Environmental Science and Pollution Research (2021) 28:29795–29805
https://doi.org/10.1007/s11356-021-12838-5

RESEARCH ARTICLE

Foreign investment, economic growth, and environmental degradation since the 1986 "Economic Renovation" in Vietnam

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Received: 30 October 2020 / Accepted: 3 February 2021 / Published online: 10 February 2021

Abstract

Vietnam has achieved impressive economic growth principally supported by foreign direct investment (FDI) in the last three decades. However, environmental deterioration is observed. No studies have ever been conducted to examine the link between economic growth and environmental degradation, focusing on the important role of the FDI, in Vietnam in both short run and long run. Using the ARDL and the threshold regression techniques for 35 years from 1986, Vietnam's "Doi Moi" (economic renovation), the U-shaped relationship between economic growth and the environmental quality is found in the long run and at the upper threshold of economic growth. FDI in the long run and at the upper threshold of economic growth also leads to further deterioration of the environmental quality. Also, consumption of fossil fuel energy deteriorates the environment in the long run, and at any level of economic growth. These findings simply mean that Vietnam has to adopt a new growth model with the focus on the quality FDI projects and clean energy sources to achieve the dual objectives: (i) sustained economic growth and (ii) improved environmental quality.

Keywords Economic growth · FDI · Environmental degradation · ARDL · Threshold regression · Vietnam

Introduction

Vietnam has been generally recognized as one of the most successful and dynamic emerging economies in Asia. The nation has achieved rapid and sustainable economic growth since its economic "Doi Moi" (Renovation) in 1986. Vietnam has maintained its annual economic growth rate above 5% since 1988, regardless of the two recent world economic downturns in 2008 and 2012. One year after "Doi Moi," Vietnam's foreign direct investment (FDI) inflows promptly increased by more than 250 times from USD40 thousand in 1986 to USD10.3 million in 1987. Then in 2018, Vietnam attracted FDI of around USD15.5 billion. In 2019, the British Petro Statistics (2019) announced that the Vietnamese economy employed nearly 3.5 exajoules of fossil energy sources, which are equivalent to more than 83 million tons of oil. This figure of fossil energy increases 15.5 times in comparison with the 1986 level. CO_2 emissions also increase by 15 times, from 18.9 million tons in 1986 to 285.9 million tons in 2019. In order to maintain sustainable economic development, the Vietnamese government has started recognizing the importance of renewable energy to achieve dual objectives for the country: (i) sustained economic growth and development; and (ii) improved quality of the environment. As a result, hydroelectric energy consumption, which is perceived as one of Vietnam's most important renewable energy sources, has been increased. This consumption level is recorded to increase by more than 40 times from 336 thousand tons of oil equivalent in 1986 to 13.9 million tons of oil equivalent in 2019 (British Petro Statistics 2019). Figure 1 below presents a clear shift of a pattern of energy sources in Vietnam in the last 35 years. Energy generation from coals for consumption exhibits a reduction from 54 per cent to 43% in the period of 35 years. It is a slow shift toward clean energy sources in Vietnam. In addition, a strong link between economic growth, proxied by per capita GDP, and CO_2 emissions are observed in the same period, as presented in Fig. 2.

A new structure for Vietnam's energy sources with an increased proportion of clean energy has been discussed. Rogers

Responsible Editor: Nicholas Apergis

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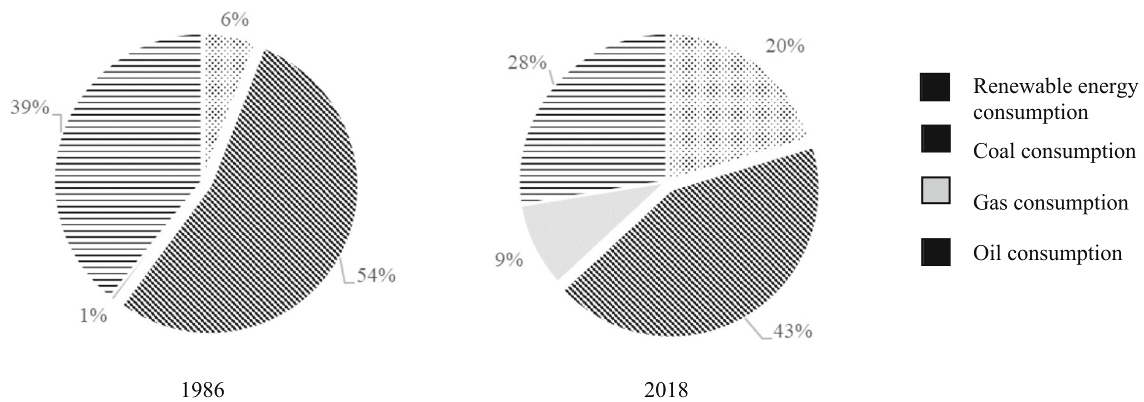

Fig. 1 A pattern of energy consumption in Vietnam

(2019) argues that Vietnam should invest more in renewable sources, even though the current focus is on natural hydro endowments and lower-cost solar and wind power. Nguyen (2020) reports that the contribution of hydroelectric, wind, solar, and other types of renewable energy to the national electricity supply is expected to reach around 67.4% in 2030. Minh (2020) reports that the Vietnamese government has been preparing for a competitive market in the energy sector. The government projects to announce a complete legal framework for the market, in which private investors can participate in producing and supplying energy in Vietnam by 2024. Accordingly, Vietnam's government currently encourages changing the energy structure toward using clean and environment-friendly resources.

The relationship between economic growth and environmental degradation is exhibited in the environmental Kuznets curve (EKC). The EKC hypothesis has been intensively investigated along with the industrial revolution since the 19th century. This hypothesis presents a bell-curved relationship between economic growth and CO_2 emissions. Empirical studies mostly focus on developed and industrial countries, such as the OECD countries, EU nations, the USA, China, and India (Dogan and Seker 2016; Raza and Shah 2018; Saboori et al. 2014; Sharif et al. 2019). Low-middle income economies like Vietnam have been left behind.

Limited empirical studies investigate the existence of the EKC hypothesis in Vietnam (Al-Mulali et al. 2015; Shahbaz et al. 2019; Tang and Tan 2015). However, Al-Mulali et al. (2015) do not include a squared term of the GDP to examine the validity of the bell-curved relationship between income and emissions. Besides, the authors alternatively employ fossil energy consumption and renewable energy consumption in two separate models. This strategy can potentially inflate the estimated coefficient of each variable due to the issue of omitted variables. On the other hand, Tang and Tan (2015) employ the Johansen test to examine the co-integration between economic growth and CO_2 emissions in Vietnam. This analysis uses the vector error correction model (VECM) and vector auto-regressive (VAR), which require a large sample. However, in that paper, the author applies the Johansen test to a small sample of only 33 time-series observations. Mixed results have been observed in relation to the validity of the EKC hypothesis for Vietnam. Tang and Tan (2015) and Shahbaz et al. (2019) find an inverted U-

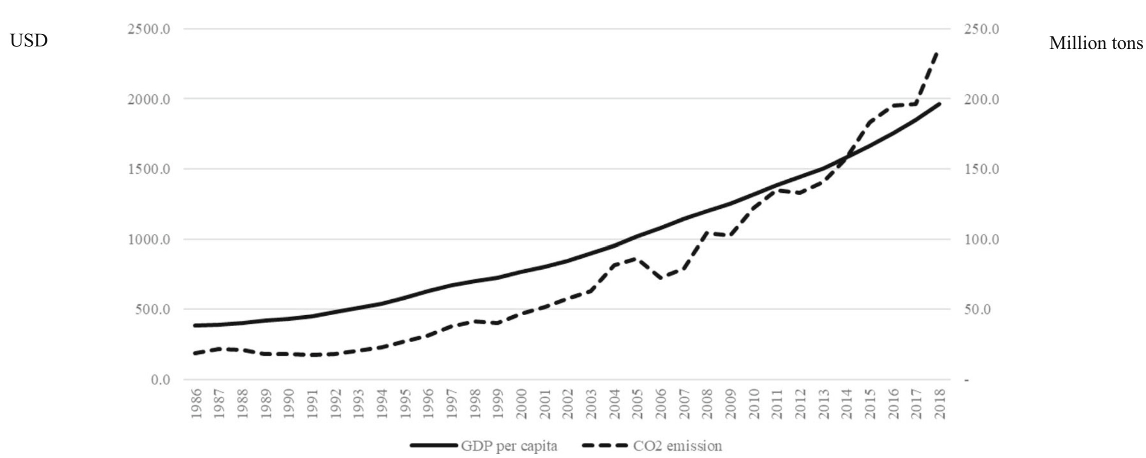

Fig. 2 GDP per capita and CO_2 emissions in Vietnam from 1986 to 2018

shaped relationship between income and CO_2 emissions in Vietnam, while Al-Mulali et al. (2015) fail to confirm this non-linear relationship.

This study revisits the important issue of the validity of the EKC hypothesis in the context of Vietnam, taking into account the weaknesses exhibited in the previous studies. Unlike previous studies for Vietnam, first, the longest possible and most updated data period, from 1986 to 2018, is used. Second, we utilize the auto-regressive distributed lags (ARDL) model, which is generally considered appropriate for a small time-series sample, to examine both short-term or long-term relationship between variables. Third, we group different energy consumption types into two main categories: (i) fossil energy consumption, including coal, gas, and oil consumption; and (ii) renewable energy consumption including hydroelectric consumption. Fourth, we perform a threshold regression to determine the per capita GDP level, which is then used in our analysis on FDI-growth-environment nexus, as a robustness check.

Following this introduction, the remainder of the paper is structured as follows. The "Literature review" section presents the literature review on the EKC hypothesis. Data and research methodology are then discussed in the "Data and methodology" section. The "Results" section presents the empirical findings, followed by the conclusions and policy implications in the "Discussion" section of the paper.

Literature review

There has been significant literature on the economic growth—environment degradation nexus in the past 50 years. A majority of studies focus on examining the EKC hypothesis's validity, which suggests an inverted U-shaped relationship between income per capita and CO_2 emissions. That is, CO_2 emissions will increase as income increases to a certain level. After this threshold, a continued increase in income per capita is associated with a reduction in CO_2 emissions.

Many studies use a multi-country panel data to examine the validity of the EKC hypothesis. Aydoğan and Vardar (2020) examine the linkage between CO_2 emissions, economic growth, agricultural value-added, and energy consumption for E7 countries between 1990 and 2014. The authors find evidence supporting the existence of the inverted U-shaped EKC in the long run and bidirectional causality between nonrenewable energy consumption and CO_2 emissions. Le and Quah (2018) examine the CO_2 emissions-growth nexus for 14 countries in the Asia-Pacific region over the period 1984–2012. The study finds evidence to support the validity of the EKC hypothesis for the high-income economies such as Hong Kong and South Korea, but not for the middle-income countries in the region. Similarly, using a sample of 24 transition economies between 1993 and 2004 with the GMM estimation, Tamazian and Bhaskara Rao (2010) present findings supporting the EKC hypothesis as well as the importance of the institutional quality for environmental quality.

Empirical studies on single-country studies on the economic growth and environmental degradation relationship have gained great attention from policymakers and academics (Nguyen et al. 2019). Aslan et al. (2018) utilize a bootstrap rolling window estimation of the vector autoregressive model for the USA from 1966 to 2013. The study confirmed that the effect of economic growth on CO_2 emissions was increasing from 1982 to 1996 but decreasing from 1996 to 2013. Fodha and Zaghdoud (2010) investigate the relationship between economic growth and environmental degradation in Tunisia during 1961–2004. Empirical results indicate a long-run co-integration relationship between GDP per capita and per capita CO_2 and SO_2 emissions. In this study, an inverted U-shaped relationship between GDP and SO_2 emissions is found. The authors conclude that emissions reduction policy and investment in pollution abatement help Tunisia achieve sustainable growth in the long run. Shahbaz et al. (2013) study the linkage in Indonesia using quarterly data from 1975 to 2011. The findings show that economic growth and energy consumption are associated with CO_2 emissions.

On the other hand, other studies have found mixed evidence about the EKC hypothesis. Fakih and Marrouch (2019) apply a non-parametric model to investigate the relationship between CO_2 emissions and economic activity. They examine the data from the Middle-East and North Africa countries from 1980 to 2010 and reject the EKC hypothesis's validity. Heidari et al. (2015) also reject the linear relationship between CO_2 emissions, energy consumption, and economic growth in five ASEAN countries. The authors suggest the existence of a non-linear relationship among these variables, but no confirmation is established about the EKC hypothesis.

A different strand of studies is conducted using the multivariate frameworks with the inclusion of other variables such as energy consumption, financial development, and agriculture activities. Tamazian et al. (2009) incorporate financial development into the relationship between environmental degradation and economic development. The authors use the standard reduced-form modeling approach to study BRICS countries over the period 1992–2004 and find that financial and economic development are determinants of environmental quality. They recommend that governments should adopt policies supporting financial openness and liberalization to limit environmental degradation. Omri et al. (2015) also examine the relationship between CO_2 emissions and economic growth by including financial development and trade for 12 MENA countries over the period 1990–2011. Using system GMM, the existence of EKC is verified. Also, bidirectional causality is found between both CO_2 emissions and trade openness and economic growth. Also using data from 12 MENA countries for the period 1981–2005, Arouri et al. (2012) examine the relationship between CO_2 emissions, energy consumption, and real GDP. Findings from this study indicate that, in the long run, energy consumption exerts the positive impacts on CO_2 emissions. However, weak evidence is found to support the EKC hypothesis, since the turning points in some countries are very low. The authors argue that not all countries in the region need to renounce economic growth to cut emissions levels as they can achieve it via energy conservation.

The ASEAN region, in particular, has attracted great attention (Vo et al. 2019). For instance, Saboori and Sulaiman (2013) investigate the EKC hypothesis for five ASEAN countries over the period 1971–2009 using the ARDL approach and Granger causality test. The study uses aggregated and disaggregated energy consumption data such as gas, oil, coal, and electricity. Empirical results show mixed evidence for the EKC hypothesis. The authors consider that these mixed outcomes are expected because the selected countries are at different economic development stages. On the other hand, Lean and Smyth (2010) also examine the EKC's existence in five ASEAN countries for the period 1980–2006. Their results support the EKC hypothesis for four out of five ASEAN countries. Malaysia is the only country in which the authors fail to establish any relationship between income and pollutant emissions. After that, Chandran and Tang (2013) carry out an investigation on the effect of income on CO_2 emissions for the same five ASEAN countries using the Johansen co-integration test within the VECM framework. The bidirectional causality is found between economic growth and CO_2 emissions for Indonesia and Thailand in the long run. However, unidirectional causality is found to run from economic growth to CO_2 emissions in the short run. However, no conclusion on the validity of the EKC hypothesis has been made in the study.

In Vietnam, two studies on the link between economic growth and environmental degradation are conducted. Shahbaz et al. (2019) point out the remarkable economic transformation the country experienced in 30 years. They also present a worrisome trend of increasing CO_2 emissions, with the figure in 2015 being double that in 1980. Vietnam's engagement in the 21st Conference of Parties (COP 21) in Paris is also considered, focusing on how the country can reduce CO_2 emissions without sacrificing economic growth. Using data from 1974 to 2016, Shahbaz et al. (2019) apply the ARDL to examine the EKC's existence in Vietnam. The authors conclude that the EKC hypothesis does not exist in the short run in Vietnam. Evidence of long-run EKC in Vietnam is found. However, an unusual N-shaped pattern is observed.

Al-Mulali et al. (2015) employ ARDL to investigate the causal relationship between CO_2 emissions and economic growth for Vietnam over the period 1981–2011. The results show that economic growth is positively related to pollution in the short run and long run, suggesting a rejection of the EKC hypothesis. The results also reveal that capital is positively correlated with CO_2 emissions, implying that capital attracts energy-intensive polluting industries where fossil fuel is used as the main energy source. The labor force is also negatively correlated with CO_2 emissions, implying that the labor force attracts lesser energy-intensive polluting industries.

On the ground of the above considerations, particularly for the case of Vietnam, a developing country in the ASEAN, testing the validity of the EKC hypothesis, provides mixed results. Besides, recent studies investigate that the EKC hypothesis in Vietnam generally employs time-series techniques such as the ARDL model. In this study, unlike other studies, we contribute to the literature of the EKC hypothesis in Vietnam from two key aspects. First, we extend the use of time-series analysis by combining two methods, the ARDL technique, and the threshold regression. The ARDL technique is utilized to examine a non-linear relationship between CO_2 emissions and economic growth in both the short term and long term. In addition, the threshold regression allows us to examine the validity of the EKC hypothesis in different stages of economic development. Second, we categorize different energy consumption into two main types: (i) fossil energy (including coal, gas, and oil) and (ii) renewable energy (hydroelectricity). Grouping each energy source into a particular group according to their characteristics provides several advantages. First, we reduce the number of explained variables associated with the advantage of using time-series analysis. Second, the current study does not focus on the energy consumption structure. As such, it is not required to include all available energy sources into the model.

Data and methodology

In this paper, we use two distinct regression methodologies to investigate the presence of the inverted U-shaped relationship between CO_2 emissions and economic growth, or the validity of the EKC hypothesis, in Vietnam. First, the ARDL model allows us to examine the long-term and short-term effects of economic growth on CO_2 emissions. To examine the inverted U-shaped relationship between per capita GDP and CO_2 emissions per capita, a squared term of GDP per capita is added in the model. As such, a threshold regression technique is used to divide the sample into two sub-samples with different per capita GDP levels to examine whether the validity of the EKC hypothesis depends on the level of GDP per capita.

In our model, CO_2 emissions per capita are the dependent variable. GDP per capita and squared term of GDP per capita are the explained variables to examine the EKC hypothesis. Moreover, we also use fossil energy (including coal, gas, and oil) consumption and renewable energy consumption, which is proxied by hydroelectric consumption—a key component of renewable energy sources where data are available. The foreign direct investment is also considered as another determinant of CO_2 emissions, based on international trade and technology transformation theories where “old” technology or capital will move from advanced countries to emerging countries such as Vietnam. The log-log model can be illustrated as follows:

$$CO_2 = f\left(GDP_t, GDP_t^2, Fossil_t, Renew_t, FDI_t\right) \quad (1)$$

where CO_2 represents for per capita CO_2 emissions, *GDP* is proxied by GDP per capita, *Fossil* denotes fossil fuel consumption including coal, gas, and oil consumption, *Renew* represents renewable energy consumption, and *FDI* is net FDI inflow measured by a proportion to GDP. Subscript “t” represents for each year from 1986 to 2018.

For time-series analysis, the VAR (vector autoregressive) or ARDL models are used. The VAR model has several advantages. However, regardless of these advantages, VAR exhibits its fundamental weaknesses with small sample size and when all variables are not stationary at the same order I(0) or I(1). As such, the ARDL model becomes a reasonable alternative in this paper. The ARDL model can perform well with a small sample, and the model is independent with the level of stationarity at either I(0) or I(1) (Danish et al. 2018; Odhiambo 2009; and Sari et al. 2008). With the presence of the endogenous problem, the ARDL can report the unbiased long-run estimates and valid test statistics (Harris and Sollis 2003). Empirical models using the ARDL are expressed as follows:

$$\begin{aligned}\Delta CO_{2t} = {} & \alpha_0 + \sum_{i=0}^{r_1}\alpha_1\Delta CO_{2,t} + \sum_{i=0}^{r_2}\alpha_2\Delta GDP_{t-i} + \sum_{i=0}^{r_3}\alpha_3\Delta GDP_{t-i}^2 \\ & + \sum_{i=0}^{r_4}\alpha_4\Delta Fossil_{t-i} + \sum_{i=0}^{r_5}\alpha_5\Delta Renew_{t-i} + \sum_{i=0}^{r_6}\alpha_6\Delta FDI_{t-i} \\ & + b_1 GDP_{t-r} + b_2 GDP_{t-r}^2 + b_3 Fossil_{t-r} + b_4 Renew_{t-r} \\ & + b_5 FDI_{t-r} + \varepsilon_t\end{aligned} \quad (2)$$

where α_i represents the short-term coefficients; b_j represents long-term effects; ε_t is the error term.

In the ARDL model, all variables are required to be stationary at the level (I(0)) or at their first difference (I(1)). We employ the modified Dicky-Fuller, augmented Dicky-Fuller, and Phillips-Peron techniques to test all variables' stationarity. Several diagnostic tests, such as serial correlation, homoscedasticity, heteroscedasticity, and model stability, are also conducted. Durbin-Watson statistic is employed to test the first-order serial correlation in the disturbance. For higher-order serial correlation, the Breusch-Godfrey test is used.

The threshold model applying for time-series analysis also requires all included variables integrated at I(0) and I(1). The threshold model for the model (1) is as follows:

$$CO_{2,t} = \begin{cases} \gamma_0 + \gamma_1 GDP_t + \gamma_2 GDP_t^2 + \gamma_3 Fossil_t + \gamma_4 Renew_t + \gamma_5 FDI_t + \mu_t, & (\text{If } GDP_{t-i} < \theta) \\ \delta_0 + \delta_1 GDP_t + \delta_2 GDP_t^2 + \delta_3 Fossil_t + \delta_4 Renew_t + \delta_5 FDI_t + \sigma_t, & (\text{If } GDP_{t-i} \geq \theta) \end{cases} \quad (3)$$

where θ represents threshold value, γ_i(i=0,5) is estimated coefficient in the lower regime, δ_i (i=0,5) is estimated coefficient in the upper regime, and μ_t andσ_t are disturbance terms in lower and upper regimes, respectively.

The θ divides the sample into two regimes of below θ and above θ. The EKC hypothesis is then tested by comparing two pairs of γ_2 and γ_3 and δ_2 and δ_3. If γ_2 (or δ_2) is significantly positive and γ_3 (or δ_2) is significantly negative, then the inverted U-shaped relationship between economic growth and environmental degradation is confirmed. Otherwise, we cannot conclude about the existence of the EKC hypothesis.

We extend our analysis using the causality test to examine a causal relationship between pairs of variables included in the model (1) after the ARDL estimation is completed. Toda–Yamamoto approach for Granger non-causality test (Toda and Yamamoto 1995), instead of the conventional Granger causality test, is used. We note that the conventional Granger causality test is based on VAR estimation. As such, the test also requires that all included variables must be integrated at the same order. The Toda–Yamamoto approach is based on augmented VAR model with $(k + d_{max})^{th}$ lag order, in which k is optimal lags of a conventional VAR model, and d_{max} is the maximal order of integration of included variables in the model. In the Toda–Yamamoto approach, the last dmax lag's estimated coefficients are excluded from the Granger causality test. By adding d_{max} lags in the VAR model, the Toda–Yamamoto approach allows us to test the Granger causality with mixed order of integration in the model.

Results

Table 1 presents the descriptive statistics of variables in the current study. Our data covers the period from 1986, Vietnam's economic reform to 2018, where the latest data are available. CO_2 emissions have increased approximately ten times, from 0.25 to 2.45 tons of CO_2 per capita with the average per capita CO_2 emissions of 0.91 tons. Meanwhile, economic growth has just increased around five times from 1986 to 2018. These statistics demonstrate a faster increase in CO_2 emissions in comparison to economic growth in Vietnam. In addition, energy consumption, including both fossil and renewable sources, has been recorded at an even higher growth rate. In particular, fossil energy consumption

Table 1 Descriptive statistics, 1986 to 2018

Variable	Observation	Mean	Std. dev.	Min	Max
CO_2 emissions per capita (tons of CO_2 emissions)	33	0.910	0.644	0.251	2.481
GDP per capita	33	961.852	477.621	384.822	1964.476
Fossil energy consumption	33	1.020	0.809	0.214	2.961
Renewable energy consumption	33	0.240	0.217	0.014	0.799
FDI inflow (% of GDP)	33	5.237	2.869	0.000	11.939

has increased 14 times, and the growth rate of renewable energy consumption has been more than 50 times. A faster increase in energy consumption than CO_2 emissions has implied efficiency of technology development in Vietnam since the economic revolution in 1986.

Unit-root test

Table 2 presents results using the augmented Dickey-Fuller test for unit root. Results from Table 2 confirm mixed orders at I(0), or I(1) integration of variables included in the model (2) and model (3) are found. As such, the ARDL model is more appropriate to be used in this study than the VAR. Furthermore, threshold regression also requires all variables to be integrated at I(0) or I(1), without the restriction of stationarities at the same order, simultaneously. As such, the threshold regression can be used in this study.

Empirical results

Table 3 presents the empirical findings in both long term and short term on the link between FDI, economic growth, and environmental degradation using the ARDL technique. The results confirm the U-shaped relationship, or an inverted EKC, between economic growth (proxied by per capita GDP) and environmental degradation (proxied by per capita CO_2 emissions) in Vietnam in the long run. In addition, the consumption of fossil fuel energy leads to environmental degradation in Vietnam in the long run. These two findings are alarming for the Vietnamese government in the long run concerning the requirement of achieving the dual objectives of sustained economic growth and improved quality of the environment. There is no clear relationship between economic growth and the quality of the environment in the short run. Thus, the validity of the EKC hypothesis is not confirmed in the short run in Vietnam. The FDI, on the other hand, appears

Table 2 Results from the augmented Dickey-Fuller test for unit root

Variable	Modified Dicky-Fuller	Augmented Dicky-Fuller	Phillips-Peron
Unit-root test at the level			
CO2 emissions per capita	−2.78	0.64	−10.30
GDP per capita	−2.72	−0.52	−10.47
Squared of GDP per capita	−2.16	0.46***	−11.97***
GDP per capita growth rate	−1.88	−4.99***	−14.59***
Fossil energy consumption per capita	−2.74	0.51	−9.91
Renewable energy consumption per capita	−2.82	−2.71*	−8.13
Foreign direct investment, net inflows (% of GDP)	−0.80	−4.16***	−13.06***
Unit-root test at the first difference			
CO2 emissions per capita	−4.66***	−4.31***	−29.46***
GDP per capita	−4.97	−3.44***	−14.23**
Squared of GDP per capita	−5.18	−3.29**	−14.23*
Fossil energy consumption per capita	−4.36***	−4.13***	−28.59***
Renewable energy consumption per capita	−4.04***	−3.78***	−26.31***
Foreign direct investment, net inflows (% of GDP)	−2.164	−3.41**	−32.64***

All variables are in the log transformation form

*, **, and *** are 1, 5, and 10% level of significance, respectively

Table 3 Results on the FDI-growth-environment nexus using the ARDL technique

The dependent variable is CO2 emissions per capita	Estimated coefficient	Standard error
Error correction adjustment coefficient	−0.65**	0.23
Long-term coefficient		
GDP per capita	−2.15***	0.42
Squared of GDP per capita	0.13***	0.02
Fossil energy consumption per capita	1.19***	0.09
Renewable energy consumption per capita	0.04	0.03
Foreign direct investment, net inflows (% of GDP)	0.01	0.01
Short-term coefficient		
GDP per capita	−5.69	5.07
GDP per capita (1-year lag)	0.12	4.85
Squared of GDP per capita	0.45	0.39
Squared of GDP per capita (1-year lag)	−0.01	0.37
Fossil energy consumption per capita	0.44	0.28
Renewable energy consumption per capita	0.05*	0.02
Renewable energy consumption per capita (1-year lag)	0.03	0.02
Foreign direct investment, net inflows (% of GDP)	−0.01*	0.00
Constant	20.25**	7.74
Observations	31	
R-squared	0.99	
Durbin's alternative test for autocorrelation	(0.73)	
LM test for autoregressive conditional heteroskedasticity (ARCH)	(0.78)	
White's test for homoscedasticity	(0.42)	
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity	(0.19)	

All variable is used in log transformation form; Tested *p* values are in round bracket

*, **, and *** are 1%, 5%, and 10% level of significance, respectively

to results in a reduction in the CO_2 emissions in the short run. However, the effect is reversed in the long run. Our analysis indicates that all four robustness checks (including Durbin's alternative test for autocorrelation, LM test for autoregressive, White's test for homoscedasticity, and Breusch-Pagan/Cook-Weisberg test for heteroscedasticity) confirm the robustness of our findings.

Table 4 presents empirical findings on the FDI-growth-environment nexus using the threshold regression. The threshold of US$765.18 for per capita GDP is reported by the threshold regression analysis. Different results on the effects of economic growth and FDI to CO_2 emissions are observed in these two levels/thresholds of per capita GDP. Three key sets of findings are worth discussing and noting from our analysis, including (i) the validity of the EKC hypothesis; (ii) the effect of FDI to the environmental quality; and (iii) the consumption of fossil fuel to the quality of the environment.

First, at the lower threshold, no significant impact from economic growth to CO_2 emissions is confirmed. However, starting from the threshold of US$765.18 per capita, the U-shaped relationship between economic growth and CO_2 emissions is clearly presented. This finding implies that, at an upper threshold of economic growth, an increase in economic growth is associated with environmental deterioration. This finding is consistent with the results for the long run using the ARDL technique. In summary, the U-shaped relationship (or an inverted EKC hypothesis) is confirmed between economic growth and environmental degradation in the long run or at the upper threshold of economic growth.

Second, findings from both lower and upper thresholds of per capita GDP of US$765.15 confirm that consumption of fossil fuel leads to the environmental degradation in Vietnam. Our analysis indicates that FDI is marginal affects the quality of the environment in both thresholds of per capita income. At the lower threshold, an increase in FDI is associated with a reduction in the level of CO_2 emissions. This finding supports the view that, at the early stage of economic growth in Vietnam, FDI contributes greatly to improving environmental quality. However, the effect is reversed when the upper threshold of per capita GDP is considered. An increase in FDI may lead to further deterioration of the environment in the future.

Third, fossil fuel consumption leads to further deterioration of the environment in Vietnam regardless of the level of economic growth. These findings support the call that the Vietnamese government should act quickly in response to

Table 4 Results on FDI-growth-environment nexus from the threshold regressions

The dependent variable is CO2 emissions per capita	Estimated coefficient	Standard error
Region 1	GDP per capita < \$765.18	
GDP per capita	0.80	1.75
Squared of GDP per capita	−0.12	0.15
Fossil energy consumption per capita	1.29***	0.10
Renewable energy consumption per capita	0.10***	0.04
Foreign direct investment, net inflows (% of GDP)	−0.01***	0.00
Constant	25.57***	5.10
Region 2	GDP per capita ≥ \$765.18	
GDP per capita	−2.64***	0.35
Squared of GDP per capita	0.16***	0.03
Fossil energy consumption per capita	1.22***	0.01
Renewable energy consumption per capita	0.05***	0.01
Foreign direct investment, net inflows (% of GDP)	0.02***	0.00
Constant	33.87***	1.11

Threshold (GDP per capita) is at \$765.18; all variables are in the log transformation form; *, **, and *** denote 1%, 5%, and 10% level of significance, respectively

the adoption of cleaner energy sources such as renewable energy to ensure that the quality of the environment, albeit currently low, is not going to further deteriorate in the future.

Figure 3 presents results from the Toda–Yamamoto approach for Granger causality test. The result is tested using the Wald test at 5% significance level. We find a bidirectional Granger causal relationship between economic growth and CO_2 emissions. Also, renewable energy and FDI have Granger causal effects on CO_2 emissions in Vietnam. We also find a bidirectional causal relationship between economic growth and FDI and between FDI and fossil energy consumption. We note that economic growth and fossil energy

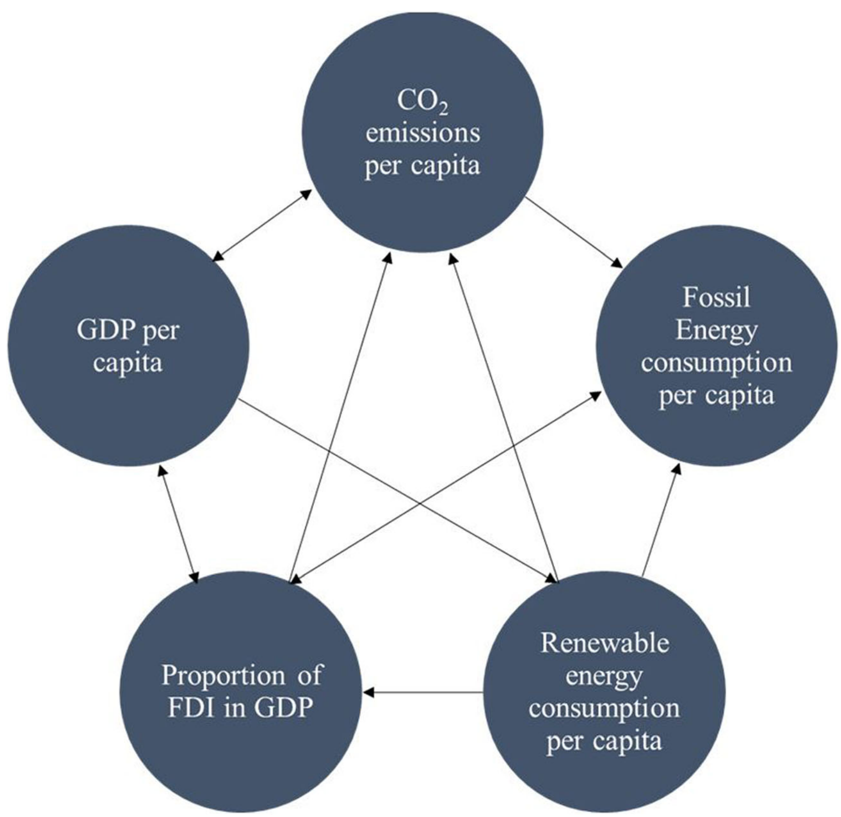

Fig. 3 Results from the Toda–Yamamoto approach for Granger causality test. The arrow represents a significant direction for Granger causality

consumption have no causal relationship for Vietnam during the research period.

The arrow represents a significant direction for Granger causality

Discussion

In this paper, we examine the link between economic growth and environmental degradation in the presence of the FDI, in Vietnam in the short run and long run. Empirical results using the ARDL regression technique suggest a U-shaped relationship between economic growth and environmental degradation, which is proxied by the CO_2 emissions in the long run. On the other hand, the U-shaped relationship between economic growth and CO_2 emissions has also been found in the threshold regression when Vietnam's GDP per capita reaches the threshold value at \$765.18. Our results support the findings from Vo et al. (2020), in which some of the CTPPP countries, including Vietnam, have exhibited a U-shaped relationship between economic growth and environmental degradation.

On the other aspect, FDI seems to improve environmental quality in the short-run (Table 3), and under a certain economic growth level (Table 4) in Vietnam. However, from the threshold regression, after the GDP per capita reaches \$765.18, FDI has provided a significant and positive effect on CO_2 emissions. Findings from the Toda–Yamamoto approach for Granger causality test also confirm that FDI has a Granger causal effect on Vietnam's CO_2 emissions. Meanwhile, a bidirectional causal relationship between economic growth and environmental degradation has been confirmed. Combining this bidirectional causal relationship with the U-shaped relationship between GDP per capita and CO_2 emissions, these findings imply that FDI on polluting industries should not be encouraged otherwise the environmental quality will be deteriorated further along with the process of economic growth and development in Vietnam in the future.

Conclusions and policy implications

Vietnam has been achieving a miracle in terms of economic growth in the Asian region and the world since the 1986 economic reform. This strong growth has been strongly supported with a strong flow of FDI from other advanced countries including Japan, South Korea, the USA, China, Australia, and European countries. However, it is noticeable that the quality of Vietnam's environment has consistently deteriorated in recent decades. As such, the Vietnamese government's fundamental issue is that the approach in which the dual objectives can be achieved: (i) a sustained economic growth; and (ii) an improved environmental quality. Economic growth should not be at the expense of environmental quality.

The link between economic growth and environmental degradation has been widely examined in the current literature. Studies with the focus of Vietnam are rather limited. More fundamentally, these limited numbers of studies focusing on Vietnam exhibit limitations in the data availability and/or the approaches. In addition, we note that the role of FDI to economic growth in Vietnam appears to be neglected in previous studies. Unlike previous studies, this study is conducted to revisit the important link between growth and the environmental quality with the focus on the important role of FDI in Vietnam. In addition, we use two time-series estimation methods, including the ARDL model and the threshold regression to ensure that available data is correctly used and the findings are robust.

Key findings from this paper can be summarized as follows. First, the U-shaped relationship (or an inverted EKC hypothesis) between economic growth and environmental quality is confirmed in Vietnam in the long term and at the upper threshold of economic growth. Second, FDI leads to an improvement in the environmental quality at the lower threshold of economic growth and in the short run. However, an increase in FDI is associated with further deterioration in environmental quality. Third, fossil fuel sources such as coal, gas, and oil consumption lead to environmental degradation in the long run and in both thresholds of economic growth.

On the ground of the empirical findings from this paper, policy implications have emerged for the Vietnamese government, policymakers, and practitioners. These implications can also be useful for other developing and emerging markets as well. In Vietnam, economic growth appears to be at the expense of the environmental quality without the government's direction and/or intervention, in particular in the long term and at the upper threshold of economic growth where Vietnam is heading to in the future. As such, a new economic growth model and development for Vietnam should be considered and implemented as soon as feasible to ensure that the trade-off between economic growth and environmental degradation is minimal. Based on the findings of this paper, we consider that policies targeting FDI and the use of fossil fuel sources of energy consumption are important to be considered.

First, FDI appears to flow into the pollution-intensive industries in emerging markets. The Vietnamese markets may be very attractive to become a pollution haven for FDI projects from developed countries. Currently, due to the Covid-19 and the trade war between the USA and China, some foreign-invested firms have been moving from China to Vietnam. The advantage of low labor costs in Vietnam is relatively obvious compared to those in China and other Asian emerging markets such as Thailand, Indonesia, and the Philippines. Vietnam should be careful in attracting the clean industries or preparing a strong framework in which the quality of the environment is the key consideration. In 2016, many Vietnam communities were suffered from many incidents of illegal dumping of toxic waste into the ocean and rivers. Cement, steel, fertilizer, and mining industries were responsible for those wastes. Approximate 60% of those wastes came from the FDI companies in Vietnam. The most harmful poison can be named for the Formosa—the steel plant in Ha Tinh province in Vietnam's central coast. The plant, which is a $10.6 billion steel complex owned by the Formosa Plastics Group, took responsibility for a massive die-off of marine life along the central coast in Vietnam. After these lessons, the Vietnam Association of Foreign-Invested Enterprises (VAFIE) proposed to develop new criteria for FDI in Vietnam in 2019. The Chairman of the VAFIE suggests that Vietnam should change the current FDI attractive strategy from tariff and financial incentives for low-cost manufacturing to prioritizing high-tech and clean sectors. The proposal expects to raise 50% of FDI companies using advanced and environment-friendly technology in 2025, and the number will be doubled in 2030.

Second, the consumption of energy from fossil fuel sources leads to the deterioration of the environment in the long term and at both thresholds of economic growth in Vietnam. As such, it appears that the Vietnamese government has to invest more in clean energies such as renewable energy in the near future to ensure that economic growth is not at the expense of the environmental quality. Vietnam has a great advantage of hydroelectric, given its massive networks of rivers and major lakes. It is a starting point. Other forms of renewable energy, including solar, wind, and others, are important to consider and develop along economic growth and development.

In conclusion, the Vietnamese government should focus on developing and implementing regulations in relation to foreign investment to limit investment projects in pollution-intensive sectors, especially in this international integration era. In addition, investing in research and development of energy-efficient technology and alternatives to fossil fuel energy also helps improve the quality of the environment in Vietnam.

Author contribution Conceptualization: Duc Hong Vo and Chi Minh Ho; methodology: Duc Hong Vo; formal analysis and investigation: Chi Minh Ho; writing - original draft preparation: Duc Hong Vo and Chi Minh Ho; writing - review and editing: Duc Hong Vo; funding acquisition: Duc Hong Vo and Chi Minh Ho; resources: Duc Hong Vo and Chi Minh Ho; supervision: Duc Hong Vo.

Funding This study is funded by Ho Chi Minh City Open University (E2020.01.1A).

Availability of data and materials The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate Not applicable

Consent for publication Not applicable

Competing interests The authors declare no competing interests.

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