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Article

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The Role of Renewable Energy Consumption and FDI in Testing the Existing of Environmental Kuznets Curve in Vietnam

Thuan Nguyen[1], Bac Hai Dang[1,2]*, Thi Diem Nga Tran[2], Thi Oanh Hoa Su[2]

[1]Ho Chi Minh City Open University, Vietnam, [2]University of Natural Resources and Environment, Ho Chi Minh City, Vietnam. *Email: haidb.16ae@ou.edu.vn

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ABSTRACT

This study tests the environmental Kuznets curve (EKC) while examining the role of renewable energy sources and FDI to potentially effect the amount of CO_2 emissions in Vietnam. Using Autoregressive Distributed Lag (ARDL) approach, the relationship between CO_2 emissions and GDP, FDI and sources of energy consumption has been investigated during 1980-2018 in Vietnam. The results of study reveal that there is non-existence EKC for Vietnam in long run and a sign of inverted U- shape in short run in this period. The analysis also shows that the coefficient of energy consumption from hydro-power renewable sources which correlates to CO_2 emissions is negative and significant while FDI leads to increasing carbon dioxide emissions in the long run. That implies Vietnam could have been benefited from a drop in CO_2 emissions at some point in the early stage of the period, however, the country has been facing environmental pollution increase as GDP and FDI growth.

Keywords: Environmental Kuznets Curve, Renewable Energy, FDI, Vietnam
JEL Classifications: O44, Q56, Q4

1. INTRODUCTION

Since embarking in 1986 on economic reform, Vietnam has made a remarkable shift to a market economy that has resulted in impressive wealth, trade and investment gains. During over the past 30 years, the economy has achieved uninterrupted growth, recording an average GDP growth rate around 6.6% a year. Energy fuel resource of various types such as coal, natural gas, petroleum have played a key role in driving the Vietnamese economy. But current consumption and production patterns are placing enormous pressure on environment. According to Audinet et al. (2016) the carbon intensity of Vietnam's economy at almost triple the world average and if Vietnam have emitted amount of CO_2 at the current pace, it will be projected to rise by 495 million tons of carbon dioxide ($MtCO_2$) in 2030. That would cause environmental degradation, undermine human productivity and limit the economy growth.

The relationship between environmental degradation and economic growth has been got attention by many economists for years. In common, economic growth will cause environmental degradation and pollution increase, however, environmental Kuznets curve (EKC) showed reverse trend at high- income levels, economic growth leads to environmental improvement. Panayotou (1993) argued EKC hypothesis at higher levels of development, by increasing environmental awareness, enforcement of environmental regulations, better technology and more environmental expenditure, which will result in declining of pollution and environmental degradation. A vary of empirical studies have been carried out to test the existence of EKC in different countries and in distinct periods. Many authors found that within a panel of countries, some of them, the EKC hypothesis is supported while it is not the case for some other (Karsch, 2019; Shahbaz et al., 2019; Stern, 2004; Sun, 1999). The author Shahbaz et al. (2019) stated the validation of the EKC hypothesis can vary in functions of the country-specific factors, study periods and underlying methods. He also noted that the EKC hypothesis holds mainly in high-income and in upper-middle-income countries.

Though scholar authors have studied EKC prolonged time, but there are only a few researches for Vietnam. In 2015, Al-Mulali et al., and Tang and Tan tested Vietnamese EKC in the period of 1981-2011 and 1976-2009 respectively, however the results of the two studies contradicted each other. The outcomes of Al-Mulali et al. (2015) revealed that there is no sign of the existence of EKC in the period of 1981-2011 and Vietnam had followed the pollution haven hypothesis (PHH) because capital increased pollution. In the contrast, Tang and Tan (2015) found an inverted U-shaped relationship between CO_2 emissions and economic growth in Vietnam during period 1976-2009. Recently, the comprehensive study about EKC in Vietnam of Shahbaz et al., (2019) has confirmed this existence in long term but not for short run in the period of 1974-2016. This study also suggested N-shaped described better long run between income - CO_2 emission relationship and made a warning that Vietnam can expect a temporary reduction in CO_2 emissions at a given stage of economic growth. However, this will be followed by a further increase of CO_2 emissions after reaching another income turning point.

Adapting from previous studies, our study extends the EKC literature by retesting EKC in Vietnam from 1980 up to 2018 and examining whether renewable energy and FDI will be effective in the role of reducing CO_2 emission. According to our knowledge, there has been no research paper that examines the potential impact of these elements for Vietnam within the EKC framework. Using EKC hypothesis, this study has conducted an Autoregressive Distributed Lag (hereafter ARDL) bounds approach to test cointegration. The impact of renewable energy consumption and FDI flow on CO_2 emissions in both short and long run in Vietnam will ensure important data for the policies towards sustainable development.

2. LITERATURE REVIEW

The Environmental Kuznets Curve (EKC) was inherited from the concept of Kuznets curve, which is inverted U- shaped between inequality and development with the hypothesis as an economy develops, market forces begin to increase and economic inequality decreases. The Environmental Kuznets Curve adheres to the same idea with the relationship between environmental quality and income per capita. Grossman and Krueger (1991) applied the hypothesis to argue that economic growth is necessary in order for environmental quality to be maintained or improved in the path of sustainable development. Based on technology, tastes and environmental investment, greater economic activities will lead to increase the environmental quality (World Bank, 1993). The EKC has also faced criticisms due to its assumption that environmental damage does not reduce economic activity sufficiently to stop the growth process and reduce the level of income in the future (Arrow et al., 1995; Stern, 2004). However, the existence (or non-existence) of an EKC has significant policy implications (Bruyn and Heintz, 1999). If true, it provides evidences for the success of sustainable development strategies and economic growth is the key to solve environmental problems. If not, it suggests country to adopt stringent environmental policies to prevent the consequences of economic growth.

In the theme of EKC framework, researchers have tested a various of environmental degradation indicators which can be group into local and global pollutants. Stern (2004) found that EKC studies using local pollutants were more likely to display an inverted U-shape relation with income because local impacts are likely to give the rise to environmental policies to correct the externalities. For global pollutants like CO_2, the empirical evidences on the validity of the EKC in recent studies fail to yield consistent results. Dinda and Coondoo (2006) found mixed results when they use a panel data cointegration methodology in a bivariate setting. They suggested a time series approach because of having a suspicion about a dynamic link between CO_2 emissions and income. Halicioglu (2009) stated that the cointegration approach of Pesaran et al. (2001) for bounding test has certain econometric advantages in comparison to other single cointegration procedure. Following the ARDL approach, many studies has confirmed the existence of the EKC in developing countries while a number of the opposed results have also been reported (Mrabet and Alsamara, 2017; Saboori and Sulaiman, 2013; Shahbaz et al., 2019).

The common factors often to be tested in EKC function are energy consumption and foreign direct investment (FDI). In the case of Vietnam, FDI has played a crucial role in economic development by attracting capital, enhancing firm-level efficiency, transferring cutting-edge technologies and encouraging product and process innovation (Hoang and Duong, 2018). However, FDI - environmental emissions linkage has become a controversial topic, whether FDI inflow could have brought to the costly negative externalities or the positive effects for the society. Tang and Tan (2015) found out that FDI is the main determinants of increasing CO_2 emissions in Vietnam in the period of 1976-2009. The debate of impact of FDI on environment in developing countries has generated opposing hypotheses that supports each line of arguments. The pollution haven hypothesis was raised to explain the increases in FDI would deteriorate the host's environment due to polluting industries in developed countries would tend to move to developing countries for lessening environmental regulations. This hypothesis supports the argument that emissions reduction in many developed countries would be partly due to the shifting of polluting activities to developing countries (Kearsley and Riddel, 2010). Although the literature is dominated with this adverse view of FDI on the environment, it is also possible that FDI can contribute to a better environment (Zarsky, 1999). The study of Zhu et al., (2016) argue that foreign companies are more sensitive to the environment as they use better management practices and advanced technologies that are conducive to the environment compared to their domestic partners which was explained by pollution halo hypothesis. Realizing the potential environmental costs associated with FDI, most countries are now selective in the type of FDI that comes into their country.

For energy consumption, it is the key factor contributing to CO_2 emissions in Vietnam because the country has mostly relied on fossil fuels as oil, gas and coal for energy. That releases carbon dioxide and other greenhouse gases, making them the primary cause of global warming and climate change. Many empirical studies show the positive effect of energy consumption on environment (Ben Jebli et al., 2015a; Kasman and Duman, 2015; Shahbaz et al., 2016). The recent studies have shown the possibility of decreasing CO_2 emissions through consumption of renewable energy (Dogan and Seker, 2016; Dong et al., 2018; Saudi et al., 2019). The progressions in energy efficiency alongside the advancement of green sources of energy are also recognized as the highly effective way of abridging the decline in environmental condition and achieving sustainable growth (Saudi et al., 2019).

3. METHODOLOGY AND DATA

3.1. Data and Research Model

The data sample covers the period from 1980 to 2018 and is collected from several sources. CO_2 represents carbon dioxide emissions which are stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring. They are measured in per capita emissions and taken from Knoema.[1] The data on GDP (in constant 2010 US$) shows annual gross domestic product per capita and FDI variable for annual foreign direct investment (in constant 2010 US$ as same as GDP) which are from United Nations Conference on Trade and Development[2]. While NONRE1 is for non-renewable energy consumption including oil and natural gas energy, RE is for hydro-power renewable energy consumption and NONRE2 is for total non-renewable energy consumption oil, gas energy and coal, measured in terawatt-hours (TWh) per year, source from Global Change Data Lab of Oxford university in project of Our World in Data[3].

The study is concentrated to analyze the short-term and long-term effects of economic growth and energy consumption impact on CO_2 emissions. In addition, the study also wants to test whether renewable energy will be effective in the role of reducing CO_2 emission while there is existence of FDI. The study added the squared term of real income per capita $(\ln GDP_t)^2$ to examine the existence of EKC in Vietnam. Therefore the long-run empirical equation of the EKC hypothesis is presented as follows:

$$\ln CO_{2t}=\beta_0+\beta_1 \ln GDP_t+\beta_2 \ln GDP_t^2+\beta_3 \ln FDI_t+\beta_4 \ln NONRE1_t+\varepsilon_t \quad (1)$$

$$\ln CO_{2t}=\beta_0+\beta_1 \ln GDP_t+\beta_2 \ln GDP_t^2+\beta_3 \ln FDI_t+\beta_4 \ln NONRE1_t+\beta_5 \ln RE_t+\varepsilon_t \quad (2)$$

$$\ln CO_{2t}=\beta_0+\beta_1 \ln GDP_t+\beta_2 \ln GDP_t^2+\beta_3 \ln FDI_t+\beta_4 \ln NONRE2_t+\beta_5 \ln RE_t+\varepsilon_t \quad (3)$$

Where t and ε denote time and error

3.2. ARDL Estimation

In order to test the role of renewable, non-renewable energy consumption in EKC context, the study applied the autoregressive-distributed lag (ARDL) technique of long run relationship (also known as bounds test). According to Pesaran et al. (2001) ARDL methodology allows that variables may be stationary in levels (I(0)) or the first difference (I(1)). Because of this convenience, ARDL method has been used in many studies and in the current study (Bölük and Mert, 2015). The ARDL framework is proposed for the study is as three function below:

$$\ln CO_2 = \beta_0 + \sum_{t=i}^{p} \beta_1 \ln CO_{2t-i} + \sum_{t=i}^{p} \beta_2 \ln GDP_{t-i} + \sum_{t=i}^{p} \beta_3 (\ln GDP_{t-i})^2 + \sum_{t=i}^{p} \beta_4 \ln FDI_{t-i} + \sum_{t=i}^{p} \beta_5 \ln NONRE1_{t-i} + \varepsilon_t$$

$$\ln CO_2 = \beta_0 + \sum_{t=i}^{p} \beta_1 \ln CO_{2t-i} + \sum_{t=i}^{p} \beta_2 \ln GDP_{t-i} + \sum_{t=i}^{p} \beta_3 (\ln GDP_{t-i})^2 + \sum_{t=i}^{p} \beta_4 \ln FDI_{t-i} + \sum_{t=i}^{p} \beta_5 \ln NONRE1_{t-i} + \sum_{t=i}^{p} \beta_5 \ln RE1_{t-i} + \varepsilon_t$$

$$\ln CO_2 = \beta_0 + \sum_{t=i}^{p} \beta_1 \ln CO_{2t-i} + \sum_{t=i}^{p} \beta_2 \ln GDP_{t-i} + \sum_{t=i}^{p} \beta_3 (\ln GDP_{t-i})^2 + \sum_{t=i}^{p} \beta_4 \ln FDI_{t-i} + \sum_{t=i}^{p} \beta_5 \ln NONRE2_{t-i} + \sum_{t=i}^{p} \beta_5 \ln RE1_{t-i} + \varepsilon_t$$

If the long-term connection among CO_2, GDP, FDI and sources of energy consumption are presented with indication then we calculate the beta value of the short run coefficients by utilizing the below equation:

$$\Delta \ln CO_{2t} = \beta_0 + \sum_{t=1}^{p} \beta_1 \Delta \ln CO_{2t-i} + \sum_{t=1}^{p} \beta_2 \Delta \ln GDP_{t-i} + \sum_{t=1}^{p} \beta_3 \Delta (\ln GDP_{t-i})^2 + \sum_{t=1}^{p} \beta_4 \Delta \ln FDI_{t-i} + \sum_{t=1}^{p} \beta_5 \Delta \ln NONRE1_{t-i} + \sum_{t=1}^{p} \beta_5 \Delta \ln RE_{t-i} + \theta ECT_{t-i} + \varepsilon_t$$

$$\Delta \ln CO_{2t} = \beta_0 + \sum_{t=1}^{p} \beta_1 \Delta \ln CO_{2t-i} + \sum_{t=1}^{p} \beta_2 \Delta \ln GDP_{t-i} + \sum_{t=1}^{p} \beta_3 \Delta (\ln GDP_{t-i})^2 + \sum_{t=1}^{p} \beta_4 \Delta \ln FDI_{t-i} + \sum_{t=1}^{p} \beta_5 \Delta \ln NONRE2_{t-i} + \sum_{t=1}^{p} \beta_5 \Delta \ln RE_{t-i} + \theta ECT_{t-i} + \varepsilon_t$$

The coefficient of the error-correction term (ECT) is the speed of adjustment parameter which shows how quickly the series attain a long-run equilibrium (Nkoro and Uko, 2016). The expected sign of this coefficient is negative and significant.

1 https://knoema.com/
2 https://unctad.org/en/Pages/Home.aspx
3 https://ourworldindata.org/

4. RESULTS

4.1. Descriptive Statistics and Unit Root Tests

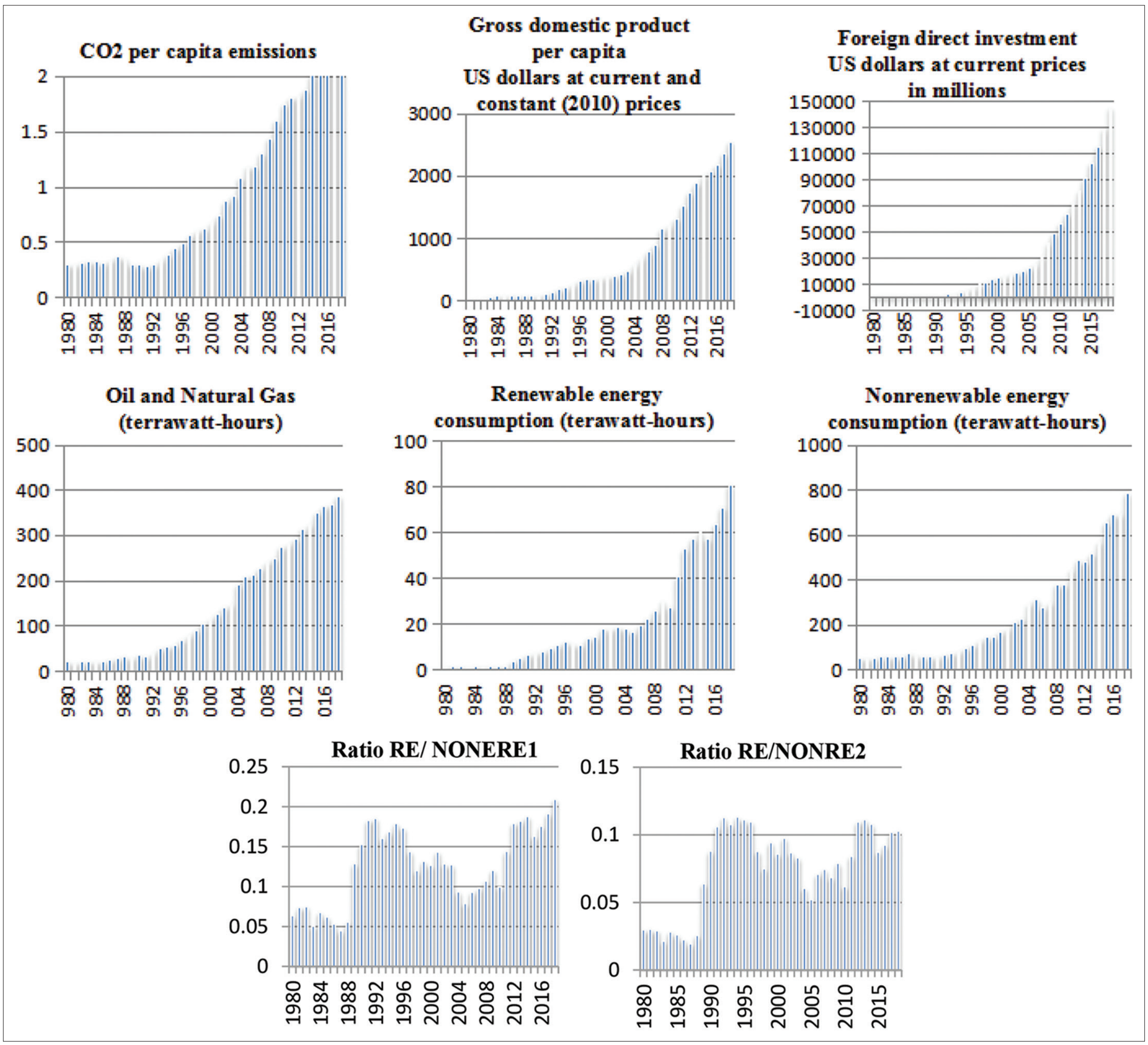
The variables chosen for this study are the amount of CO_2 emissions (CO_2), GDP per capita (GDP), annual foreign direct investment (FDI), non-renewable energy consumption including oil and natural gas energy (NONRE1), renewable energy consumption (RE) and total non-renewable energy consumption as oil, natural gas energy and coal energy (NONRE2) in a period of 1980 - 2018. The study presents summary of all variables in Table 1 and Figure 1 below.

In general, Viet Nam has average 30128.4 USD annual foreign direct investment, gross domestic product per capita is more than 713 USD. This country used about 146 terrawatt-hours oil and natural gas energy, 21.21 terawatt-hours renewable energy consumption and 246.21 terawatt-hours nonrenewable energy consumption (oil, natural gas energy and coal energy) per year. As a result, it emitted

Table 1: Descriptive statistics

Variables	CO_2	GDP	FDI	NONRE1	RE	NONRE2
Mean	0.9633	713.7542	30128.4	146.1726	21.2100	246.21
Std. Dev.	0.7412	773.1238	40497.78	122.9895	22.2889	22.2889
Min	0.2870	33.9437	9.09	20.3710	1.223	1.223
Max	2.81	2558.956	144991.3	385.4224	80.7062	80.7062

Figure 1: Time trends of the considered variables



NONRE1 is for oil and natural gas energy, RE is for hydropower renewable energy consumption and NONRE2 is for oil, gas energy and coal more than 0.9633 carbon emissions into the environment. Figure 1 presents the trends of the 6 time-series, highlighting the tendency toward rising of all the variables over the 1980-2018 period.

The Result from Figure 1 shows that all variables have break point. To overcome the problem, this study uses the (Zivot and Andrews, 1992) unit root test to find out account endogenous structural breaks in the series. The result of the Zivot and Andrews structural break unit root test are reported in Table 2. The structural breaks in intercept at 1988 and in trend at 1990. In this study, the year of 1990 is chosen for break because this year reflected the beginning of its significant Vietnamese economic growth. Then the models which are changed by adding the dummies at the break year in 1990, are presented as follows:

$$\ln CO_{2t} = \beta_0 + \beta_1 \ln GDP_t + \beta_2 \ln GDP_t^2 + \beta_3 \ln FDI_t + \beta_4 \ln NONRE1_t + \beta_5 d_t + \varepsilon_t \quad (4)$$

$$\ln CO_{2t} = \beta_0 + \beta_1 \ln GDP_t + \beta_2 \ln GDP_t^2 + \beta_3 \ln FDI_t + \beta_4 \ln NONRE1_t + \beta_5 \ln RE_t + \beta_6 d_t + \varepsilon_t \quad (5)$$

$$\ln CO_{2t} = \beta_0 + \beta_1 \ln GDP_t + \beta_2 \ln GDP_t^2 + \beta_3 \ln FDI_t + \beta_4 \ln NONRE2_t + \beta_5 \ln RE_t + \beta_6 d_t + \varepsilon_t \quad (6)$$

Where t and ε denote time and error and error d is dummy

In order to apply ARDL regression, all variables are transformed to their logarithmic forms to achieve consistent empirical evidences.

Table 2: Results of Zivot and Andrews structural break unit root test

	Break in intercept		Break in trend	
	Test statistic	Break year	Test statistic	Break year
$\ln CO_2$	−4.3*	1988	−3.985*	1990

*Significant at 10%; **Significant at 5%; ***Significant at 1%

Table 3: Unit root tests results

Variables	ADF test	Order of integration
$\ln CO_2$	−3.974***	I (1)
lnGDP	−5.313***	I (1)
$\ln GDP^2$	−4.884***	I (1)
lnFDI	−3.982***	I (1)
lnNONRE1	−6.225***	I (1)
lnRE	−4.737***	I (1)
lnNONRE2	−5.162***	I (1)

*Significant at 10%; **Significant at 5%; ***Significant at 1%

It is well known that log-linear equation moderates sharpness in the time series data and allows for better results that control variance as compared to simple specification (Mrabet and Alsamara, 2017).

This study uses Unit Root test namely ADF (Augmented Dickey Fuller) to find out the order of integration of the variables in all 3 models and ensure continuity in time series from 1980-2018. The study applied the unit root test on the natural logarithms of the variables in level and difference forms. As the result of Table 3, the study concluded that all the variables are stationary at the 1st difference.

Thus, ARDL bound test (Pesaran et al., 2001) is used for empirical analysis. It provides better results than multivariate cointegration approaches in case of small sample properties. This test of cointegration can be used regardless of the stationarity level of the underlying variables whether they are I (0), I(1) or a combination of both.

According to the results in Table 4, the calculated F statistic value in 3 models respectively are 7.163 (Modle 1); 12.788 (Model 2) and 5.027 (Model 3) which are above the I(1) critical value for 1% confidence intervals. Therefore, the ARDL bound test results reject the null hypothesis in all 3 models. It conclude that there is a long-term cointegration relationship between the dependent variable CO_2 and the independent variables GDP, GDP^2, FDI, NONRE1, RE and NONRE2. These results also show that the independent variables in all models have effect on the carbon emissions in long-term. However, to measure the direction and magnitude of these effects, this study continues to perform short and long-term ARDL models.

4.2. ARDL Long-run and Short-run Results and EKC hypothes in Vietnam

The ARDL analysis is presented in Table 5 for the long-run and short-run estimates. The 3 models have the Durbin–Watson d statistic which are in turn of 2.1484; 2.406; 2.6928, are far from the center of its distribution (d = 3). Therefore, this study doesn't contain auto-correlation. Besides, the results of Ramsey RESET test have proofed no omitted variable bias problems in diagnostics tests.

ECT indicates the error correction term and shows the adjustment speed of the variables towards the long-run equilibrium which is presented by ADJ in the table. The ADJ coefficients which have statistically significant, confirm a deviation from the long run equilibrium level of CO_2 emission in one year is corrected by

Table 4: ARDL bound test results

Dependent variable: $\ln CO_2$								
Quadratic model with NONRE1 (Model 1)			Quadratic model with NONRE1 and RE (Model 2)			Quadratic model with NONRE2 and RE (Model 3)		
F value = 7.163			F value = 12.788			F value = 5.027		
Prob.	Lower Limit I(0)	Upper Limit I(1)	Prob.	Lower Limit I(0)	Upper Limit I(1)	Prob.	Lower Limit I(0)	Upper Limit I(1)
1%	3.41	4.68	1%	3.15	4.43	1%	3.15	4.43
5%	2.62	3.79	5%	2.45	3.61	5%	2.45	3.61
10%	2.26	3.35	10%	2.12	3.23	10%	2.12	3.23

Table 5: Long-run and short-run carbon functions of 3 models

Dependent variable: $lnCO_2$								
Quadratic model with NONRE1 (Model 1)			Quadratic model with NONRE1 and RE (Model 2)			Quadratic model with NONRE2 and RE (Model 3)		
Variables	Coefficient	P-value	Variables	Coefficient	P-value	Variables	Coefficient	P-value
ADJ	−2.3295***	0.004	ADJ	−3.0409***	0.000	ADJ	−1.7182**	0.015
Long−run coefficient estimates								
lnGDP	−3.4262***	0.002	lnGDP	−2.6504***	0.000	lnGDP	−1.4451**	0.042
$lnGDP^2$	0.2329***	0.001	lnGDP2	0.1985***	0.000	lnGDP2	0.0918**	0.021
lnFDI	0.1616**	0.081	lnFDI	0.1193**	0.029	lnFDI	0.2713**	0.032
lnNONRE1	1.0035***	0.000	lnNONRE1	0.9807***	0.000	lnNONRE2	1.0200***	0.000
D1990	−0.1434	0.364	lnRE	−0.2035***	0.001	lnRE	−0.3073***	0.000
			D1990	−0.0765	0.399	D1990	−0.3984*	0.088
Short−run coefficient estimates								
lnGDP (2)	−2.2004**	0.022	lnGDP (2)	2.1450***	0.009	lnGDP (3)	0.4853***	0.007
$lnGDP^2$ (2)	0.2515**	0.015	lnGDP2 (1)	−0.1488**	0.027	lnGDP2 (2)	0.1231**	0.054
lnFDI (3)	−0.1035	0.133	lnFDI (2)	−0.1598**	0.018	lnFDI (2)	−0.1729**	0.011
lnNONRE1 (2)	−1.5512***	0.005	lnNONRE1 (2)	−1.8644***	0.002	lnNONRE2(2)	−0.8339**	0.017
			lnRE (3)	0.4879***	0.007	lnRE (4)	0.2824**	0.017
Constant	13.0690**	0.017	Constant	9.4972***	0.007			
R^2	0.9398		R^2	0.9903		R^2	0.9499	
Adj - R^2	0.7725		Adj - R^2	0.9338		Adj - R^2	0.8296	
Diagnostic test statistics								
Durbin-Watson Test	2.1484		Durbin-watson test	2.406		Durbin-watson test	2.6928	
Ramsey-RESET test	4.46	0.0568	Ramsey-RESET test	0.16	0.9141	Ramsey-RESET test	1.07	0.4214

*Significant at 10%; **Significant at 5%; ***Significant at 1%

232.98% (model 1), 304.09% (model 2) and 171.82% (model 3) over the following year.

In the long run, this study concluded identity of 3 models which have U-shaped relationship between GDP and CO_2 emissions. This finding is consistent with Tang and Tan (2015) the suggestion of Shahbaz et al. (2019) of period 1974-2016 that in long run this relationship will be N-shaped relationship. That means the curve has turn from inverted U- shaped into U-shaped in the period of this study. For that evidence, Vietnam may benefit from a drop in CO_2 emissions at some point, although it has to be cautious because the emissions may rise again when a second income turning point is reached.

The results in long run of 3 models show that FDI is positively and significantly at 5% linked with CO_2 emissions. This finding is in line with the results of Tang and Tan (2015) which implies PHH does exist in Vietnam in a period of 1980-2018. Vietnam should adopt stringent polices to select suitable FDI flow to ensure both aims of economic growth and environmental protection.

Besides that, the study in 3 models indicated NONRE1 and NONRE2 (oil, gas energy and coal energy) have significant at 1%, positively correlated to pollution in long run. These results indicate that nonrenewable energy consumption is not environmentally friendly. These souces of energy can increase environmental pollution and will not solve the climate crisis in near future. This finding is in line with the results of Ben Jebli and Ben Youssef (2015b), Shahbaz et al. (2016) and Demena and Afesorgbor (2020).

Moreover, in model 2 and 3, renewable energy consumption is negatively correlated to CO_2 in long run. It is also significant at 1% (moldel 2) and 5% (model 3) which indicates that hydropower renewable energy can be a key solution in reducing the pollution level for Viet Nam and will be good for long-term energy strategy. These results are consistent with previous studies, such as Apergis and Payne (2009); Lean and Smyth (2010), Pao et al., (2011), Nasir and Ur Rehman (2011), Du et al. (2012), Saboori and Sulaiman (2013), Shahbaz et al., (2014).

In short run, the results of 3 models have significant but heterogeneous. Model 1 with NONRE1 (oil and gas energy) and model 3 with NONRE2 (total nonrenewable energy consumption) have U-shaped relationship between GDP and CO_2 emissions. While model 2 which includes NONRE1 (oil and gas energy) and RE (hydropower renewable energy) given out inverted U - shaped between GDP and CO_2 emissions. The results can be explained by the RE/NONRE1 ratio in model 2 is higher than RE/NONRE2 (Figure 1). The existence of EKC in short run in Model 2 indicates that increasing economic growth will lead to reduce CO_2 emissions. These results show there is the possibility of transferring process from PHH to pollution halo in Vietnam in recent. Vietnam has gradually comprehended that the influx of foreign direct investment should be responsible for domestic CO_2 mounting situation. To solve pollution environment, Vietnam has changed to use green and clean technology in industries little by little.

In addition, by increasing the share of renewable energy consumption in the ratio RE/NONRE1 that helps to reduce CO_2 emission in short term. On the other hand, renewable energy consumption is negatively correlated to CO_2 emissions in long-run but positive in short - run. It is also significant in both long and short run which indicates the host country has tried to use environment-friendly and low carbon technology recently. However, this clean technology is not only imperfect but also impurities. The more incomplete the technology is, the more degraded environment is.

To check the stability of the ARDL model, we applied the CUSUM and CUSUMsq tests recommended by Brown et al., (1975) to examine the constancy of the parameters.

The results in Figures 2 and 3 show that CUSUM and CUSUMsq in model 1 and 2 are between the upper and lower critical bounds at the 5% significance level, confirming the stability of the ARDL estimates. However, the model 3 in Figure 4 is beyond the lower critical bounds. This indicates the model 3 is not quite stability.

4.3. Granger Causality Analysis

This section is devoted to the causality analysis among CO_2 emissions and the considered variables in Vietnam. The study conducts the relationship between variables to carbon emissions by VECM Granger test. For the best results, this study has just tested VECM Granger test for Model 2 based on is informative and stability.

The results in Table 6 present the results of the causal test between carbon emissions, energy sources and economic growth based on the VECM Granger causality test.

Beginning with the short-run effects, there is unidirectional causality runs from CO_2 emissions and GDP per capita to annual foreign direct investment, from oil and natural gas energy (NONRE1) to GDP square per capita and renewable energy consumption (RE). In addition, the bidirectional causality is found between annual foreign direct investment and CO_2 emissions. This result confirms when the host country attracts foreign direct investment, it affects CO_2 emissions in short term, especially in

Figure 2: Plot of the cumulative sum and cumulative sum of the squares of Model 1

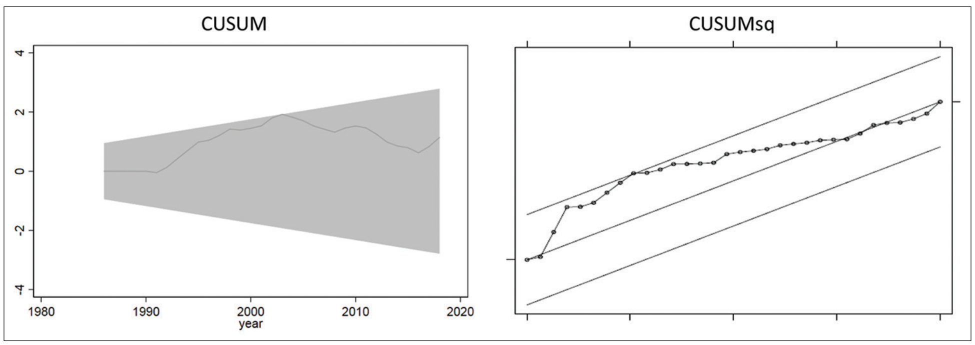


Figure 3: Plot of the cumulative sum and cumulative sum of the squares of Model 2

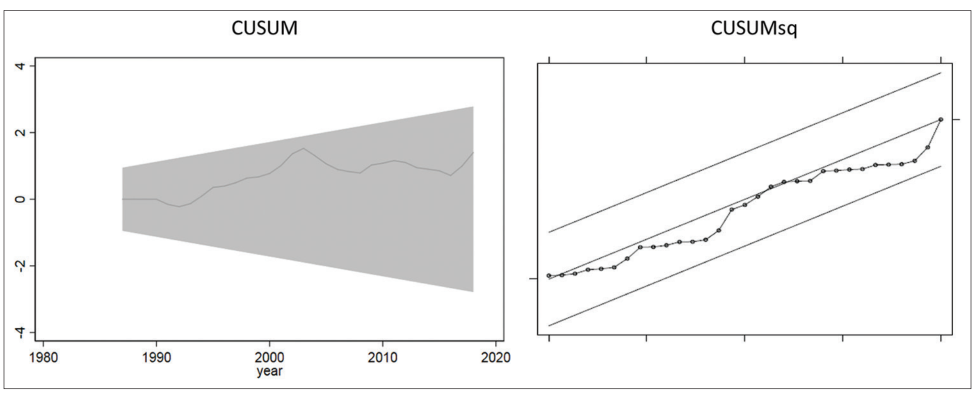


Figure 4: Plot of the cumulative sum and cumulative sum of the squares of Model 3

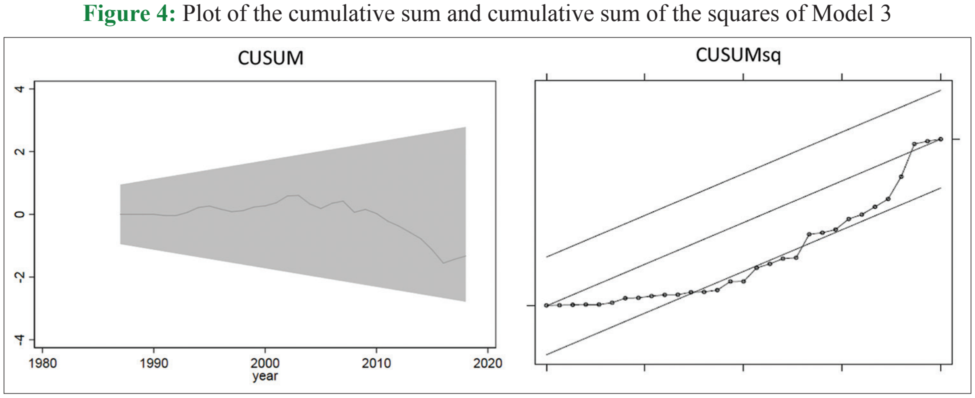


Table 6: The VECM Granger causality test

Dependent variables	Type of causality						
	Short run						Long run
	$lnCO_{2t-1}$	$lnGDP_{t-1}$	$lnGDP^2_{t-1}$	$lnFDI_{t-1}$	$lnNONRE1_{t-1}$	$lnRE_{t-1}$	ECM_{t-1}
$\Delta lnCO_{2t}$		−0.6485 (0.593)	0.0652 (0.542)	−0.5528* (0.069)	−0.7807* (0.061)	0.2058 (0.410)	−2.9892** (0.037)
$\Delta lnGDP_t$	1.0813* (0.090)	…	0.1314 (0.257)	0.1805 (0.564)	−1.2836 (0.012)	−0.1444 (0.593)	−2.8268* (0.069)
$\Delta lnGDP_t^2$	7.4379 (0.396)	−13.8223 (0.421)	…	2.8615 (0.483)	−14.3358** (0.032)	−1.6488 (0.640)	−26.9340 (0.183)
$\Delta lnFDI_t$	−3.2065** (0.043)	−5.8040* (0.067)	0.4746 (0.089)	….	1.0284 (0.344)	−0.3148 (0.515)	−0.3953 (0.166)
$\Delta lnNONRE1_t$	−0.4995 (0.267)	−0.8352 (0.158)	0.0665 (0.240)	0.2060 (0.352)	…	−0.3409 (0.060)	−0.1143 (0.149)
$\Delta lnRE_t$	−1.6248 (0.214)	−2.524 (0.349)	−0.2398 (0.167)	0.7894 (0.243)	1.965** (0.033)	…	−0.2816 (0.246)

*, **, ***Represent the significance level at 10%, 5% and 1% respectively

the developing country. And in contrast, pollution also changes the way to classify, choose and use the investment from foreign country well.

Turning to the long-run causality result, the unidirectional causality is found running from GDP square per capita and foreign direct investment to CO_2 emissions without a feedback. There is reveal that CO_2 emissions are caused by developing economy. This will certainly happen when Vietnam has achieved economic growth to the certain extent.

Besides that, this study shows oil and natural gas energy (NONRE1) and renewable energy consumption (RE) which cause CO_2 emissions in the Granger sense. This implies that Vietnam should limit the industries to dirty energy - oil and natural gas energy which causes environmental pollution, leads to global warming. In addition, by turning to more renewable energy - forms of hydrogen, we can make a big impact and lower greenhouse gas emissions and pollution.

We also found bi-directional causality running between GDP per capita to CO_2 emissions in long term. This implies there is close and connected relationship between economics and the quality of the environment. We thus conclude N-shaped relationship between economic growth and CO_2 emissions will happen in Vietnam in near future.

5. DISCUSSION AND CONCLUSION

This paper has investigated the relationship between economic growth and environmental degradation in Vietnam by choosing CO_2 emission as indicator. FDI and non-renewable, renewable energy consumption as determinants of CO_2 emissions over the 1980-2018 period using annual data. The three models with the different sources of energy consumption have showed the empirical results that the EKC does not exit in Vietnam in long run and FDI has also significantly contributed to the increase of CO_2 emissions. That implies Vietnam has attracted non - environmental friendly FDI flow for years and followed the PHH. However, the negative coefficients of FDI for three models in short run would suggest the current stricter environmental regulations has reversed the effect of FDI on environment. Vietnam should have appropriated stringent regulations to select the FDI that comes into the country. Many countries are now promoting the so-called "green" FDI that focuses on FDI that can promote economic growth and also internalizes the adverse environmental externalities associated with industrial production (Golub et al., 2011).

The other findings of the study are confirmations of the effect of energy consumption sources as non-renewable energy and renewable energy to amount of CO_2 emissions in Vietnam. All of three models reveals the consistent results of significant and positive effect from non-renewable energy and negative effect from renewable energy consumption to CO_2 emissions in long run. The green energy shows the effective ways to limit environmental pollution to pursue sustainable development. Therefore, Vietnam should keep on increasing the share of renewable energy and decreasing the consumption of non-renewable energy for a better environment. Though the paper has just tested hydro - renewable energy, Vietnam should also increase energy consumption of various renewable sources, that would help to decrease the CO_2 emission, protect environment while developing economy. In addition, government should more focus on environmental public awareness to promote renewable energy policies for households such as solar energy and as well as to change customer's preferences to energy saving products.

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