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Economic Growth, Energy Consumption and Environmental Quality: Evidence from Vietnam

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ABSTRACT

The purpose of this study is to explore the relationship between economic growth, energy consumption and environmental quality in Vietnam from 1995 to 2018 with the Autoregressive Distributed Lag Cointegration (ARDL) approach. The results confirm a long-term equilibrium relationship between CO_2 (carbon dioxide) emissions, income, energy consumption, trade openness, and FDI (Foreign Direct Investment). Among those, income positively affects CO_2 emissions, but its long-run elasticity is smaller than the short-run one, implying that carbon dioxide emissions decrease as income is on the increase over time. This is similar to the findings of [1] for Cambodia [2] for Turkey, [3] for Jordan, Kuwait, Qatar, South Asian countries, Latin American countries, and [3]-[4] for Viet Nam. In addition, there exists statistical evidence of the impact of energy consumption, trade openness and FDI flows on the level of environmental pollution in Vietnam. From that, the author proposes a few policy implications in protecting the environment and promoting economic growth in Vietnam.

1. INTRODUCTION

Global economic growth has made great achievements, but it is accompanied by the shortage of natural resources and increasing environmental pollution due to the adverse impact of climate change. Therefore, the worldwide economies, specially the developing countries become more inclined to use green energy along with a significant reduction in CO_2 emissions from their rapid economic growth [5]. Though globalization enables developing economies to nurture their economies in terms of reducing barriers to trade and investment, facilitating technology transfer, mobilizing capital and labor, it has increased the burden of pollution due to higher energy consumption. It is shown that the better the economic development and quality of life, the greater need for improving environmental quality [5] is required, reflecting the EKC hypothesis.

First known for the inverse U-shaped relationship between income and income inequality proposed by Simon Kuznets in 1955, the EKC was adopted in environmental economics literature from the 1990s by well-known researches such as [6]–[9] to show an inverse U-shaped relationship between pollution and income for different pollutants including CO_2 [1], [5], [9], SO_2, fine smoke and particulate matter (PM) [6] or wastewater [10], *etc.* Various empirical studies have also examined EKC over the past decades in emerging countries: Brazil, Turkey, India, China, South Africa and those in the Association of Southeast Asian Nations (ASEAN) with the use of techniques on time series and panel data clustered in groups of countries, single countries and cross-sectional data [1].

For differences in countries size, location and economic characteristics, an analysis of individual countries would be a more reasonable choice for better findings and implications [5]. There are also arguments that EKC shows the relationship between pollution and other environmental degradation variables over time, indicating that EKC is a long-term phenomenon [11]. Therefore, applying the time series data technique has an advantage in testing EKC relationship [12].

Although the literature reviews on the environmental quality-growth relationship is quite abundant, both causal direction between the environmental quality and economic growth and study methodologies remain a controversial topic. Nevertheless, none of such empirical research is carried out in low-income countries like Vietnam where impressive economic growth of the Doi Moi period has not just begun until 1986. In the recent decades, Vietnam has witnessed a remarkable increase in economic development towards industrialization and economic reforms, catching up with the global economy. The annual economic growth rate is recorded stable at 6.5% in the period of 2010-2019. Despite its rapid economic development, it is noted that higher energy demand - especially for industries, following greater environmental concerns. Consequently, in the period of 1995-2017, the per capita energy consumption level has increased by more than 460% in the country. Moreover, the rapid and strong urbanization rate with the discharge of untreated wastewater, solid waste and industrial waste has negatively affected the environmental quality of

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Vietnam. Typically, CO_2 emissions have climbed up by more than 300% over the past 20 years. However, the balance between economic development and quality of life in Vietnam is always of interest. Evidence of the need for better environmental quality is also found, representing efforts of the Vietnamese Ministry of Natural Resources and Environment in improving the quality of the environment by implementing policies to conserve natural resources, limiting the harmful effects of climate change, and combating plastic waste, as well as urban planning and management policies. These could help to form an inverse U-shaped relationship between income and pollution. Therefore, in this study, the EKC hypothesis was considered to examine the relationship between environmental quality and economic growth in Vietnam in both short and long run. In addition, the authors assessed the impact of energy consumption, trade openness, and the inflow of foreign direct investment on the level of greenhouse gas emissions and thus on the level of pollution in Vietnam.

This article contributes to the literature on the growth-environment relationship in several aspects. Firstly, to test the EKC hypothesis, most previous studies use GDP and GDP squared, where these two variables are combined to determine if an inverse U-shaped relationship is found between the pollution index and its GDP squared, meaning the EKC hypothesis exists. However, the inclusion of GDP variable and GDP squared variable in the same research model can lead to a serious multicollinearity problem in the model and falsify research results. To address the above, the authors apply the method of Narayan and Narayan [3] to identify the EKC relationship. Secondly, compared to a few studies of the same subject in Vietnam [4], [13]-[14] conducted in both war and the pre-Doi Moi periods - our research sample from 1995 to 2018 helps to eliminate war effects, backward development, self-sufficiency, pure agriculture without focusing on international trade and investment nor the environmental quality - economic growth relationship. In addition, this paper analyzes the relationship between environmental quality and economic growth in Vietnam using a multivariate approach rather than a two-variable one. Theoretically, the two-variable estimation results are likely to be more biased due to the lack of related variables [15]. The energy-growth literature shows that energy consumption, trade openness and Foreign Direct Investment (FDI) are important variables affecting economic growth and their relationship with air emission levels into the environment [5], [14], [16], [17]. Not only assessing the simultaneous impact of variables on economic growth and environmental quality in Vietnam, the study provides a comprehensive view and true representation of the relationship between CO_2 emissions and economic growth in Vietnam with a reliable findings and an establishment of relevant basis for policy making.

The study is structured: Section 2 presents the theoretical framework of the EKC hypothesis on the relationship between environmental quality and economic growth and an overview of relevant empirical studies. The research methodology and data and research results are in Section 3 in Section 4, respectively. Section 5 is the conclusion and policy implications for environmental quality improvement that is paralleled to boosting economic growth in Vietnam.

2. THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.1 Environmental Kuznets Curve (EKC)

The EKC is named after Kuznets [18], who hypothesized that income inequality first increased and then decreased as economic development took place. The EKC is used to denote the relationship between economic growth and environmental quality. It is based on the hypothesis of an inverse U-relationship between output per capita and the measure of environmental pollution.

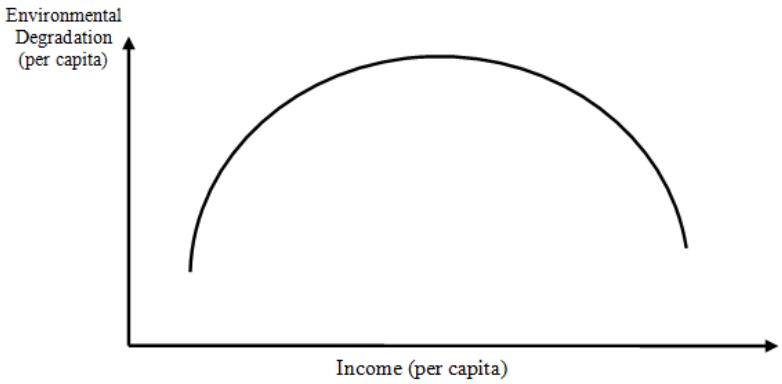

Fig. 1. Environmental Kuznets curve

To put it simply, given that the economy has no structural or technological change, pure economic growth in terms of size will increase pollution and affect the environment. This is called the scale effect. Hence, the scale effect reflects the inconsistencies in economic development and environmental quality goals. On the contrary, the EKC hypothesis states that at a higher level of development, the structure of the economy shifts its

direction to industries and services that use more information, better technology, along with better awareness and enforcement of environmental regulations, higher spending on environmental protection will reduce environmental degradation [19].

Stern [20] explained the mechanism of the above through changes in economic structure or product mix, technology, input mix, as well as the basic causes such as environmental regulation, awareness and education.

2.2 Empirical Studies on the Relationship between Environmental Quality and Economic Growth

Grossman and Krueger [6], who first carried out empirical study on EKC, evaluate the potential environmental impact of NAFTA by estimating EKC with SO_2, fine smoke and particulate matter (PM), using a cubic function at the levels (non-logarithmic) of GDP per capita, other relevant variables, and time trends. Threshold points for SO_2 and fine smoke are found to be approximately 4,000 - 5,000 USD while the concentration of particulate matter appears to decrease even at low-income levels. Estimates show all three pollutants on the increase at income levels above 10,000 - 15,000 USD.

The study of Shafik and Bandyopadhyay [9], the findings of which have been used in the 1992 World Development Report [21], in other words, they are particularly influential, estimates the EKC with 10 different indices using log-linear, log-quadratic, and cubic function of logarithmic GDP per capita purchasing power parity, as well as variables relative to time and objects. They have found that the lack of urban sanitation and clean water decreases when income increases while both measures of deforestation have an insignificant correlation with income. River quality also deteriorates as income increases. However, the EKC hypothesis exists with two air pollutants. The threshold points of the EKC curves are at income level between 3000 and 4000 USD.

Later papers studying on the EKC hypothesis can be divided into two groups. The first group involves cross-sectional data studies [1], [2], [5], [10], [17], [22]-[25]. Ahmed and Long [5] examine the impact of economic growth, trade openness, population density as well as energy consumption on CO_2 emissions in Pakistan from 1971 to 2008. Using the ARDL method, the authors show that the EKC hypothesis is supported in both short and long terms. Additionally, trade liberalization improves environmental quality while population density and energy consumption degrade the environment in Pakistan. Ang [22] confirms an inverted U-shaped relationship between environmental pollution and economic growth in France. In the short run, energy consumption has a one-way impact on economic growth. Conversely, economic growth has causal effects on energy consumption and pollution in the long run. Ozturk and Acaravci [2] test the EKC hypothesis in Turkey in the period of 1968-2005 with model variables of CO_2 emissions, economic growth, employment rates and energy consumption. Their results show that the employment rate is the Granger cause of economic growth in the short term and no evidence is found to support the EKC hypothesis. Jebli and Youssef [23], studying the EKC hypothesis in Tunisia has indicated that there is a one-way causal relationship from CO_2 emissions, GDP, trade and non-renewable energy to renewable energy in the short term and the EKC hypothesis is not supported in the long run. Halicioglu [17] uses the limited ARDL test to examine the causal relationship between income, energy consumption, trade openness, and CO_2 emissions in Turkey in the period of 1960 - 2005. Granger causality test results show the existence of a two-way relationship between income and CO_2 emissions in both short and long run. A two-way relationship between energy consumption and CO_2 emissions is also found in the short run. Finally, the EKC hypothesis is verified in the long run. Ozturk and Al-Mulali [1] test the relationship between environmental quality and economic growth in Cambodia and examine the role of corruption control during 1996 - 2012. Results from GMM and 2SLS estimates reveal that GDP, urbanization, energy consumption and trade openness increase CO_2 emissions while corruption control can reduce them. The researchers also confirm that the EKC hypothesis is not identified in Cambodia. Shu *et al.* [10] study the relationship between water pollution and economic growth in four cities of Guangdong China based on the EKC hypothesis, using urban data over the period of 1990-2009. Wastewater and GDP per capita are used as environmental and economic indicator, respectively. The cubic function is necessary in terms of building the relationships and making a comparison with quadratic and logarithmic functions. The results indicate that the relationship between the wastewater and GDP per capita of Guangzhou City is an inverted U-shape, however, none is found in Shenzhen, Hebei, and Huizhou until 2009. Sarkodie and Ozturk [24] examine the validity of the EKC hypothesis, energy efficiency and energy consumption indicators in Kenya, using the Autoregressive Distributed Lag model and the U-test method with data from 1971 to 2013. The findings identify an inverted u-shaped curve, meaning that the environmental Kuznets curve hypothesis is validated in Kenya. Tang *et al.* [25] analyze the relationship between energy consumption and economic growth in Vietnam using the neoclassical Solow growth framework during the 1971–2011 period and confirm the existence of cointegration among the variables in which Energy consumption, FDI and capital stock all positively influence economic growth in Vietnam.

The second research group involves in the panel data study [4], [16], [20], [26]-[30]. Arouri *et al.* [16] examining the EKC hypothesis in Middle Eastern and North African with a quadratic function of income to identify the significant impact of energy consumption on CO_2 emissions in the long run and confirm the inverted U-shaped relationship between income and environmental pollution in most sample countries . Stern [20] studies the rise and fall of the EKC and concluded that developing countries are solving environmental problems, sometimes with standards of developed countries but in a short time lag and even perform better

than a few developed ones. Also, it is concluded that the EKC has a very fragile statistical background. The new efficient decomposition and frontier models can help to resolve real relationships between development and environment and possibly lead to the collapse of classical EKC. Jebli *et al.* [26] examine the role of income, trade, renewable and non-renewable energy consumption on CO_2 emissions to test the EKC hypothesis in OECD countries over the period of 1980-2010. Using Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) estimations, these researchers provided evidence of the existence of the EKC hypothesis in OECD countries and indicate that non-renewable energy consumption increases CO_2 emissions while commercial or renewable energy consumption reduces them. Apergis and Ozturk [27] use GMM method on panel data to test EKC hypothesis in Asian countries. The results support the EKC hypothesis of an inverted U-shaped relationship between CO_2 emissions and income. On the same topic, Ozcan [28] studied the EKC relationship in MENA countries. The results show one-way causal effects of GDP on energy consumption in the short run, energy consumption outcomes and output to CO_2 emissions in the long run. Evidence of the EKC hypothesis are found in only 3 countries: Egypt, Lebanon and the UAE. Le and Ozturk [29] examined the impacts of globalization, financial development, government expenditures, and institutional quality on CO_2 emissions, incorporating energy consumption, and GDP per capita in the EKC model for 47 Emerging Markets and Developing Economies (EMDEs) in the period of 1990 - 2014. The findings demonstrated that globalization, financial development, and energy consumption increase CO_2 emissions. Besides, the EKC hypothesis was affirmed in EMDEs. Nasreen *et al.* [30] investigating the relationship between financial stability, economic growth, energy consumption and CO_2 emissions in South Asian countries over the period of 1980–2012 indicate that economic growth, energy consumption and population density had negative impacts on environmental quality and financial stability improves environmental quality in the long run, in line with the EKC hypothesis in South Asian countries.

Al-Mulali *et al.* [4], Taguchi [13] and Tang and Tan [14] are of a few studies evaluating the EKC in Vietnam. Those have not found a consensus, but [13]-[14] provide evidence to support the Kuznets curve hypothesis while [4] states that Vietnam is a pollution paradise when a positive relationship between economic growth and environmental pollution is found. The difference may stem from the research period that both war and the pre-Doi Moi periods are included in Vietnam. During which, the economy was outdated, the whole country faced many difficulties to recover after the war as well as in a state of self-sufficiency, and composed of mainly small-scale agricultural production, the level of trade and foreign investment attraction is limited and not recommended. This may cause the relationship between economic growth and CO_2 emissions and other variables to be insufficiently reflected. Not only studying a longer research sample and excluding the effects of the post-war period, our research differs from previous studies by simultaneously assessing the impact of the other variables on emission levels that have been reported in previous studies including international trade levels, foreign direct investment and energy consumption [5], [17], [26], [28].

3. METHODOLOGY AND DATA

3.1 Model

To test the cointegration relationship between variables, the Autoregressive Distributed Lag (ARDL) bounds cointegration test according to [31] is adopted.

Pesaran *et al.* [31] introduce the Autoregressive Distributed Lag model known as the ARDL Bound Test model for the cointegration relationship, which is more suitable for small samples and allows a mixed data set of time series variables I(0) and I(1).Only a single equation is needed to simultaneously identify the short and long-term relationships between the variables. While other cointegration techniques require the regression variables to be incorporated with the same lag, with the ARDL approach, the regression variables can tolerate different optimal lags. Furthermore, estimates using the ARDL method are more efficient with small sample sizes. On the other hand, in the ARDL model, all variables are considered endogenous to eliminate endogenous problems associated with the Engle-Granger method [31]. ARDL is considered one of the most successful, flexible, and easiest approach to use models for multivariate time series analysis.

Previous studies on the EKC hypothesis often estimate a quadratic or cubic function of GDP in the model. However, this can cause serious collinearity or multicollinearity problems that affect the regression results. Therefore, Narayan and Narayan [3] propose an alternative approach to test the inverted U-shaped relationship between income and environmental pollution by comparing short-term and long-term income elasticities of CO_2 emissions. If the long-run income elasticity is lower than the short-run one, it is understood that the increase in income leads to less CO_2 emissions, or the EKC hypothesis is proved, and vice versa. As discussed above, based on recent empirical literature, the unrestricted error correction model (UECM) in the ARDL is considered to model the relationship between environmental quality and economic growth as follows:

$$\Delta LCO2_t = \beta_0 + \sum_{i=1}^{n1} \beta_{1i} \Delta LCO2_{t-i} + \sum_{i=0}^{n2} \beta_{2i} \Delta LGDP_{t-i} + \sum_{i=0}^{n3} \beta_{3i} \Delta LEN_{t-i} + \sum_{i=0}^{n4} \beta_{4i} \Delta LTO_{t-i} + \sum_{i=0}^{n5} \beta_{5i} \Delta LFDI_{t-i} + \theta_0 LCO2_{t-1} + \theta_1 LGDP_{t-1} + \theta_2 LEN_{t-1} + \theta_3 LTO_{t-1} + \theta_4 LFDI_{t-1} + \varepsilon_t \quad (1)$$

where Δ is the first difference operator; β_0 is the constant; the coefficients θ represent the long-run relationship while the short-run one is expressed by β_{ji}. L represents the natural logarithm; CO_2 is the level of CO_2 emissions per capita; the GDP variable means the level of GDP per capita; EN is the energy consumption per capita; the TO is the trade openness calculated by the ratio of total exports and imports to GDP and FDI is the real net inflow of foreign direct investment. To calculate real FDI, we discount the nominal FDI by a consumer price index. ε_t is a standard error term at time t. The lag for the ARDL model is selected based on the minimum value of the Akaike criterion value (AIC). The hypothesis states that the variables without cointegration relationship will be rejected if the value of F-statistic with H0 are coefficients θ that equal zero is greater than the upper bound. Pesaran *et al.* [31] formulate bound values for large sample sizes (500 -1000 observations) and Narayan and Narayan [3] produce bound values for small sample sizes (more than 30 observations). If the F-statistic is lower than the lower bound value, the variables are not cointegrated. Also, if the F-statistic is in the interval between the two bound values, the cointegration relationship is not clear. From the results of cointegration test, the coefficients representing the relationship in the short and long-run are estimated as well.

If the variables have a cointegration relationship, then the long-run relationship coefficient of between variable Z and LCO_2 is determined by the opposite number of the ratio between the estimated coefficient of variable $Z_{(t-1)}$ and the estimated coefficient of the variable $LCO_{2(t-1)}$. That is if the long-run equations of the variables are:

$$LCO2_t = c + b_1 LGDP_t + b_2 LEN_t + b_3 LTO_t + b_4 LFDI_t + v_t \quad (2)$$

Then $b_z = -\theta_z / \theta_0$ with z = 1; 2; 3; 4, respectively.

Then the estimation equations for the short-run relationship will be expressed as follows:

$$\Delta LCO2_t = \beta_0^S + \sum_{i=1}^{n1} \beta_{1i}^S \Delta LCO2_{t-i} + \sum_{i=0}^{n2} \beta_{2i}^S \Delta LGDP_{t-i} + \sum_{i=0}^{n3} \beta_{3i}^S \Delta LEN_{t-i} + \sum_{i=0}^{n4} \beta_{4i}^S \Delta LTO_{t-i} + \sum_{i=0}^{n5} \beta_{5i}^S \Delta LFDI_{t-i} + \gamma^S EC_{t-1} + \varepsilon_T^S \quad (3)$$

$EC_{(t-1)}$ is error correction term and γ^S shows the speed of the adjustment in the short run to return to equilibrium in the long run. The estimated coefficient of EC should be negative and have statistical significance.

If the EKC hypothesis is correct, the signs of b_1 and β_2^S will be positive, however, the magnitude of b_1 should be less than β_2^S.

Economic growth is achieved through the contribution of several industries and companies and therefore economic growth tends to increase the demand for energy. At the same time, energy consumption is considered the most contributing factor to CO2 emissions and causing environmental degradation. These show the relationship between economic growth in energy consumption and environmental pollution. We expect the sign of b_2 and β_3^S are positive. Some studies on this topic are [32]-[37].

After identifying energy and economic growth, trade openness is considered the next major contributor to environmental degradation. The Hecksher-Ohlin trade theory states that developing countries will specialize in the production of in-depth goods in terms of the elements they are endowed with in relative abundance: labor and natural resources. Developed countries will specialize in human capital and capital-intensive activities. Trade that requires the movement of goods is produced in a country for consumption or further processing. This implies that the pollution is created in the production of this good and is related to consumption in another country [17]. Many studies have focused on the relationship between trade and environmental quality, but the direction of impacts depends on the characteristics and policies implemented in different countries. Conclusions of the studies are divided into two groups, either supporting or refusing the impact of trade on environmental degradation. Studies showing negative effects of trade openness include [2], [38]-[40]. However, some studies have argued that trade openness will positively impact environmental quality by finding and accessing advanced technology to increase growth but decrease

environmental impact. Studies showing that international trade improves environmental quality include [9], [41]-[43].

Finally, the authors examine the effects of foreign direct investment (FDI) on environmental quality. Studies including FDI as the deciding factor for environmental degradation are [14], [44]-[47]. In fact, FDI inflows to developing countries are often models that use unsustainable energies for the environment according to the "pollution haven" hypothesis. Developing countries often have to trade-off between globalization, attracting foreign direct investment capital flows together with economic growth and energy intensity as well as environmental pollution. Therefore, in this study, we include FDI inflows with three other main factors to outline a general picture of environmental degradation.

Finally, the suitability and stability of the model in both short and long run are checked by the normality, serial correlation as well as heteroskedasticity tests of residual, RESET test, cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ).

3.2 Data

Data for this study are collected from the World Development Indicators (WDI) of the World Bank and Database of the United States Energy Information Administration (EIA) for Vietnam at an annual frequency from 1995 to 2018, focusing on the theoretical relationship of the EKC hypothesis and the determinants of environmental degradation including energy consumption, economic growth, trade openness, and foreign direct investment. Therefore, the series of variables collected include CO_2 emissions per capita (tons), GDP at constant 2010 prices per capita (USD), energy consumption per capita (million Btu), and real FDI (USD).

Descriptive statistics of the research variables are presented in Table 1. The average CO_2 emission per capita in the period of 1995-2018 in Vietnam is 1.33 tons/year. Meanwhile, the average GDP per capita for the whole period remains at USD 1156. The average energy consumption is 17.8 thousand Btu per person, equivalent to 5.217 kWh/person per year.

4. EMPIRICAL RESULTS AND DISCUSSIONS

4.1. Unit Root Tests Results

The first step in time series analysis is to determine the integration order of each variable and to ensure that the input data series satisfy the requirement of an ARDL cointegration test in which all variables in the model are not integrated of order 2. This study uses the Phillips-Perron unit root test and the KPSS stationary test since these unit root tests and stationary tests have been well explained in existing literature, further discussion on testing procedures is not necessary.

Table 2 shows that the null hypothesis where exists a unit root in level variables cannot be rejected by the PP test, but the one in which the variable series is stationary is rejected by KPSS stationary test. When the variables are taken for the first difference, results in both PP and KPSS tests show that all first difference series are stationary. Thus, all research variables are series integrated of order 1 – I (1), satisfying the conditions of the ARDL model.

Table 1. Statistical summary.

Variable	Average	Standard deviation	Min	Max
CO_2	1.3285	0.6914	0.3883	2.81
GDP	1155.609	415.5971	583.3141	1964.476
EN	17.7998	8.8348	6.1082	34.2507
TO	138.6239	61.5528	49.4072	262.1515
FDI	5.86E+09	4.65E+09	1.30E+09	1.55E+10

Note: CO_2 emissions per capita (CO_2) are measured in metric tons, real GDP per capita (GDP) are measured in US dollars constant 2010, energy consumption per capita (EN) in million Btu, the trade openness (TO) calculated by the ratio of total exports and imports to GDP and real inflow of foreign direct investment (FDI) are measured in US dollars.

Table 2. Unit root tests results.

Variable	Phillip-Perron test	KPSS test
LCO_2	-1.8154	0.60400*
LGDP	-1.0655	0.6005*
LEN	-3.2197*	0.5789*
LTO	-1.6005	0.5886*
LFDI	-0.3355	0.5151*
ΔLCO_2	-3.8656**	0.2644
ΔLGDP	-3.5710*	0.1562
ΔLEN	-5.8066**	0.4563
ΔLTO	-3.7268*	0.2054
ΔLFDI	-3.3943*	0.1348

*Note: * and ** represent 10% and 5% statistical significance, respectively.*

4.2. Cointegration Tests Results

To perform the ARDL cointegration test, the optimal lag structure of the system according to the AIC was determined first because it has outstanding efficiency in small sample studies. Cointegration test results are shown in Table 3, indicating that the F-statistic is greater than the upper bound at the 1% significance level. Therefore, there exists the long-run links among the analysis variables in the model.

To assess whether the estimated results are stable or not, according to [33], the *t-statistic* of the regression coefficient θ_0 corresponding to the variable $LCO_{2\ (t-1)}$ should be considered. If the absolute value of this *t-statistic* is greater than the absolute value of the upper bound of the variable [33], the cointegration result obtained in Table 4 is supported. The found *t-statistic* is -5.408474 while the upper bound of the dependent variable at the 1% significance level is -4.6, meaning that it is possible to confirm cointegration between the variables.

Next, the research model is included error correction term to accurately reflect both short and long-run relationships among the variables.

Table 3. Cointegration test results.

		F-Critical							
k	F-Statistic	90%		95%		97.50%		99%	
		I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
4	8.8504***	2.752	3.994	3.354	4.774	3.25	4.49	4.768	6.67

*Note: *** represents 1% statistical significance.*

Table 4. Results of ARDL estimation with dependent variable LCO_2.

Long-run elasticities				
Variable	*Coefficient*	*Std. Error*	*t-Statistic*	*Prob.*
LGDP	2.7291**	1.0856	2.5139	0.0331
LEN	-1.3046	0.7444	-1.7525	0.1136
LTO	0.6048***	0.1553	3.8953	0.0036
LFDI	-0.0100	0.0304	-0.3287	0.7499
$EC = LCO_2$ - (2.7291 * LGDP - 1.3046 * LEN + 0.6048 * LTO - 0.0100 * LFDI)				
Short-run elasticities				
Constant	-13.6897***	1.6844	-8.1276	0.0000
ΔLGDP	5.1597***	0.9663	5.3398	0.0005
ΔLEN	0.8636***	0.2170	3.9791	0.0032
ΔLEN_{t-1}	0.9443***	0.2537	3.7215	0.0048
ΔLTO	0.4226**	0.1439	2.9371	0.0166
ΔLTO_{t-1}	-0.5541***	0.1443	-3.8389	0.0040
ΔLFDI	-0.1667***	0.0281	-5.9255	0.0002
EC_{t-1}	-0.7449***	0.0932	-7.9950	0.0000
Diagnostic tests				
R^2	0.9174			
Adjusted-R^2	0.8729			
F-Statistic	20.6236	(0.0000)		
χ^2_{NORMAL}	0.9201	(0.6213)		
χ^2_{SERIAL}	4.0471	(0.0679)		
χ^2_{ARCH}	0.7769	(0.3781)		
χ^2_{RESET}	0.3243	(0.5847)		

*Note: ** and *** represent 5% and 1% statistical significance, respectively. ( ) is the p-values.*

4.3. ARDL Estimation Results

Finally, the ARDL model (1,1,2,2,1) with the optimal lags selected according to the AIC was estimated, the results are shown in Table 4 with the dependent variable of CO_2 emission level.

The existence of EKC was checked. According to the new approach of [3], the short-run and long-run coefficients of GDP are compared. The income elasticity results of CO_2 emissions in the short-run and long-run are presented in Table 4. The findings reveal that the impact coefficients of GDP are both positive and

statistically significant at 5 percent level in both long and short term. Particularly, the long-run elasticity of CO_2 emissions to GDP in the long run is 2.7291, smaller than the short-run result of 5.157. It is clear that CO_2 emission levels increase more slowly than income growth in the long run, implying CO_2 increases in the early stages of economic growth and in the next period, emissions decrease due to greater demand for clean technologies, and awareness of environmental protection among people and businesses as well as possible measures suggested by the Government to limit environmental pollution level. The above is also consistent with the findings of previous studies on the relationship between environmental quality and economic growth [1] - [4].

A positive impact of trade openness on CO_2 emissions both in the short and long run has been found, consistent with findings of previous studies [2], [5], [39]. The estimated coefficient of the variable LTO is 0.6048 and is statistically significant at 1% level, which means that CO_2 emissions per capital will increase by 0.6048% for every 1% increase in trade openness. Economic theory shows that the liberalization of trade between countries with different environmental protection methods could cause the pollution industry to be concentrated in countries with loose environmental standards [48]. International trade is negatively affecting the environmental quality in Vietnam though its impact is relatively low. This is because Vietnam is a net importer during the research period with the majority of the country imports are machinery and equipment, petroleum products, steel products, raw materials, electronics, plastics, and automobiles, which are highly energy-intensive and heavily polluted. This is also a common feature among less developed countries specializing in products that cause pollution to catch economic growth [48], [49].

In the short term, statistical evidence of the impact of all variables is found in the model on CO_2 emissions. Energy consumption has a positive impact on CO_2 emissions with a high statistical significance, consistent with previous studies in developing countries in general and Vietnam in particular [4], [39]. Economic growth of these countries has largely come from the promotion of industries, many of which highly involve pollution, especially when the level of development is still low, the industries consumes more energy and emits more waste than before. Meanwhile, post-production waste treatment has not been given adequate attention and has not received enough investment in technology. Another reason is due to certain changes in people's living standards as their better income including an increase in energy usage, leading to greater CO_2 emissions.

FDI has a negative impact on CO_2 emissions, consistent with the results of [14], [50]-[52]. The estimated coefficient of the FDI variable is -0.1667 and is statistically significant at 1% level, which means that CO_2 emissions per capita decreases by 0.1667% for every 1% increase in FDI inflows. It is clear that FDI inflows into Vietnam, with its low impact, are selective capital flows, using energy sources that are quite friendly to the environment, meaning that Vietnam's government's selection of FDI inflows has shown positive results for environmental pollution, supportive to the neo-liberal argument that FDI inflows are good for the environment and reduce pollution by transferring environmentally friendly technologies and manufacturing techniques from developed countries to Vietnam. Therefore, the pollution paradise hypothesis in Vietnam was rejected.

Finally, a series of diagnostic tests are performed on the ARDL model and the model passes all diagnostic tests. It was found that the residuals are normally distributed and serially uncorrelated up to order two. Furthermore, no evidence of the ARCH (AutoRegressive Conditional Heteroskedasticity) effect for the error variance of the model exists. The Ramsey RESET test indicates that the model is correctly specified. The CUSUM and CUSUMSQ statistics fluctuate within the 5% critical bound, implying that the estimated parameters are accurate and stable over time (see Figure 2).

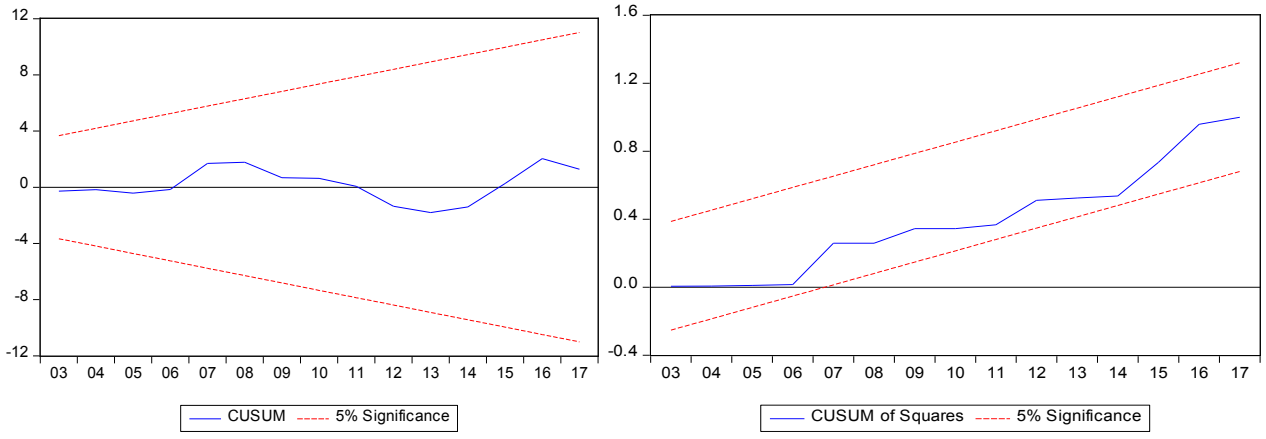

Fig. 2. The plots of CUSUM and CUSUMSQ statistics.

5. CONCLUSIONS AND POLICY RECOMMENDATIONS

This study is conducted to investigate the relationship between income, energy consumption, FDI, trade openness and CO_2 emissions in Vietnam. Using the ARDL cointegration approach with data in the period of 1995 - 2018, our results of the cointegration test provide evidence of the long-run relationship between CO_2 emissions, income, energy consumption, trade openness and FDI in Vietnam. Long-run income elasticity of CO_2 emissions per capita is found lower than the short-run one, which implies that Vietnam has reduced carbon dioxide emissions over time (as the rising income). This result is in line with the findings of [1] for Cambodia; [2] for Turkey, [3] for Jordan, Kuwait, Qatar, South Asian countries, Latin American countries and [3]-[4] for Vietnam. Obviously, energy consumption causes greater CO_2 emissions, and international trade increases pollution in countries with trade deficit for mainly energy-intensive imports like Vietnam. FDI inflows into Vietnam help to reduce CO_2 emissions and pollution, rejecting the "pollution heaven" hypothesis in Vietnam.

From the above, the authors offer a few recommendations that can help Vietnamese policymakers to formulate effective environmental policies and simultaneously stimulate economic growth. First of all, to promote economic growth and ensure environmental quality, Vietnam should emphasize on the development of clean technologies, limit the use of carbon-intensive technologies, select effective manufacturing technologies to reduce costs and increase productivity, which in turn can reduce environmental damage and stimulate economic growth. Secondly, businesses and other production and business establishments are instructed to strictly follow the environmental regulations and take social responsibility for the environment. The government should encourage a circular economy to reuse waste, recyclable products and reduce emissions into the environment.

Thirdly, international trade and FDI inflows play an important role in stimulating economic growth in Vietnam with the advantages of technology transfer and investment stimulation. The research results show that FDI inflows can reduce the degree of environmental degradation, so policy makers need to better locate and select FDI inflows to improve as well as maintain higher environmental standards in the Vietnamese economy. At the same time, they need to consider the ranking of foreign investment projects on environmental criteria as a basis for attracting investments. Regarding international trade, the Government also needs to issue policies to control imported goods, set environmental standards for imported products to limit negative impacts on the environment in the process of developing the economy.

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