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FACTORS AFFECTING CO_2 EMISSION IN VIETNAM: A PANEL DATA ANALYSIS

Le Trung Thanh*
University of Economics and Business, Vietnam National University

Nguyen Duc Khuong
University of Economics and Business, Vietnam National University

Abstract. *The purpose of this study is to investigate the major factors in the process of economic growth that influence the carbon dioxide (CO_2) emission in Vietnam. An Autoregressive Distributed Lag (ARDL) model was used to evaluate the impact based on Environmental Kuznets curve (EKC) and Pollution haven hypothesis (PHH) in 1990–2011. The results indicate that the economic growth, energy consumption, financial development and trade openness positively influence the CO_2 emissions, whereas foreign direct investment has a negative impact in the short term. Coefficient of joining ASEAN is not statistically significant. The findings of this study also support the validity of EKC and PHH in the Vietnamese economy. Therefore, it is important to use green energy, examine requirements for foreign investment and adopt trade-related measures and policies to increase environmental protection.*

Key words: *Environmental Kuznets Curve hypothesis, pollution haven hypothesis, economic growth, CO_2 emission*

1. Introduction

Vietnam has been considered as one of the countries that enjoy the fastest economic growth rate of around 6 percent between 2010 and 2015 (Statistical yearbook of Vietnam, 2016). However, like other countries in the world, this growth is usually accompanied by the significant increase in energy consumption and environmental problems, for example, CO_2 emissions (Balibey, 2015; Linh & Lin, 2014). According to Vietnam development report (2011), the level of emissions per capita in Vietnam remained at about two metric tons of CO_2, ranking 111th in the world and, it is expected to rise dramatically in the coming time (Jan, 2011). Vietnam is regarded as a country with air pollution reaching alarming levels. The population growth, urbanization and industrialization have momentous impacts on the natural environment, especially in Ho Chi Minh City and Hanoi.

* Corresponding author: University of Economics and Business, Vietnam National University. Room 705, Building E4, No. 144, Xuan Thuy Street, Cau Giay District, Hanoi, Vietnam, email: ltthanh@vnu.edu.vn

The fact that Vietnam became a member of The World Trade Organization in 2006 means that it has to fulfill a range of commitments on opening markets, which considerably affects its economy and environment. In this context, it is important to clarify factors affecting the environment. The primary aim of this study is to examine the effects of the economic growth, energy consumption, foreign direct investment, trade openness, financial development, and participation in ASEAN on CO_2 emissions in Vietnam. The ARDL model is adopted in this study.

This study is organized as follows: section 2 reviews the relation between CO_2 emissions and other factors. Section 3 presents the data collection and methodology. The empirical results are shown in Section 4. Section 5 concludes the study.

2. Literature reviews

The Environmental Kuznets Curve (EKC) hypothesis is one of the most popular theories about the relationship between economy and environment. In this theory, the Inverted U-shape graph (Kuznets, 1955) describes the non-linear relationship between income and pollution. Initially, it represents a positive relationship, in which, when income goes up, the environmental pollution becomes more serious. Up to a certain level of income, environmental standards are enhanced. Then, the development of science and technology results in more effective pollution control. The relationship is negative during this time. It means that we can reduce the degradation by improving income. There are some researchers supporting the EKC hypothesis such as Ang (2007) and Jalil and Mahmud (2009). However, studies by Lacheheb, Rahim and Sirag (2015) indicated that EKC did not exist in Algeria; it was also not supported in the case of Tunisia (Farhani & Ozturk (2015). Holtz- Eakin and Selden (1995) only identified a linear relationship, either positive or negative. In addition, Grossman and Krueger (1995) provided an N shape to explain that, at very high income levels, the scope of economic activity is too broadened, so the negative impacts on the environment cannot be rebalanced.

Many studies examined other additional explanatory variables or adopted different techniques to get more accurate results. For example, Lau, Choong and Eng (2014) discovered that the relationship between GDP and CO_2 emissions was only significant when adding two variables – FDI and trade openness. Ang (2007), Chen and Huang (2013) found out the effect of economic growth on the environment through energy consumption. The impacts of these variables on the environment follow two directions. Initially, the growth on demand for energy and natural resources increases emissions (positive relationship). After that, the improvement in advanced technology will reduce environmental pollution (negative relationship). In this study, we analyse six variables including: energy consumption (EC), financial development (FD), foreign direct investment (FDI), trade openness (TRADE) and participation in economic organizations.

Firstly, most of the studies agree that fossil fuels will have a positive impact on emissions (Apergis & Payne, 2009; Mercan & Karakaya, 2015) through the combustion process. According to Odhiambo (2009), energy consumption promotes economic expansion and financial development in developed countries where financial indicators make the significant contribution to total GDP (Al-Mulali & Sab, 2012). However, it also generates a large amount of CO_2 emissions, one of the main causes of global warming. While people enjoy high income, pollution from manufacture restrains life quality and productivity in the long term and negatively affects the economic development (Omri et al., 2015). Hence, Ali, Yusop and Hook (2015) support the issue of energy policies, green energy for example, to curb carbon emissions as well as maintain the economic growth.

Secondly, the PHH explains that because of high costs for waste management in developed countries, companies tend to move production facilities to developing countries through international trade and FDI, broadening pollution in these countries. Balibey (2015) indicated the positive relationship between FDI and CO_2 emission. Al-muladi (2012) emphasized that FDI was the major cause of the expansion of CO_2 emissions in Middle Eastern countries. However, FDI also promotes technology transfer that will help to control pollution in the country receiving investment through environmental standards and output products. In fact, FDI contributes to the economic growth and energy consumption without raising CO_2 emissions in G20 countries (Lee, 2013) and BRICSAM (Khachoo & Sofi, 2014); it even decreases CO_2 in Turkey (Ozturk & Oz, 2016). Kivyiro and Arminen (2014) defined both positive and negative effects on environment in sub-Saharan Africa.

Thirdly, trade openness affects directly CO_2 emissions by reallocating resources between polluted sectors. Commercial activities enable the economy to expand scale, which leads to promotion of the use of natural resources and spread of pollution (Jalil & Mahmud, 2009; Sharma, 2011). Lau, Choong and Eng (2014) found that trade along with FDI directly influenced the economic growth and emissions. This finding is consistent with the study by Bouttabba (2014) on the Iranian economy. However, trade liberalization encourages the change in production technology, enhances comparative advantages for developing countries, and creates many financial resources to reduce pollution (Maji & Habibullaha, 2015). It facilitates growth towards diversification in order to avoid excessive dependence on resource-based exports. Like in the EKC hypothesis, Jayanthakumaran, Verma and Liu (2012) and Akin (2014) used an inverted-U shape to illustrate effects on emissions. Trade openness intensifies pollution up to a certain level, after that it restrains environmental degradation.

Fourthly, financial development not only stimulates the economic growth, but also affects environmental qualitites. On the one hand, financial development enables many governments to access new and cheaper sources. It means the government can afford to invest in technical innovation and advanced technology to decrease emissions in areas such as Middle East and North Africa (MENA) (Omri et al., 2015); Indonesia

(Shahbaz et al., 2013); Malaysia (Islam et al.,2013); 24 economies in the world (Tamazian & Rao, 2010) and Tunisia (Farhani & Ozturk, 2015); financial development is declared to reduce emissions through technological innovation. In addition, countries could save a large amount of money because they do not need to pay expenditure for environment protection. On the other hand, Sadorsky (2010) insisted that financial development will boost energy consumption. It demonstrates the positive relationship between FD and emissions (Zhang, 2011; Bouttabba, 2014) or a positive correlation but not statistical significance in the long term (Acaravci & Ozturk, 2010). Last but not least, Phimphanthavong (2014) explained that the economic competition in ASEAN encouraged Laos to improve its economic performance, including strengthening investment, and trade cooperation, which affects environmental degradation indirectly.

Different results can be derived not only selecting explanatory variables but also applying various research models. With different methods such as ordinary least squares-OLS model, VECM Granger causality and Johansen cointegration, the existence of hysteresis and constraints observed in the sample could affect the results of analysis. For example, in Turkey, Ozturk and Oz (2016) pointed out that both in the short and long term, EKC hypothesis was proved with the ARDL model. Earlier, Halicioglu (2009) only clarified the Granger causality relationship; Ozturk and Acaravci (2010) concluded that the EKC hypothesis at causal framework by using a linear logarithmic model is not valid in the Turkish case.

In Vietnam, there are many studies on the EKC hypothesis. Manh (2014) claimed a strong relationship between the CO_2 emissions and income per capita in the period 1985–2010 and existence of the EKC in Vietnam. Meanwhile, with an insignificant coefficient Linh and Lin (2014) concluded that the EKC did not exist in Vietnam. In another research, by using the Johansen cointegration test and Granger causality, Tang and Tan (2015) showed that energy consumption, FDI and GDP were the most important determinants of CO_2. Inconsistent findings may arise from the lack of explanatory variables or limitation of econometric models.

3. Materials and method

In this study, the ARDL model is applied because of some advantages: (i) consistent and small sample size, estimated with a unique equation; (ii) possibility to be used irrespective of whether variables are I (0), I (1) or a mixture of both, finally, (iii) calculating in a short-term with error correction model (ECM) and long-term model without loss of degree of freedom (Pesaran, Shin & Smith, 2001; Ozturk & Acaravci, 2013). In the proposed model, all variables are converted into logarithm natural. Data are collected from the World Bank in the period 1990–2011.

The main objective of this research is to analyze factors affecting CO_2 emissions in Vietnam. To answer this question, we study two independent cases as shown in Equation (1) and (2). Equation (1) illustrates the EKC hypothesis, whereas Equation (2) expresses the pollution haven hypothesis and technology transfer.

$$CO_{EKC} = f(GDP, GDP^2, EC, FD, FDI, TRADE, Dum_{ASEAN}) \quad (1)$$

$$CO_{PHH} = f(TRADE, TRADE^2, EC, FD, FDI, GDP, Dum_{ASEAN}) \quad (2)$$

ARDL models for two cases are presented in equations (1a) and (1b), as follows:

$$\begin{aligned} CO_t = {} & \alpha_1 + \sum_{i=1}^{a1} b_{1i} CO_{t-i} + \sum_{j=1}^{a2} c_{1j} GDP_{t-j} + \sum_{g=1}^{a3} d_{1g} GDP^2_{t-g} + \sum_{h=1}^{a4} e_{1h} GDP^3_{t-h} + \sum_{k=1}^{a5} f_{1k} TRADE_{t-k} \\ & + \sum_{m=1}^{a6} x_{1m} EC_{t-l} + \sum_{n=1}^{a7} y_{1n} FDI_{t-n} + \sum_{p=1}^{a8} z_{1p} FD_{t-p} + \sum_{q=1}^{a9} \theta_{1p} Dum ASEAN_{t-q} + \varepsilon_{1t} \end{aligned} \quad (1a)$$

$$\begin{aligned} CO_t = {} & \alpha_1 + \sum_{i=1}^{a1} b_{1i} CO_{t-i} + \sum_{j=1}^{a2} c_{1j} TRADE_{t-j} + \sum_{g=1}^{a3} d_{1g} TRADE^2_{t-g} + \sum_{h=1}^{a4} e_{1h} TRADE^3_{t-h} \\ & + \sum_{k=1}^{a5} f_{1k} GDP_{t-k} + \sum_{m=1}^{a6} x_{1m} EC_{t-l} + \sum_{n=1}^{a7} y_{1n} FDI_{t-n} + \sum_{p=1}^{a8} z_{1p} FD_{t-p} + \sum_{q=1}^{a9} \theta_{1p} Dum ASEAN_{t-q} + \varepsilon_{1t} \end{aligned} \quad (1b)$$

where: CO: per capita of CO_2 emissions (metric tons per capita); GDP: per capita income; EC: per capita of energy consumption (kg oil per capita); FDI: foreign direct investments (BoP, current US $); TRADE: trade openness, calculated as the ratio of the total value of exports and imports to total real GDP (%); FD: financial development, represented by domestic credit to private sector (Islam et al., 2013); Dum_{ASEAN}: dummy D equals 1 when Vietnam joins ASEAN, otherwise it equals 0, and ε is error.w

Coefficients d_{1g} and e_{1h} indicate the corresponding shape of the hypothesis. If d_{1g} is smaller than 0 and statistically significant, the model suggests the existence of EKC hypothesis with the inverted U shape, while when e_{1h}, is smaller than 0 and statistically significant, it is illustrated by an N shape.

We establish the relationship by using the ARDL model in the following four steps. Firstly, cointegration is calculated by Bounds test with F statistics. Secondly, the ARDL with optimal lag is estimated based on Schwarz-Bayes Criterion (SBC) or Akaike Information Citerion (AIC). Thirdly, the relationship between economic growth and CO_2 emissions in a short term and a long term is analysed. Finally, the stability and compatibility of models are examined by Heteroskedasticity test (HET), Correlation Langrange multiplier test (LM), Ramsey RESET test (RESET), Cumulative sum of recursive residuals (CUSUM) and Cumulative sum of squares of recursive residuals (CUSUMSQ). In fact, Eviews 9.5 software can help to choose automatically optimal lag with a fixed Dum_{ASEAN} variable.

Bounds test is based on the hypothesis that variables have I (1) or I (0), therefore occurrence of variable I(2) makes models inappropriate. Augmented Dickey-Fuller test statistic is used to reject I(2) or more. The bounds tests are shown in equations (2a) and (2b) as follows (Jayanthakumaran, Verma & Liu, 2012; Akin, 2014):

$$\Delta CO_t = \alpha_0 + \sum_{i=1}^{a1} b_{2i}\Delta CO_{t-i} + \sum_{j=1}^{a2} c_{2j}\Delta GDP_{t-j} + \sum_{g=1}^{a3} d_{2g}\Delta GDP^2_{t-g} + \sum_{h=1}^{a4} e_{2h}\Delta GDP^3_{t-h}$$
$$+ \sum_{k=1}^{a5} f_{2k}\Delta TRADE_{t-k} + \sum_{m=1}^{a6} x_{2m}\Delta EC_{t-l} + \sum_{n=1}^{a7} y_{2n}\Delta FDI_{t-n} + \sum_{p=1}^{a8} z_{2p}\Delta FD_{t-p} + \lambda CO_{t-1} + \lambda_1 GDP_{t-1} \quad (2a)$$
$$+ \lambda_2 GDP^2_{t-1} + \lambda_3 GDP^3_{t-1} + \lambda_4 TRA_{t-1} + \lambda_5 EC_{t-1} + \lambda_6 FDI_{t-1} + \lambda_7 FD_{t-1} + \lambda_8 DumASEAN_{t-1} + \varepsilon_{2t}$$

$$\Delta CO_t = \alpha_0 + \sum_{i=1}^{a1} b_{2i}\Delta CO_{t-i} + \sum_{j=1}^{a2} c_{2j}\Delta TRADE_{t-j} + \sum_{g=1}^{a3} d_{2g}\Delta TRADE^2_{t-g} + \sum_{h=1}^{a4} e_{2h}\Delta TRADE^3_{t-h}$$
$$+ \sum_{k=1}^{a5} f_{2k}\Delta GDP_{t-k} + \sum_{m=1}^{a6} x_{2m}\Delta EC_{t-l} + \sum_{n=1}^{a7} y_{2n}\Delta FDI_{t-n} + \sum_{p=1}^{a8} z_{2p}\Delta FD_{t-p} + \lambda CO_{t-1} + \lambda_1 TRADE_{t-1} \quad (2b)$$
$$+ \lambda_2 TRADE^2_{t-1} + \lambda_3 TRADE^3_{t-1} + \lambda_4 TRA_{t-1} + \lambda_5 EC_{t-1} + \lambda_6 FDI_{t-1} + \lambda_7 FD_{t-1} + \lambda_8 DumASEAN_{t-1} + \varepsilon_{2t}$$

In both equations (2a) and (2b), coefficients *b, c, d, e, f, x , y, z* represent a short-term relationship, λ, λ_1, λ_2, λ_3, λ_4, λ_5, λ_6, λ_7, λ_8 show a long-term relationship. F test demonstrates cointegration with null hypothesis $H_0\ \lambda = \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = \lambda_6 = \lambda_7 = \lambda_8 = 0$. Let us assume that Upper critical bounds – UCB are the values when the variable is I (1) and Lower critical bounds – LCB when the variable is I (0). Cointegration exists if F> UCB; it does not exist if F <LCB; and is inconclusive if LCB <F <UCB. If cointegration exists, we estimate the long-run and short-run models. Equations (3a) and (3b) illustrate the relationship in a short term as follows:

$$\Delta CO_t = \alpha_3 + \sum_{i=1}^{a1} b_{3i}\Delta CO_{t-i} + \sum_{j=1}^{a2} c_{3j}\Delta GDP_{t-j} + \sum_{g=1}^{a3} d_{3g}\Delta GDP^2_{t-g} + \sum_{h=1}^{a4} e_{3h}\Delta GDP^3_{t-h}$$
$$+ \sum_{k=1}^{a5} f_{3k}\Delta TRADE_{t-k} + \sum_{m=1}^{a6} x_{3m}\Delta EC_{t-l} + \sum_{n=1}^{a7} y_{3n}\Delta FDI_{t-n} + \sum_{p=1}^{a8} z_{3p}\Delta FD_{t-p} \quad (3a)$$
$$+ \lambda_8 DumASEAN_{t-1} + \omega ECT + \varepsilon_{3t}$$

$$\Delta CO_t = \alpha_3 + \sum_{i=1}^{a1} b_{3i}\Delta CO_{t-i} + \sum_{j=1}^{a2} c_{3j}\Delta TRADE_{t-j} + \sum_{g=1}^{a3} d_{3g}\Delta TRADE^2_{t-g} + \sum_{h=1}^{a4} e_{3h}\Delta TRADE^3_{t-h}$$
$$+ \sum_{k=1}^{a5} f_{3k}\Delta GDP_{t-k} + \sum_{m=1}^{a6} x_{3m}\Delta EC_{t-l} + \sum_{n=1}^{a7} y_{3n}\Delta FDI_{t-n} + \sum_{p=1}^{a8} z_{3p}\Delta FD_{t-p} \quad (3b)$$
$$+ \lambda_8 DumASEAN_{t-1} + \omega ECT + \varepsilon_{3t}$$

4. Results and discussion

Environmental qualities and economic growth have a strong relationship. Polluted environment constrains the economic development because an input component for economic growth is taken from the environment. The World Bank Indicator database shows that environmental pollution in Vietnam annually damages 5% of GDP. Emissions per capita in 1960 were 0.21 tons, in 1991 were 0.31 tons, but increased sharply to 1.97 tons in 2011, while GDP per capita only rose from 143 USD in 1991 to 1,542 USD in 2011. Some economic experts predict that if GDP doubles without environmental

protection, the pollution will expand three or four-fold in the next 10 years. In the period 2000–2009, total primary energy consumption in Vietnam grew on average by 6.54% per year. The size and efficiency of energy consumption are low while the intensity of using energy is twice as high as the average of the world. In 1991, energy consumption was 269 kg of oil per capita and increased to 667 in 2013.

(a) Table 1 reports summary statistics of the annual data. The result of ADF test indicates that at the 5% level of significance, all variables are feasible to use ARDL at first difference.

TABLE 1. **Results of statistical analysis**

	CO	GDP	TRADE	EC	FDI	FD
Mean	-0.293	6.099	4.658	5.996	21.35	3.563
Std. Dev.	0.613	0.766	0.285	0.304	1.010	0.737
Skewness	-0.036	-0.167	-0.077	0.289	-0.245	0.198
Kurtosis	1.681	2.25	1.847	1.799	2.99	1.608
Jarque-Bera	1.599	0.619	1.241	1.628	0.22	1.92
Prob.	0.45	0.734	0.538	0.443	0.896	0.383
Obs.	22	22	22	22	22	22
ADF test I(0)	0.563	-1.635	-0.193	1.146	-2.189	0.011
Prob.	0.98	0.45	0.93	0.99	0.22	0.95
ADF test I(1)	-4.262	-5.615	-7.917	-4.8	-3.248	-4.802
Prob.	0.01	0.00	0.00	0.00	0.03	0.00

(b) Establishing ARDL for the two cases with all variables and rejecting variables that are insignificant, we have results in Table 2. F test is greater than UCB at the significant level 1%, so we could reject the null hypothesis of no cointegration. It is understood that the pure EKC and PHH models have only independent variables (GDP, GDP^2) or (TRADE, $TRADE^2$).

TABLE 2: **Cointegration bound test results**

Model	F-statistic	k	Significance	I0 Bound	I1 Bound
EKC & EC, TRADE	5.2732	4	1%	3.29	4.37
PHH & EC, FD, FDI	10.9621	5	1%	3.06	4.15

(c) Table 3 presents ARDL model with optimal lag. Based on AIC and SBC, we selected two optimal ARDL models for two cases: ARDL(1, 1, 1, 2, 2) and ARDL(2, 1, 1, 0, 0, 1).

TABLE 3. **ARDL optimal model results**

EKC & EC, TRADE			PHH& EC, FD, FDI		
ARDL(1, 1, 1, 2, 2)			ARDL(2, 1, 1, 0, 0, 1)		
Variable	Coef.	Prob.	Variable	Coef.	Prob.
CO(-1)	-0.7037	0.10**	CO(-1)	-0.053	0.82
GDP	-2.4885	0.10**	CO(-2)	-0.767	0.01***
GDP(-1)	5.2845	0.02***	TRADE	6.653	0.00***

GDP^2	0.1548	0.19	TRADE(-1)	3.279	0.06**
GDP^2(-1)	-0.3955	0.03***	$TRADE^2$	-0.642	0.01***
EC	2.0484	0.00***	$TRADE^2$(-1)	-0.283	0.12*
EC(-1)	1.6353	0.03***	FD	0.130	0.18
EC(-2)	-0.426	0.27	FDI	-0.073	0.03***
TRADE	-0.0579	0.80	EC	1.206	0.01***
TRADE(-1)	0.6117	0.02***	EC(-1)	1.049	0.01***
TRADE(-2)	-0.1762	0.24			
C	-29.7277	0.00***	C	-39.126	0.00***

*, **, *** *significant at 15%, 10%, 5 % level*

(d) Short run and long run ARDL models are shown in Table 4. The main results of our research are as follows:

(i) the EKC hypothesis with the inverted- U shape exists only in the long term in Vietnam. In the short term, the relationship between income and CO_2 emissions is illustrated by a U-shape, not complying with the EKC (the coefficient of GDP^2 is 0.155). An increase of 1% in real GDP per capita leads to a reduction of 2.488% in CO_2 emission in the short term but enlargement of 1.6412% in the long term. Meanwhile, GDP^2 broadens emissions by 0.155% in the short term and reduces it by 0.14% in the long term. Our result contrasts with Linh and Lin (2014); Al-Mulali, Saboori and Ozturk (2015), whereas it complements Manh (2014) for the impact of energy consumption.

(ii) Trade openness has a positive impact on CO_2 emissions, each increasing percent of the trade openness leads to a 6.63% rise in CO_2 emissions in the short term and about 5.46% in the long term. This was attributed to the value of Vietnamese imports being greater than that of exports in the considered period. The ratio export to import for Vietnam was about 0.39 in 1990 and grew to 0.95 in 2011, which was always less than 1. The coefficient of $TRADE^2$ is negative and statistically significant (cf. Akin, 2014) and supports PHH in Vietnam. The highest value is 214.56%, after that trade openness will reduce pollution.

(iii) Energy consumption always maintains 2-dimensional relationships in both cases. In the case of the EKC, an increase of 1% in EC leads to 2.048% emissions in the short run and 1.9121% in the long run. This coefficient is higher than other countries in Asia. It is 1.15 for China , 0.97 for India and 0.7 for Malaysia (Islam et al., 2013). The positive relationship between EC and CO_2 emissions is also consistent with the results from the study by Tang and Tan (2015) in Vietnam and most of studies in the world such as: Halicioglu (2009), Apergis and Payne (2009), Mercan and Karakaya (2015) and Chen and Huang (2013). Our result supports the view of Ang (2007) that the influence of the economic growth is explained by energy consumption and pollution expansion in the long term. The impact of EC decreases when

considering models in the case of PHH. One percent increase in EC causes only a 1.1957% increase in CO_2 in the short term and that of 1.235% in the long run, which shows that technology transfer has promoted innovation to help narrow emissions.

(iv) The influence of FDI on the CO_2 emissions is not reflected in the case of the PHH instead of the EKC hypothesis. The study results show important similarities with Maji and Habibullaha (2015) to suggest that FDI plays a (significant) role in emission reduction. When FDI inflow to Vietnam increases by 1%, the degradation will drop by 0.0647% in the short term and by 0.0402% in the long term. This is explained by the contribution of FDI to the economic growth by improving industrial production capacity and exports. Small reduction may stem from slow transfer of advanced technologies. On the other hand, most of the FDI allocated to underdeveloped sectors is protected. Although FDI creates more job opportunities for those who are not highly skillful, it does not provide the same advantages for the domestic private sector and might prevent the labor mobility in the country, especially labor with high levels of workmanship. The decrease in labor productivity is illustrated by low growth of income. Therefore the impact of FDI does not comply with the hypothesis.

(v) Financial development in Vietnam has a statistically significant positive relationship with pollution in the short term but insignificant in the long term. Each added percent of FD increases environmental pollution by 0.1189% (about 0.13% in the long run). Our result is similar to the findings by Al-Mulali and Sab (2012), Farhani and Ozturk (2015), Bouttabba (2014). It is explained by the fact that the private sector is entitled to less preferential treatment from the government. The private sector, mostly small and medium-sized businesses, has restricted access to commercial capital. In addition, the existence of institutional barriers and unfavorable business environment restrains domestic private enterprises from the motivation for long-term investment, expanding the business scale, or innovating technology to improve productivity and competitiveness. Continuous usage of outdated technologies causes low productivity and negative impact on environment.

(vi) Finally, there is no evidence for the assumption that Vietnam's participation in ASEAN would affect indirectly the environmental degradation in the country. The coefficient ECM (-1) is negative and statistically significant, which confirms a stable long-run relationship and efficient establishing. **So, the error correction mechanism for this model is working properly, which means that carbon emission converges to its long run equilibrium by 170.4% speed of adjustment in the case of Equation (1) and 180.06% in the case of Equation (2).**

TABLE 4. **Estimated short and long run coefficients**

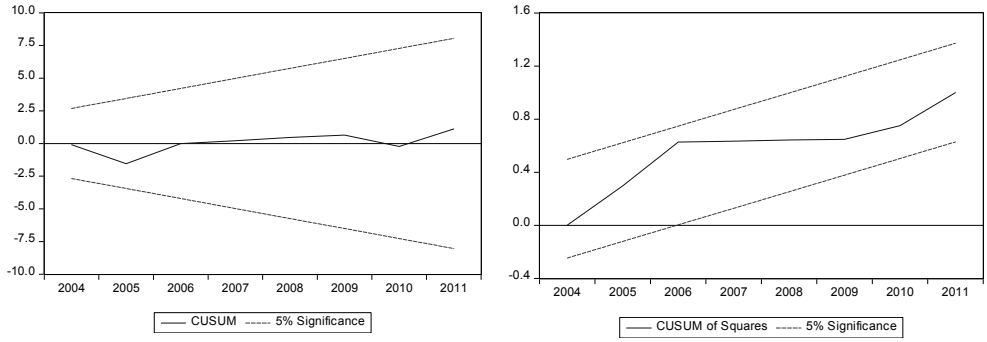
EKC & EC, TRADE					
Short run			Long run		
Variable	Coef.	Prob.	Variable	Coef.	Prob.
D(GDP)	-2.488	0.00	GDP	1.6412	0.00
$D(GDP^2)$	0.155	0.01	GDP^2	-0.1413	0.00
D(EC)	2.048	0.00	EC	1.9121	0.00
D(EC(-1))	0.426	0.05	TRADE	0.2216	0.20
D(TRADE)	-0.058	0.60	C	-17.4493	0.00
D(TRADE(-1))	0.176	0.06			
ECM(-1)	-1.704	0.00			
$ECM = CO - (1.6412*GDP -0.1413*GDP^2 + 1.9121*EC + 0.2216*TRADE -17.4493)$					
PHH& EC, FD, FDI					
Short run			Long run		
Variable	Coef.	Prob.	Variable	Coef.	Prob.
D(CO(-1))	0.7747	0.00			
D(TRADE)	6.6324	0.00	TRADE	5.4556	0.00
$D(TRADE^2)$	-0.6420	0.00	$TRADE^2$	-0.5081	0.00
D(EC)	1.1957	0.00	EC	1.2389	0.00
D(FD)	0.1189	0.06	FD	0.0714	0.17
D(FDI)	-0.0647	0.02	FDI	-0.0402	0.01
ECM(-1)	-1.8006	0.00	C	-21.4931	0.00
$ECM = CO- (5.4556*TRADE -0.5081*TRADE^2 -0.0402*FDI +1.2389*EC + 0.0714*FD -21.4931)$					

Where: $D(GDP)= \Delta GDP_t - GDP_{t-1}$; $D(CO(-1))= \Delta CO_{t-1} - CO_{t-2}$;
$D(EC)= \Delta EC_t - EC_{t-1}$; $D(FD)= \Delta FD_t - FD_{t-1}$; $D(FDI)= \Delta FDI_t - FDI_{t-1}$;

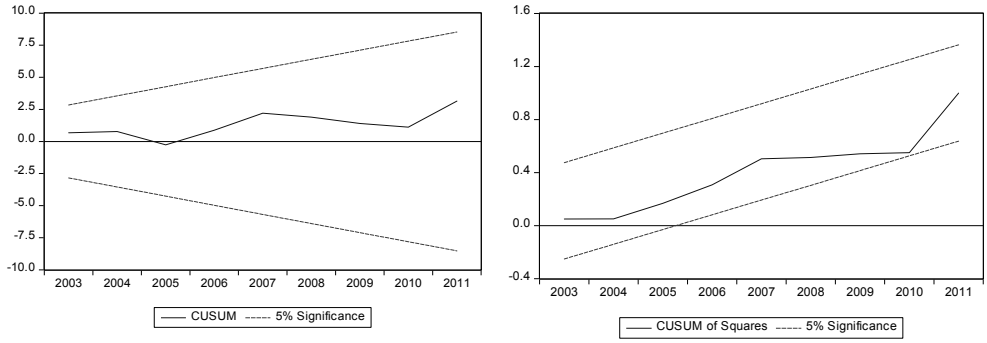
(e) Residual and Stability diagnostic results in Table 5 accepted the null hypothesis H_0: model has no heteroscedasticity, no correlation level 2 and no omitted variables. Since CUSUM and CUSUMSQ lines stay within the critical bounds at the 5 % level (Figure 1), the model estimations are stable.

TABLE 5. **Diagnostic results**

Model		**HET**	**LM**	**RESET**	**CUSUM**	**CUSUMSQ**
EKC & EC, TRADE	Coef.	9.6386	5.0595	3.7962	stable	stable
	Prob.	0.56	0.08	0.09	stable	stable
PHH & EC, FD, FDI	Coef.	12.6523	4.6310	2.9976	stable	stable
	Prob.	0.24	0.10	0.12	stable	stable



EKC & EC, TRADE



PHH & EC, FD, FDI

FIG. 1. **Plot of cumulative sum and cumulative sum-squared**

5. Conclusions

By using an ARDL model, this research analyses factors affecting CO_2 emissions in the period 1990–2011. The results of this study show that while the EKC hypothesis only exists in the long term, the PHH hypothesis occurs in Vietnam in both a short and a long term. The openness of economy has a positive impact on emissions. GDP per capita reduces emissions in the short term but increases the level of pollution in the long term. Energy consumption plays an important part in promoting emission. The role of FDI is only significant in the theory of PHH. The Financial development shows positive considerable impact in the short term. This raises the issue of expansion of trade and economic growth, while ensuring control of environmental degradation. Additionally, these results do not find any evidence of the negative effect on the increase of CO_2 emission since Vietnam joined ASEAN.

The difference between coefficient GDP^2 in the short run and long run in Vietnam could be explained by the ideas in Salim, Rafiq & Shafiei (2017). Developing economies achieve a certain level of economic growth, their emissions tend to decline. It is when environmental standards are raised after the pursuit of economic goals. Another important result is that the coefficients of Vietnam are similar to those of Lao (Phim-

phathvong, 2014), Indonesia, the Philippines in the short-term; and Malaysia, Singapore and Thailand (Saboori & Sulaiman, 2013) or China (Jalil & Mahmud, 2009) in the long term. This requires a careful consideration of characteristics of each member in cooperation policy. Basically, analyzing the impact of economic development on environment by the PHH is more appropriate than the EKC hypothesis in Vietnam. According to our calculation, trade openness at the extreme points is 214.56% of total real GDP (trade openness was 178.77% in 2015). Assuming that remaining conditions do not change, there is a big gap before the expansion of trade openness could restrain emissions. Especially, in the upcoming time when Vietnam becomes the member of economic organizations and implements commitments on opening markets, the risks to the environment would continue to spread. Besides, financial development and economic growth have a positive influence on emissions. Thus, the economic development policies need to strengthen the role of environmental protection.

Our research supports the view that economic growth increases pollution through the use of energy. This requires Vietnam to develop green energy, green industry and improve energy productivity to achieve high GDP growth rates and lower environmental emissions.

According to our study, FDI contributes to reducing the CO_2 emissions. However, in Vietnam, there were periods in which FDI caused serious pollution, especially with untreated sewage and industrial wastewater discharged into rivers, which degraded ecosystems and threatened the lives and health of people. For that reason, Vietnam needs to enhance the inspection requirements for foreign investors and accelerate the transfer of advanced environmentally-friendly technologies. Green growth has been the leading strategy today.

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