, 5%, and 1% level, respectively.*

At the same time, the coefficient of $\Delta LnEC_{t-1}$ is significant at the 10% level, indicating that in the short run, energy consumption influences CO_2 emission with a one-year lag. This result specifies that if energy consumption rises by 1% in the current year, then it will contribute to the increase in CO_2 emission by 1.2945% next year. These results confirm previous findings in the literature of He and Richard (2010), Hamit-Haggar (2012), and Govindaraju and Tang (2013). Likewise, this study conducts Tests of Cumulative Sum of Recursive Residuals (CUSUM) and Cumulative Sum of Square of Recursive Residuals (CUSUMSQ) to examine the stability of the model. Results of these tests presented in Figure 1, demonstrating that the cumulative sum of recursive residuals and the cumulative sum of a square of recursive residuals fall within the range of 5% significant level. Therefore, the model is concluded to be stable.

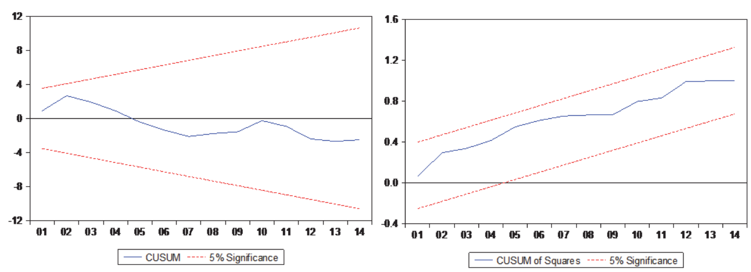
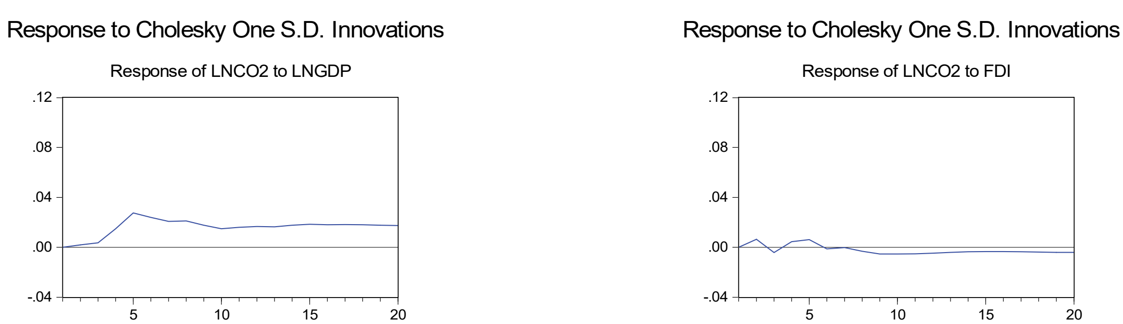


Fig. 1. Results of Cumulative Sum of Recursive Residuals and Cumulative Sum of Square of Recursive Residuals

Also, this research carried out the impulse response function to examine the response of CO_2 emission to the changes of GDP per capita, foreign direct investment as the percentage of GDP, energy consumption per capita, and trade openness. As can be seen from Fig. 2, the response of CO_2 emission to GDP per capita increases in the first 3 years, then dramatically rises in the next 2 years. During the period from 5th year to 10th year, it drops, afterward, rises inconsiderably in the next 5 years, and remains stable from the 15th year. According to the response of CO_2 emission to FDI, during the first six years, the effect of FDI shocks cause the continuous fluctuation of CO_2 emission, thereafter, CO_2 emission slightly falls from 7th year, and then remains quite stable. The response of CO_2 emission to EC is positive during the first year. After that, it gradually reduces until the 10th year and stabilizes from the 13th year. The response of CO_2 emission to trade openness tends to increase during the first year. From the 2nd year to the 7th year, CO_2 emission slightly fluctuates then remains stable.



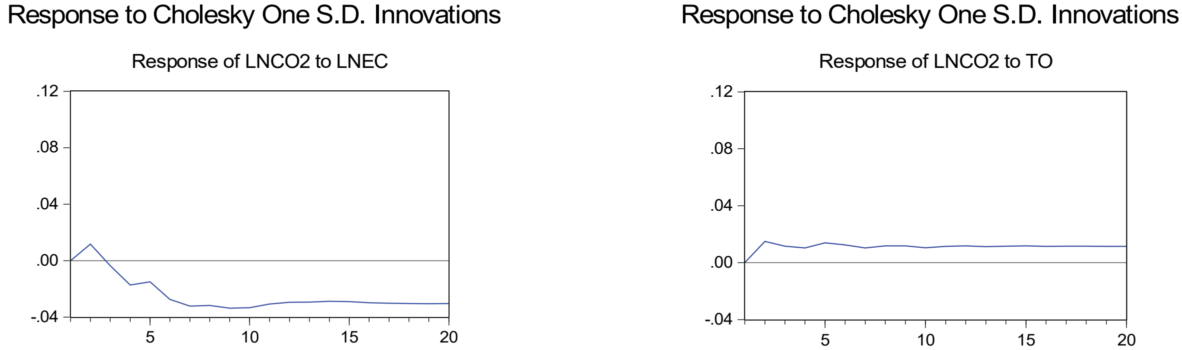


Fig. 2. A response of CO_2 emission to LnGDP, LnEC, FDI, TO

Finally, the article carried out the variance decomposition analysis to measure the proportion of a variable's forecast error variance that appears as the consequence of a shock from each of the variables into contribution originating from its own and the other variables' variances for 20 years. The results in Table 6 describe that, during the first year, the variance of CO_2 depends on its own innovation. From 2^{nd} year, the contribution of CO_2 to its variance gradually decreases, while other factors' variances increase. Until the 10^{th} year, CO_2 approximately accounts for 83.14% to the total variance, whilst the contributions of the variances of GDP, EC, FDI, and TO to the total variance are 4.93%, 9.46%, 0.31%, 2.15%, respectively. At the end of 20 years, the forecast error variance for CO_2 emission, explained by its innovation, is 79.25%, and GDP, EC, FDI, and TO represent 5.28%, 12.85%, 0.31%, and 2.31% of the variance of CO_2, respectively. In the long run, energy consumption per capita and GDP per capita considerably affect CO_2 emission. The findings are consistent with the empirical results of Akbostanci (2009) when examined the data during the period 1968–2003 and 1992–2001 in Turkey or the findings of Ang (2007) in France, Fodha and Zaghdoud (2010) in Tunisia.

Table 6
Decomposition of variance

Period	S.E.	LNCO2	LNGDP	LNEC	FDI	TO
1	0.079889	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.125253	97.40316	0.026014	0.875129	0.265010	1.430686
3	0.151254	97.45375	0.074772	0.657066	0.256129	1.558287
4	0.172815	95.88978	0.800386	1.497271	0.262697	1.549867
5	0.190156	93.24998	2.762426	1.856190	0.318626	1.812781
6	0.202658	90.45659	3.824912	3.460191	0.284962	1.973340
7	0.213744	87.96906	4.383383	5.384615	0.256289	2.006650
8	0.224785	85.94548	4.840623	6.872017	0.251667	2.090218
9	0.235325	84.25379	4.982570	8.325055	0.281710	2.156877
10	0.245880	83.14584	4.929121	9.460523	0.305372	2.159143
11	0.256701	82.47130	4.910877	10.11764	0.322010	2.178169
12	0.267173	81.97965	4.919229	10.56771	0.328925	2.204482
13	0.277241	81.60182	4.919196	10.94010	0.327307	2.211577
14	0.286981	81.26082	4.972795	11.21938	0.320717	2.226292
15	0.296223	80.88896	5.054443	11.49459	0.314456	2.247551
16	0.305023	80.50996	5.117776	11.80163	0.309643	2.260998
17	0.313554	80.15003	5.177275	12.09263	0.306285	2.273786
18	0.321839	79.81126	5.229755	12.36611	0.304997	2.287871
19	0.329911	79.50949	5.262387	12.62549	0.304952	2.297687
20	0.337842	79.25261	5.286574	12.84999	0.305143	2.305679

4. Conclusion

This study has implemented a Vector error correction model to investigate the long-run and short-run relationships among CO_2 emission, GDP per capita, energy consumption, FDI, and trade openness. Based on the results, in the long run, the changes in variables influence the CO_2 emission: GDP growth per capita has a negative influence on CO_2 emission. According to the Kuznets curve for the relationship between carbon dioxide emission and economic growth, the environment pollution represented by CO_2 emission has risen at the early stages of economic growth; however, CO_2 emission began to reduce after GDP per capita reached a certain point on the Kuznets curve. The result of the cointegration equation is appropriate with the Kuznets curve in the long term. Whereby, the GDP of Vietnam accumulated to a certain level would enable Vietnam to pay more attention to environmental issues, which could decrease the CO_2 emission. Moreover, in the long term, energy consumption and trade openness negatively affect CO_2 emission. The foreign direct investment as the percentage of GDP in a long time has a positive relationship with CO_2 emission. Furthermore, in the vector error correction model, the short-run GDP per capita affects CO_2 emission with two-year lags. At the same time, energy consumption influences CO_2 emission with a one-year lag. This result specifies that if the energy consumption rises in the current year, then it will contribute to the increase in CO_2 emission by next year. According to these findings, this paper suggests several issues that should be conducted in Vietnam to design policies that encourage FDI inflow and liberalize the level of trade in Vietnam. Firstly, the most important issue in economic development is the government needs to issues strict regulations and laws to reduce CO_2 emission. To reduce CO_2 emission, the authority must consider carefully the new wave of FDI inflow to Vietnam in this period to limit the effect of FDI on environmental quality. On the other hand, the authority needs to work hard with the non-governmental organizations and educational institutions in tackling the issue. The higher rate of taxation on the environment and violate environmental law might be taken into account. Secondly, international trade represents a negative impact on the environment. This indicates that policymakers should encourage importing high and green technology to replace obsolete technologies. Moreover, policymakers must limit the export-oriented industries that damage the environment such as cement and so on.

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