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Economic Growth, Financial Development, Transportation Capacity, and Environmental Degradation: Empirical Evidence from Vietnam*

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Abstract

In recent years, there has been a substantial theoretical and empirical study on the role that financial market development has significantly played in promoting economic growth and development in the world. The development of an economy requires the financial industry to be developed. In the context of rapid economic development, global warming has become a serious problem with issues such as rising average temperatures, climate change, rising sea level, and increasing carbon dioxide emissions. This study aims to examine the influence of economic growth, financial development, transportation capacity, and environmental degradation. Using time-series data from 1986 to 2019 and environmental degradation being measured by CO2 emissions, the study employs a quantity of ample unit root tests, the structural break unit root tests, Autoregressive Distributed Lag (ARDL), and cointegration bounds test. The results show that there is a significant long-term cointegration among study variables. Empirical findings also indicate that an increase in per capita GDP and financial development worsens environmental quality whereas transportation capacity and foreign investment can improve environmental quality.

Keywords: Economic Growth, Finance, Transportation, Environment, Structural Break

JEL Classification Code: C58, E51, G15, Q54

1. Introduction

Global warming resulting in the rising average temperature on the surface of the Earth has been a major concern in this current century. In this context, global climate change is caused by an increase in emissions of greenhouse gases with the main source of emission being carbon dioxide (CO2) and methane, and changing large-scale shocks in weather patterns (Peter, 2019). Besides, using more fossil fuels such as coal, oil, and gas, which is the major source of these emissions (Olivier & Peters, 2020). According to the IEA (2020a), global energy-related CO2 emissions have predominantly increased between 1990 and 2019 with 11.3Gt for advanced economies and 9.1Gt for other economies in 1990, and 11.3Gt for advanced economies and 22Gt for other economies in 1990. It meant that a large amount of CO2 emissions was contributed by developing and emerging economies (IEA, 2019).

To solve climate change and global problems worldwide, and to relieve negative externalities from climate change, the Intended Nationally Determined Contributions (INDCs) agreement was officially signed in Paris in 2015 in which 196 members together under Paris agreement aim to reduce the global temperature by 1.5 to 2 degrees Celsius in the current century. Besides, members suggested that a long-run goal for sustainable development should be considered, for example, to increase the ability to solve the adverse effect of climate change. The United Nations Framework Convention on Climate Change is an international environmental treaty

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addressing climate change, negotiated and signed by 154 states at the United Nations Conference on Environment and Development, informally known as the Earth Summit, held in Rio de Janeiro from 3 to 14 June 1992. The ultimate objective of the Convention is to stabilize greenhouse gas concentrations "at a level that would prevent dangerous anthropogenic (human-induced) interference with the climate system." It states that "such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner.

Responding to the agreement of the COP-21, the Vietnamese Government (2018) has recognized that the impact of climate change has been felt in the country with an average temperature increase of about 0.5 degrees celsius each year. Further, sea levels have risen by about 20cm, therefore, natural disasters and floods are increasingly becoming dangerous. Vietnam has proactively taken actions to relieve the negative impact of climate change. More specifically, Vietnam is likely to expect to reduce greenhouse emissions by 8 percent by 2030 and by up to 25 percent with international financial support (MONRE, 2015). As shown by EIA (2020a), Vietnam has entirely increased its non-hydro renewables in its power development plan from 9.4% to 21% by 2030, and therefore, declined the share of coal-fired capacity from 52% to 43% at the same time. Additionally, Vietnam emitted a huge amount of CO2 emissions each year, and the energy industry had contributed approximately 66% of these emissions. To be sustainable, Vietnam had suggested a few policies aiming to reduce greenhouse emissions by 8% below the scenario of the Business and Usual (BAU) by 2030.

To implement the target of the greenhouse emissions, the contraction of the share of coal-fired capacity from 52% to 43% by 2030 is a must. Besides, coal-fired power and oil plants held the highest emissions factors during 1990 and 2018, for example, 2.223 ktoe for coal, and 2.711 ktoe for oil energy in 1990, and 22.499 ktoe for coal, and 36.740 ktoe for oil energy in 2018 (IEA, 2020a). In other words, other fossil fuels such as natural gas, hydro, biofuels, and waste have significantly contributed a small part to CO2 emissions in Vietnam. As shown by the revised National Power Development Master Plan for the period of 2011–2020, and the vision to 2030, the Vietnamese Government is expecting to supply adequate electricity for local demand and prioritize the development of renewables' resources for electricity production from 3.5% of total electricity output in 2010 to 6% of total electricity output in 2030 (IEA, 2020b). It is precisely confirmed that Vietnam's government has followed the ambitious target of carbon dioxide reduction in the line of significant development of the energy industry.

This present research extremely differs from relevant previous studies in many ways, and it possesses three main contributions to the literature review of environmental quality. First, this study is to examine carbon dioxide emissions with reference to the empirical analysis in an emerging economy. Second, we examine based on plenty of unit root tests, for example, the Augmented Dickey-Fuller (ADF), the Phillips–Perron (PP), the Eliot–Rothenberg–Stock (ERS), and the Kwiatkowski–Phillips–Schmidt–Shin (KPSS); and the Zovit–Andrews, the Clemente–Montanes-Reyes (CMR) tests are employed to discover structural breaks. Third, the ARDL approach, and cointegration bounds test are employed to analyze the short and long-run relationships between major factors, and environmental pollution. A few previous studies have estimated the effect of economic growth, financial development, and especially transportation capacity on CO2 emissions as a proxy for environmental quality. This paper hopes to fill the gap and enrich the growing economic literature.

2. Literature Review

This section briefly reviews previous studies related to CO2 emissions. Previous studies suggested that energy sources were scarce and most of them generated emissions, which contributed to climate change. Each country had its own agreements and plans to reduce emissions. Therefore, research should be carried out for a single country or a group of countries.

Mardani et al. (2019) presented a comprehensive overview of the relationship between CO2 emissions and economic growth. The results of this paper demonstrated that the nexus between CO2 emissions and economic growth gives reasons for policy options that have to reduce emissions by imposing limiting factors on economic growth as well. Given the fact that bidirectional causality exists, as far as economic growth increases or decreases, further CO2 emissions are stimulated in higher or lower levels and consequently, a potential reduction of the emissions should have an adverse influence on economic growth. Similarly, Fan et al. (2006), using the STIRPAT model, analyzed the impact of population, affluence, and technology on the total CO2 emissions of countries at different income levels over the period 1975–2000. Their main results showed that at the global level that economic growth has the greatest impact on CO2 emissions, and the proportion of the population between ages 15 and 64 has the least impact. The proportion of the population between 15 and 64 has a negative impact on the total CO2 emissions of countries at the high-income level, but the impact is positive at other income levels.

Dong et al. (2019), using the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) model and an unbalanced panel dataset of 128 countries covering 1990–2014, examined the key impact factors (KIFs) of the global and regional carbon dioxide (CO2) emissions and analyzed the effectiveness of non-renewable and renewable energies. The overall estimation implied that the KIF(s) at the global level is economic growth, followed by population size, non-renewable energy, and energy intensity in order of their impacts on CO2 emissions; conversely, the KIFs at the regional level varies across different regions and estimators. The results also suggested that renewable energy can lead to a decline in CO2 emissions at the global level. At the regional level, only for two regions (i.e., S. & Cent. America and Europe & Eurasia) renewable energy has a significant and negative effect on CO2 emissions, which may be affected by the share of renewable energy consumption in the primary energy mix. Finally, the results indicate varied causality relationships among the variables across regions.

Shahbaz et al. (2013) examined the linkages among economic growth, energy consumption, financial development, trade openness, and CO2 emissions for $1975Q_1$–$2011Q_4$ in the case of Indonesia. Their results confirmed that the variables are cointegrated; it means that the long-run relationship exists in the presence of structural breaks. The empirical findings indicated that economic growth and energy consumption increase CO2 emissions, while financial development and trade openness compact it. The VECM causality analysis had shown the feedback hypothesis between energy consumption and CO2 emissions. Economic growth and CO2 emissions are also interrelated i.e. bidirectional causality. Financial development Granger causes CO2 emissions. The study opened up new policy insights to control the environment from degradation by using energy-efficient technologies. Financial development and trade openness can also play their role in improving environmental quality.

Climate change has become the most critical issue of the world within the past decades as the amount of carbon dioxide emission is increasing significantly. As a result, there is a global effort towards mitigating climate change and its impact through multidisciplinary research that increases the global debate and bring to light new evidence to create awareness and provide information for national policy and planning in climate change. Mohiuddin et al. (2016) showed new evidence from Pakistan by investigating the carbon dioxide emissions, energy consumption, electricity production from sources, and GDP using the econometric approach. Evidence from the study showed that a 1% increase in energy production of oil in Pakistan will increase carbon dioxide emissions by 13.7% in the long-run. In this way, the exploration of other renewable energy resources will reduce the carbon footprint in Pakistan.

Sarkodie (2018) examined the drivers of environmental degradation and pollution in 17 countries in Africa from 1971 to 2013. The investigation of the nexus between environmental pollution economic growth in Africa confirmed the validity of the EKC hypothesis in Africa at a turning point of US$ 5702 GDP per capita. However, the nexus between environmental degradation and economic growth revealed a U shape at a lower bound GDP of US$ 101/capita and upper bound GDP of US$ 8050/capita, at a turning point of US$ 7958 GDP per capita, confirming the scale effect hypothesis. The empirical findings revealed that energy consumption, food production, economic growth, permanent crop, agricultural land, birth rate, and fertility rate play a major role in environmental degradation and pollution in Africa, thus supporting the global indicators for achieving the sustainable development goals by 2030.

Zhu et al. (2019) investigated CO2 emissions and used a regression model of stepwise multivariate. The empirical results showed that China's CO2 emissions have obvious timescales of 6.17 years, 9.25 years, 18.5 years, 37.0 years, and long-term trend. At the short-term timescales, fuel structure and economic structure have significant impacts on CO2 emissions. At the medium-term timescales, urban population and fuel structure are the major contributors to CO2 emissions. At the long-term timescale, only per capita GDP has a positive effect on CO2 emissions. Finally, they proposed the policy implications at the short, medium, and long timescales. In another study, Bekun and Agboola (2019) revisited the dynamic relationship between electricity consumption, real gross domestic product per capita, and carbon dioxide emissions in Nigeria. Empirical evidence showed there exists a long-run equilibrium relationship between electricity consumption, real gross domestic product per capita, and carbon dioxide emissions. The long-run regression suggests a statistically significant and positive relationship between economic growth and electricity consumption.

Recently, there has been a growing interest in environmental issues, due to climatic-based problems associated with escalated levels of pollution and degradation of the environmental quality. This is widely believed to be caused by increased economic and human activities. Akadiri et al. (2019) examined the causal and long-run relationship between carbon emissions, energy consumption, and economic growth for Iraq. They applied the bounds test for cointegration and Toda-Yamamoto for a Granger causality test using annual data for the period from 1972 to 2013. The sample coverage was restricted by data unavailability. Empirical results proposed unidirectional causality running from economic growth to energy consumption and from carbon emissions to energy consumption in the long-run. Findings revealed that there is no feedback relationship between economic growth, carbon emissions, and energy consumption of Iraq.

Zhang et al. (2021) verified whether strengthening the construction of urban transportation infrastructure can reduce haze pollution. The core innovation of this paper was that the fixed asset investment of urban municipal public facilities and urban road areas are used as the proxy indicator of transportation infrastructure, which is rarely adopted in the existing literature. The relationship between transportation infrastructure and haze pollution was discussed, and the endogenous problems caused by variables omission are also considered. Based on the panel data of 13 prefecture-level cities of Beijing-Tianjin-Hebei (BTH) region from 2005 to 2016, they used the slope index as the instrumental variable for urban transportation infrastructure, with the two-stage least squares method (2SLS) applied. The results suggest that: (i) increasing urban transportation infrastructure investment can significantly improve the air quality of the sample cities and mitigate haze pollution levels; (ii) After using the instrumental variable to alleviate endogenous bias, the inhibitory effect is more obvious; (iii) Compared with the fixed asset investment in the construction of public facilities, the increase of urban road area has a better effect on the improvement of haze pollution. What they learned from the conclusions was: traffic management department should strengthen the transportation infrastructure construction to realize the balance between urban construction and environmental protection.

In the early 1990s, the attention of economists was captured by empirical evidence suggesting that rising income levels in developing countries could be good rather than bad for the environment. This evidence drove a stake into the heart of those opposing growth on environmental grounds (Carson, 2010). Ultimately, the view that income growth by itself eventually will be good for the environment also appears to be wrong because a causal relationship between income and environmental quality cannot be demonstrated. The original empirical estimates appear fragile at best compared to estimates using more representative datasets, higher-quality data, and more appropriate econometric techniques (Carson, 2010). More plausible explanations for the observed data revolve around good government, effective regulation, and diffusion of technological change. These factors tend to be related in a diffuse manner with higher income and suggest it is likely, but not inevitable, that society will choose to reduce pollution levels as it becomes wealthier (Carson, 2010).

This research fills the gap in empirical studies related to this subject. We modify the model in which we use some new interesting factors compared to previous studies. These factors are economic factors including economic growth, foreign direct investment, trade openness, broad money supply, and transportation capacity, which impact CO2 emissions.

3. Data and Methodology

3.1. Data

The data in this study will be collected from the World Development Indicators (WDI) and General Statistics Office (GSO) of Vietnam, covering the period from 1986 to 2019. In Vietnam, "Doi Moi" is the name given to the economic reforms initiated in Vietnam in 1986 with the goal of creating a "socialist-oriented market economy". In this study, the data include carbon dioxide emissions (kt), foreign direct investment (current US$), per capita gross domestic products, trade openness (% of GDP), financial development with denoted by broad money supply (% of GDP), and transportation capacity (total volume of transported goods and services, mt). The study has been conducted on a developing economy, which is Vietnam. The functional form of this study can be clarified as follows:

$$EP_t = f(FDI_t, GDP_t, TO_t, FD_t, Transport_t)$$

In this study, we used the log-linear formation to examine the interaction among the variables. Accordingly, the study has created the log-linear model and used it for estimation, we have:

$$\ln EP_t = \alpha_0 + \alpha_1 \ln FDI_t + \alpha_2 \ln GDP_t + \alpha_3 \ln TO_t + \alpha_4 \ln FD_t + \alpha_5 \ln Transport_t + u_t$$

Table 1: Variables, Measurement, and Data Sources

Variables	Abb.	Variables measurement	Data source
Carbon dioxide emissions	EP	Carbon dioxide emissions (kt)	(WDI, 2020)
Foreign direct investment	FDI	Foreign direct investment, net inflows (BoP, current US$)	(WDI,2020)
Gross domestic product per capita	GDP	Gross domestic product per capita (current US$)	(WDI,2020)
Trade openness	TO	Trade openness (% of GDP)	(WDI, 2020)
Financial development	FD	Broad money (% of GDP)	(WDI,2020)
Transportation	Transport	The total volume of goods transported (mt)	(GSO, 2020)

Note: VDOS = Vietnamese Department of Statistics; WDI = World Development Indicators.

where:

lnEP, lnFDI, lnGDP, lnTO, lnFD, and lnTransport are, respectively, the usual logarithm of CO2 emissions, FDI, GDP, trade openness, financial development, and transportation;

$\alpha_0, \alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5$ are, respectively, estimation coefficients of lnEP, lnFDI, lnGDP, lnTO, lnFD, and lnTransport,

α_0 is the constant term,

u_t denotes for the stochastic error term.

In this study, we follow the annual time-series data to estimate the impact of factors on the environmental degradation from 1986 to 2019 in Vietnam. Table 1 below reports the description of the variables used in the study:

3.2. Research Model

Followed by Pesaran and Shin (1995) and Nguyen and Do (2020), in this study, we perform estimated regression based on Autoregressive Distributed Lag - ARDL model. The functional form of the ARDL bounds test cointegration equation can be shown as follows:

$$\Delta \text{lnEP}_t = \alpha_0 + \sum_{i=1}^{m} \alpha_1 \Delta \text{lnEP}_{t-1} + \sum_{i=1}^{n} \alpha_2 \Delta \text{lnGDP}_{t-1} + \sum\nolimits_{i=1}^{n} \alpha_3 \Delta \text{lnTO}_{t-1} + \sum\nolimits_{i=1}^{n} \alpha_4 \Delta \text{lnFD}_{t-1} + \sum\nolimits_{i=1}^{n} \alpha_5 \Delta \text{lnTransport}_{t-1} + \mu_1 \text{lnEP}_{t-i} + \mu_2 \text{lnGDP}_{t-i} + \mu_3 \text{lnTO}_{t-i} + \mu_4 \text{lnFD}_{t-i} + \mu_5 \text{lnTransport}_{t-i} + u_t$$

$$\Delta \text{lnEP}_t = \alpha_0 + \sum_{i=1}^{m} \alpha_1 \Delta \text{lnEP}_{t-1} + \sum_{i=1}^{n} \alpha_2 \Delta \text{lnGDP}_{t-1} + \sum_{i=1}^{n} \alpha_3 \Delta \text{lnTO}_{t-1} + \sum_{i=1}^{n} \alpha_4 \Delta \text{lnFD}_{t-1} + \sum_{i=1}^{n} \alpha_5 \Delta \text{lnTransport}_{t-1} + \theta_1 \text{ECT}_{t-1} + \varepsilon_t$$

where,

α_i, μ_j are the regression coefficients, in which stands for the dynamics for error correction in the short run meanwhile stands for the long-run relationship among variables.

u_t is the error term, that has a simultaneous association without association with its lags and explanatory variables. ECT_{t-1} stands for the error correction term, and showing the long-run equilibrium speed of adjustment.

In this study, it is evident that the ARDL model can be analyzed in the following steps:

Step 1, checking of the stationarity of time series should be carried out.

Step 2, presenting the optimal lag length of the ARDL model.

Step 3, the bounds test cointegration.

Step 4, the estimated results of the ARDL model. To find out the best model, the study needs to check diagnostics such as using the Ramsey Reset test to check if the conditional mean is correctly specified. The stability of the long-run coefficients along with the short-run relationship is evaluated by using CUSUM and CUSUMSQ. The stability test of the ARDL model must be according to the cumulative sum of recursive residuals (CUSUM), the cumulative sum of square recursive residuals (CUSUMSQ), and the test of the residuals without autocorrelation based on the Lagrange Multiplier test (LM test).

4. Empirical Findings

4.1. Descriptive Statistics, and Correlation Matrix

Table 2 below indicates the descriptive statistics of variables in this study. It shows that lnEP, lnGDP, lnFD, and lnTRANSPORT are normally distributed but lnFDP, and lnTO do not have a normal distribution according to the Jarque-Bera test (Gujarati, 2004; Abbas et al., 2020; Dao et al., 2021). Therefore, the ARDL model is likely to solve the problem of non-normality. Besides, Table 2 also depicts the results of the correlation matrix for all variables (economic performance, foreign investment, trade openness, financial development, and transportation capacity) that have a positive correlation with carbon dioxide emissions.

4.2. Unit Root Tests, and Structural Break

The time-series data should be checked for stationarity. Theoretically, where the variables are integrated in the order of both I(0) and I(1), the ARDL should be applied. In this study, we check the stationarity based on advanced methods, that is, Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), Augmented Dickey-Fuller–Generalized Least Squares (DF-GLS) (or ESR), and Kwiatkowski-Phillips-Schmidt-Shin (KPSS). Table 3 below depicts the results of the unit root tests and indicates that variables in this study are stationary in both I(0) and I(1). In the study of Persaran and Shin (1995), the ARDL and especially the ARDL bounds test approach should be focused on.

In statistics, a structural break will occur when a time-series data significantly changes at a point in time. Accordingly, in this study, we need to verify the stationarity with a structural break. Table 4 indicates the results of the Zivot-Andrews and CMR breakpoint unit root tests. The results show that some variables such as lnGDPand lnTO have no problem of unit root at the level, but other factors have a problem of unit root test; therefore, we have to check this issue at the first difference according to Zivot-Andrews structural break unit root test. Besides, variables had no unit

Table 2: Descriptive Summary and Correlation Matrix

Items	LNEP	LNFDI	LNGDP	LNTO	LNFD	LNTRAN SPORT
Mean	11.104	20.971	6.400	4.637	3.955	12.704
Median	11.220	21.390	6.235	4.790	4.045	12.675
Maximum	12.240	23.530	7.910	5.350	5.110	14.340
Minimum	9.770	10.600	4.550	2.940	2.970	11.320
Std. Dev.	0.833	2.776	0.988	0.616	0.805	1.028
Skewness	–0.148	–2.070	–0.109	–1.425	–0.020	0.064
Kurtosis	1.534	7.441	2.007	4.623	1.368	1.533
Jarque-Bera	3.168	52.248	1.462	15.250	3.774	3.071
Probability	0.205	0.000	0.481	0.0004	0.151	0.215
Sum	377.550	713.030	217.600	157.690	134.470	431.950
Sum Sq. Dev.	22.905	254.475	32.2182	12.5533	21.428	34.876
Obs.	34	34	34	34	34	34
LNEP	1.000					
	–					
LNFDI	0.740***	1.000				
	(0.000)	–				
LNGDP	0.735***	0.572***	1.000			
	(0.000)	(0.001)	–			
LNTO	0.735***	0.795***	0.620***	1.000		
	(0.000)	(0.000)	(0.001)	–		
LNFD	0.778***	0.681***	0.712***	0.710***	1.000	
	(0.000)	(0.000)	(0.000)	(0.000)	–	
LNTRANSPORT	0.790***	0.750***	0.728***	0.800***	0.782***	1.0000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	–

Note: ***, **, * significance at 1%, 5%, and 10% level.

root problem at the level or stationarity at the level according to CMR structural break unit root test. Thus, we recognize that all variables were stationary in the combination of I(0) and I(1).

4.3. Optimal Lag, and Cointegration Bounds Test

To evaluate the optimal lag length in this study, we use the value of the Hannan–Quin information criterion to choose the most appropriate model. The Hannan-Quinn information criterion (HQC) is a measure of the goodness of fit of a statistical model and is often used as a criterion for model selection among a finite set of models. The optimal lag length will affect the ARDL model, and the selection will follow numerous times with lags descending to 0. As a result, the smallest Hannan – Quin criterion value in the twenty models could be chosen. Figure 1 shows that the best model is ARDL (2,2,0,2,3,3).

For further investigation on the long-run relationship among the variables in the study, we check the cointegration bounds test. Table 3 shows that F-statistic is larger than the upper bounds of 3.79 at the significant level of 5 percent. It means that cointegration could be present in this study.

4.4. ARDL Estimation

The selected ARDL model is shown as the single error correction model (useful for estimating both short-term and long-term effects of one-time series on another) to clarify the long-run and the short-run relationship between

Table 3: Unit Root Tests

Intercept/ trend	**Var.**	**ADF**	**PP**	**ERS**	**KPSS**
At level					
Intercept	LNEP	–4.406***	–0.168	0.82	0.652**
	LNFDI	–5.608***	0.648**	–1.123	0.648**
	LNGDP	–0.536	–0.349	–0.201	0.599**
	LNTO	–3.159**	–3.662***	–0.726	0.737**
	LNFD	0.186	–0.0151	0.875	0.642**
	LNTRANSPORT	–0.172	0.7680	2.255	0.669**
Intercept and trend	LNEP	–1.882	–2.179	–1.788	1.108
	LNFDI	–2.646	–6.507***	–2.709	0.142*
	LNGDP	–7.000***	–4.313***	–2.328	0.127*
	LNTO	–2.833	–3.743**	–2.384	0.173**
	LNFD	–1.948	–2.146	–1.582	0.097
	LNTRANSPORT	–2.596	–2.79	–1.718	0.115
At first difference					
Intercept	LNEP	–4.661***	–4.661995***	–4.655***	0.150
	LNFDI	–9.535***	–9.412***	–2.461**	0.428*
	LNGDP	–4.269***	–4.351***	–4.025***	0.184
	LNTO	–5.471***	–5.487***	–5.065***	0.304
	LNFD	–4.396***	–4.450***	–4.4***	0.156
	LNTRANSPORT	–2.595	–2.471	–1.99	0.249
Intercept and trend	LNEP	–4.130***	–4.635***	–4.7***	0.150**
	LNFDI	–9.673***	–9.698***	–4.714***	0.158**
	LNGDP	–4.498***	–4.498***	–4.358***	0.097
	LNTO	–6.039***	–6.048***	–5.584***	0.354***
	LNFD	–4.348***	–4.413***	–4.55***	0.133*
	LNTRANSPORT	–2.423	–2.256	–2.371	0.170**

Note: ADF, PP, ERS, and KPSS respectively indicate the Augmented Dickey–Fuller, the Phillips – Perron (PP), the Elliot – Rothenberg – Stock (ERS), and the Kwiatkowski – Phillips – Schmidt – Shin (KPSS). ***, **, * significance at 1%, 5%, and 10%, respectively.

Table 4: Results of Zivot–Andrews and CMR Structure Break Unit Root Tests

Items	**Zivot–Andrews structural break unit root test**				**CMR structural break unit root test**			
	Level		1st difference		Level		1st difference	
	T–statistic	Break	T–statistic	Break	T–statistic	Break	T–statistic	Break
LNEP	–3.185	2009	–7.097	1996	9.039	2005	2.118	1991
LNFDI	–4.813	2014	–4.998	1994	8.256	1991	–3.035	1992
LNGDP	–6.865	2014	–10.041	2014	9.300	2006	4.271	1989
LNTO	–7.739	1992	–18.902	1993	6.133	2001	–2.693	1990
LNFD	–2.267	2010	–5.694	2000	12.808	2002	2.369	1997
LNTRANSPORT	–3.646	2008	–3.970	2003	9.873	2006	4.503	1993

Note: Zivot–Andrews test having critical values are, respectively, –4.93, –4.42, and –4.11 at the level of significance of, respectively, 1%, 5%, and 10%. Further, the CMR (Clemente–Montanes–Reyes) structural break unit root test having a critical value of –3.56 at the level of significance of 5%.

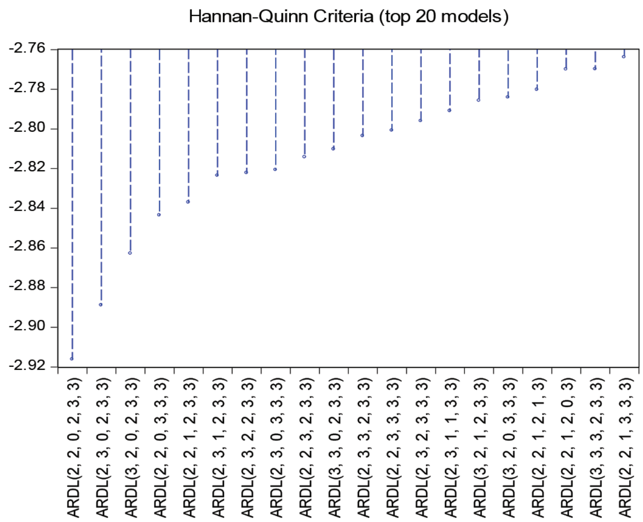

Figure 1: Hann-Quin's Criteria for the 20 Best Models

Table 5: Results of Cointegration Bounds Test

No	Null Hypothesis: No long-run relationship exists		
1	Test Statistic	Value	K
	F-statistic	4.135567	5
	Critical value bounds		
2	Significance	I(0)	I(1)
	10%	2.26	3.35
	5%	2.62	3.79
	1%	3.41	4.68

environmental quality and FDI, economic growth, trade openness, broad money supply, and transportation capacity.

4.4.1. Autocorrelation Test

The Breusch–Godfrey test is used to assess the validity of some of the modeling assumptions inherent in applying regression-like models to observed data series. In particular, it tests for the presence of serial correlation that has not been included in a proposed model structure and which, if present, would mean that incorrect conclusions would be drawn from other tests or that sub-optimal estimates of model parameters would be obtained. According to Breuscho – Godfrey serial correlation Lagrangian multiplier test for,

(i) The null hypothesis H0: There is no autocorrelation at first order.
(ii) The alternative hypothesis Ha: There exists an autocorrelation at first order.

Table 6 indicates that the *p*-values of the ARDL (2,2,0,2,3,3) model are greater than zero. They are all greater than 0.05, therefore, the null hypothesis cannot be rejected, indicating that there does not exist autocorrelation among variables in this model.

4.4.2. Test of Model Specification

To back-test the model specification of ARDL (2,2,0,2,3,3), the Ramsey Reset test can be deployed. Ramsey Regression Equation Specification Error Test (RESET) test is a general specification test for the linear regression model. More specifically, it tests whether non-linear combinations of the fitted values help explain the response variable. Theoretically, the probability value extracted from the test result is larger than 0.05, meaning that the model is well-specified at the significance level of 5%. Table 8 shows the required test satisfying the model specification is good.

4.4.3. Stability Test

The stability of the long-run coefficients along with the short-run relationship is evaluated by using CUSUM and CUSUMSQ. CUSUM checks for the cumulative sum of recursive residuals whereas CUSUMSQ checks for the cumulative sum of square recursive residuals. Moreover, the standard range at the significance level of 5% contains the CUSUM of the residuals, which leads to the fact that the residual of the model has stability and therefore the model has stability. Figure 2 indicates that plots of CUSUM and CUSUMSQ statistics are within the critical bounds of 5 percent significant level or within the pairs of the red straight lines. Accordingly, the results of the study are stable.

4.5. Discussion

Table 6 indicates the empirical results of the long-run relationship, which are presented as follows:

$$\begin{aligned} \ln EP_t = &-0.05343*\ln FDI_t + 0.65627*\ln GDP \\ &+ 1.09773*\ln TO + 0.93619*\ln FD \\ &-0.96219*\ln TRANSPORT + u_t \end{aligned}$$

The estimate results indicate that independent variables such as GDP, TO, and FD could significantly explain the volatility of carbon dioxide emissions at a 1% level of significance. Further, the estimated coefficients are positive, indicating that economic growth, trade openness, and broad money supply could significantly increase carbon dioxide emissions or worsen the environmental quality in the case of Vietnam. Besides, the estimated coefficient of GDP is 0.656270, indicating that a one percent increase in economic performance could harm environmental quality by about

Table 6: ARDL (2,2,0,2,3,3) Estimation with Dependence Variable of lnEP

Variable	Coeff.	Std. Error	T–statistic	Prob.
Short–Run Coefficients				
D(LNEP)	0.87129	0.17728	4.91468	0.0003
D(LNEP(–1))	0.97927	0.22579	4.33693	0.0008
D(LNFDI)	–0.11082	0.05351	–2.07091	0.0588
D(LNFDI(–1))	–0.08923	0.02337	–3.81737	0.0021
D(LNGDP)	0.72713	0.29350	2.47742	0.0277
D(LNTO)	1.08479	0.31685	3.42361	0.0045
D(LNTO(–1))	0.21164	0.10423	2.03056	0.0633
D(LNFD)	0.43429	0.15477	2.80591	0.0149
D(LNFD(–1))	0.03042	0.16032	0.18973	0.8524
D(LNFD(–2))	–0.36078	0.15835	–2.27833	0.0402
D(LNTRANSPORT)	–1.70367	0.68705	–2.47967	0.0276
D(LNTRANSPORT(–1))	–0.59775	0.66050	–0.90498	0.3819
D(LNTRANSPORT(–2))	0.75538	0.36224	2.08526	0.0573
CointEq(–1)	–1.10797	0.22564	–4.91024	0.0003
Long–Run Coefficients				
LNFDI	–0.05343	0.04583	–1.16588	0.2646
LNGDP	0.65627	0.24989	2.62618	0.0209
LNTO	1.09773	0.31459	3.48934	0.0040
LNFD	0.93619	0.24028	3.89621	0.0018
LNTRANSPORT	–0.96219	0.47995	–2.00477	0.0663
C	11.46180	3.13208	3.65948	0.0029
Cointeq = $LNEP_t$ – (–0.0534*$LNFDI_t$ + 0.6563*$LNGDP_t$ + 1.0977*$LNTO_t$ + 0.9362*$LNFD_t$ – 0.9622*$LNTRANSPORT_t$ + 11.4618)				

Table 7: Lagrangian Multiplier Test for the Residual of the ARDL Model

F-statistic	1.431	Probability of *F* (1,6)	0.254
Obs*R-squared	3.304	Probability of Chi-Square (1)	0.069

Table 8: Test Results of Model Specification

Items	Value	Degree of freedom	Corresponding probability value
Student statistic	1.1282	12	0.2813
Fisher statistic	1.2729	(1, 12)	0.2813

0.65 percent. This is supported by the empirical findings of Fan et al. (2006) who used the STIRPAT model to analyze the impact of population, affluence, and technology on the total CO_2 emissions of countries at different income levels over the period 1975–2000. Their main results showed at the global level, economic growth has the greatest impact on CO_2 emissions. Similarly, Dong et al. (2019) also found similar evidence on a sample data of 128 countries worldwide from 1990 to 2014. Shahbaz et al. (2013) showed that economic growth and energy consumption increase CO_2 emissions, while financial development and trade openness compact it.

Further, the estimated coefficient of TO is 1.097735, indicating that a one percent increase in trade openness could significantly harm environmental quality by the highest effect with about 1.09 percent. In fact, in recent years, Vietnam has a high trade openness with approximately 200 percent of GDP (Nguyen, 2020). Nguyen (2020) demonstrated that

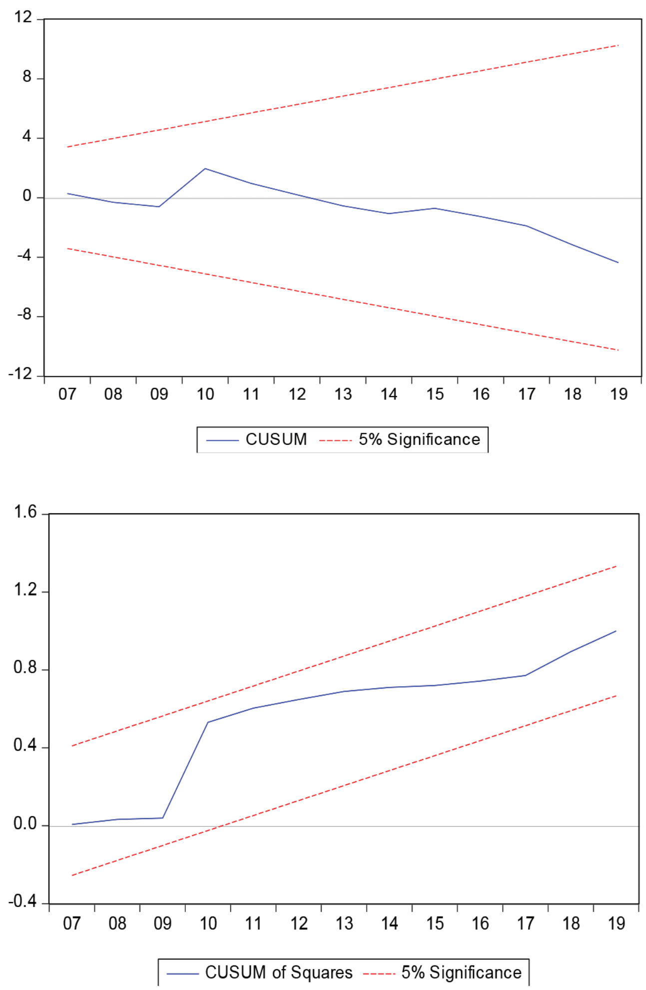

Figure 2: The Cumulative Sum of Recursive and Square Residuals of the ARDL Model at the Significance Level of 5%
Source: Results from Stata

foreign direct investment performance has significantly embraced trade liberalization with gusto. Further, the open trade policy in relation to FTAs could significantly promote foreign investment and maximize its benefits on the economy. This finding is not in line with Shahbaz et al. (2013) who showed that economic growth and energy consumption increase CO_2 emissions, while financial development and trade openness compact it. Mutascu (2018) explored the comovement between trade openness and carbon dioxide (CO_2) emissions in France, over the period 1960–2013 by using the wavelet tool. The investigation offered detailed information about this interaction, for different sub-periods of time and frequencies. It also reveals the lead-lag nexus between variables under cyclical shock and anti-cyclical shock.

The estimated coefficient of FD is 0.936196, indicating that a greater broad money supply could significantly decrease environmental quality by the second-highest effect. The broad money supply is normally controlled by the central bank in every country. This result is consistent with Shahbaz et al. (2013). Based on panel data from 97 countries for 2000–2014, Lv and Li (2021) used the spatial econometric model to reexamine the effect of financial development on CO_2 emissions. The results indicated that there was a spatial correlation between CO_2 emissions among countries during this period. More importantly, they found that a country›s CO_2 emissions could be influenced by the financial development of its neighbors. Specifically, the significantly negative spillover effect of financial development on CO_2 emissions dominated the significant positive direct effect, thus suggesting a significant negative total effect. These findings implied that financial development plays a fundamental role in the mitigation of CO_2 emissions and that being surrounded by nearby countries with a high financial development could improve a country›s environmental performance. These empirical insights are of particular relevance to policymakers as they act as a reminder of the importance of considering the influence of financial development both in a given country and in its neighboring countries.

Zhang et al. (2021) examined the drivers of energy consumption-related CO_2 emissions in China during 1978–2014 from a multiscale perspective. The empirical results showed that China's CO_2 emissions have obvious timescales of 6.17 years, 9.25 years, 18.5 years, 37.0 years, and long-term trend. At the short-term timescales, fuel structure and economic structure have significant impacts on CO_2 emissions. At the medium-term timescales, urban population and fuel structure are the major contributors to CO_2 emissions. At the long-term timescale, only per capita GDP has a positive effect on CO_2 emissions. Finally, we propose the policy implications at the short, medium, and long timescales.

Table 6 also indicates that the coefficient of error correction term (ECT) is –1.108, and it is significant. Theoretically, it is evidence that the ECT coefficient is expected to be between –2 and 0, indicating that the system is converged to equilibrium and further suggested the model is totally stable. In this case, the level of the speed of adjustment from the previous year's equilibrium was 110.8 percent, indicating that EP converges on its long-run equilibrium at 110.8% with the speed of adjustment via the channel of FDI, GDP, TO, and Transport.

The short-run relationship is also presented in Table 6; estimated coefficients are statistically significant except from D(LNFD(–1)) and D(LNTRANSPORT(–1)). More specifically, a positive impact can be found for D(LNEP), D(LNEP(–1)), D(LNGDP), D(LNTO), D(LNTO(–1)), D(LNFD), and D(LNFD(–2)). It indicates that a higher level of economic performance, trade openness or financial development has a significant positive and short-run effect on environmental pollution. These results are likely to be consistent with the findings of Zhu et al. (2019) who argued that economic structure, and especially economic performance has a positive impact on CO2 emissions. Further, Saud et al. (2018) also confirmed that financial development and trade openness positively affect environmental pollution.

In this research, a negative impact of foreign investment and transportation capacity on environmental pollution can be found in the short run. It depicts that foreign investment has a negative short-run effect on environmental pollution. This finding is likely to be related to the results given by the study of Saud et al. (2018) who suggested that an increase in foreign investment can positively improve environmental quality. Besides, a 1 percent increase in foreign investment will decrease CO2 emissions by 0.11 percent in the short run. Results of transportation capacity depict that transportation capacity has a negative effect on environmental pollution in the short run, where a 1 percent increase in transportation capacity will decrease CO2 emissions by 1.70 percent.

5. Conclusion

The aims of this study discover the effect of economic growth, financial development, and transportation capacity on the environmental degradation of Vietnam between 1986 and 2019. Advanced methods such as the test of stationarity of Augmented Dickey-Fuller (ADF), Phillips – Perron (PP), the Eliot – Rothenberg – Stock (ERS), and the Kwiatkowski – Phillips – Schmidt – Shin (KPSS); the structural break unit root tests of the Zivot – Andrews, and CMR, as well as the cointegration bounds test are deployed. Results demonstrate that economic growth, financial development, and trade openness have negatively impacted environmental quality in the long run. Further, transportation capacity has a positive and significant impact on environmental quality in the long run but this effect is weak. In the short run, economic growth, trade openness, financial development can harm environmental quality while a higher level in foreign investment and transportation capacity can significantly increase environmental quality in Vietnam.

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