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Short Communication

Investigating the environmental Kuznets curve hypothesis in Vietnam

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HIGHLIGHTS

- The environmental Kuznets curve (EKC) hypothesis in Vietnam is investigated.
- The Autoregressive Distributed Lag (ARDL) methodology was utilized.
- The EKC hypothesis does not exist.

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ABSTRACT

This study investigates the existence of the environmental Kuznets curve (EKC) hypothesis in Vietnam during the period 1981–2011. To realize the goals of this study, a pollution model was established applying the Autoregressive Distributed Lag (ARDL) methodology. The results revealed that the pollution haven hypothesis does exist in Vietnam because capital increases pollution. In addition, imports also increase pollution which indicates that most of Vietnam's imported products are energy intensive and highly polluted. However, exports have no effect on pollution which indicates that the level of exports is not significant enough to affect pollution. Moreover, fossil fuel energy consumption increases pollution while renewable energy consumption has no significant effect in reducing pollution. Furthermore, labor force reduces pollution since most of Vietnam's labor force is in the agricultural and services sectors which are less energy intensive than the industrial sector. Based on the obtained results, the EKC hypothesis does not exist because the relationship between GDP and pollution is positive in both the short and long run.

1. Introduction

In the last three decades, Vietnam achieved a fast and remarkable economic development. From the year 1986, the Vietnamese government launched political and economic improvements under the name (Doi Moi), which means renovation (The World Bank, 2014a,b,c). This movement helped transform Vietnam from a poor closed economy with a per capita income of 240 US dollars in 1985 to an open emerging economy with a per capita income of 1755 US dollars in 2012 (The World Bank, 2014a,b,c). Moreover, this country has managed to reduce its poverty rate from 58% in 1993 to 4.5% in 2012 (The World Bank, 2014a,b,c). However, Vietnam's remarkable boost in its economic development, urbanization, industrialization, energy consumption, and consumption of natural resources caused an increase in the environmental pressure. This can be seen by the level of CO_2 emission which more than doubled in the last 30 years (The World Bank, 2014a,b,c). However, the government of Vietnam proposed several actions to reduce the degradation of its environment through the Poverty Reduction Support Credits (PRSC). The PRSC proposed a number of strategies to improve the environmental management by enhancing the environmental valuation actions, pollution prevention and control, as well as maintaining a sustainable management of forests and water resources (The World Bank, 2014a,b,c). Furthermore, the substantial increase in the income level may increase the demand for a better quality of environment which is assumed by the environmental Kuznets curve (EKC) hypothesis.

The EKC hypothesis explains that during the early stages of economic development, when the country's income level is low, the increase in income will, consequently, increase the environmental degradation. Therefore, the relationship between income and the

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Table 1
Summary of the literature on the environmental Kuznets curve.

Author	Period	Country/region/organization	Methodology	Variables used in the study	EKC hypothesis
Studies on East Asia and Pacific					
Du et al., (2012)	1995–2009	China	Fixed effect (FE) and the generalized method of moments (GMM)	CO_2 emission, GDP, GDP square, urbanization, industrial composition, energy consumption, technology progress, and trade openness.	No
Chandran and Tang (2013)	1971–2008	The Association of Southeast Asian Nations (ASEAN).	Johansen cointegration test, VECM Granger causality.	CO_2 emission, energy consumption for road transportation, GDP, and GDP square.	No
Jalil and Feridun (2011)	1953–2006	China	The ARDL bounds testing approach, VECM Granger causality.	CO_2 emission, energy consumption, GDP, GDP square, financial development, and trade openness.	Yes
Shahbaz et al. (2013a)	1971–2011	Malaysia	The ARDL bounds testing approach, VECM Granger causality.	CO_2 emission, energy consumption, GDP, trade openness, financial development, and the square of financial development.	Yes
Jalil and Mahmud (2009)	1975–2005	China	The ARDL bounds testing approach, Pair wise Granger causality.	CO_2 emission, energy consumption, GDP, GDP square, and Trade openness.	Yes
Wang et al. (2011)	1995–2007	China	Pedroni cointegration, and VECM Granger causality.	CO_2 emission, GDP, GDP square, and energy consumption.	No
Saboori et al. (2012)	1980–2009	Malaysia	The ARDL bounds testing approach, VECM Granger causality.	CO_2 emission, GDP, and GDP square.	Yes
Lean and Smyth (2010)	1980–2006	ASEAN	Fisher cointegration, dynamic OLS (DOLS), and VECM Granger causality.	CO_2 emission, energy consumption, GDP, and GDP square.	Yes
Saboori and Sulaiman (2013a,b)	1971–2009	ASEAN	The ARDL bounds testing approach, and VECM Granger causality.	CO_2 emission, energy consumption, GDP, and GDP square.	Yes in Singapore and Thailand.
Haisheng et al. (2005)	1990–2002	China	Random and fixed effect model.	Industrial waste water, SO_2 emission, GDP, GDP square, trade openness, and foreign direct investment (FDI).	Yes
Llorca and Meunié (2009)	1985–2003	China	Fixed effects model.	SO_2 emission, GDP, GDP square, GDP cubic, FDI, industrial output,	No
Lau et al. (2014)	1970–2008	Malaysia	The ARDL bounds testing approach and VECM Granger causality.	CO_2 emission, GDP, GDP square, FDI, and trade openness.	Yes
Saboori and Sulaiman (2013a,b)	1980–2009	Malaysia	The ARDL bounds testing approach and VECM Granger causality.	CO_2 emission, GDP, GDP square, and energy consumption.	No
Studies on Europe and Central Asia					
Ang (2007)	1960–2000	France	Johansen cointegration test, The ARDL bounds testing approach, VECM Granger causality.	CO_2 emission, energy consumption, GDP, and GDP square.	Yes
Halicioglu (2009)	1960–2005	Turkey	The ARDL bounds testing approach, VECM Granger causality.	CO_2 emission, energy consumption, GDP, GDP square, and trade openness	Yes
Ozturk and Acaravci (2010)	1968–2005	Turkey	The ARDL bounds testing approach	economic growth, carbon emissions, energy consumption and employment	No
Iwata et al. (2010)	1960–2003	France	The ARDL bounds testing approach, Pair wise Granger causality.	CO_2 emission, energy consumption, urbanization, nuclear electricity production, GDP, GDP square, and trade openness.	Yes
Ozturk and Acaravci (2013)	1960–2007	Turkey	The ARDL bounds testing approach	Financial development, trade, economic growth, energy consumption and carbon emissions	Yes
Shahbaz et al. (2013b)	1970–2010	Turkey	The ARDL bounds testing approach and VECM	CO_2 emissions, energy intensity, economic growth and globalization	Yes
Acaravci and Ozturk (2010)	1960–2005	Europe	The ARDL bounds testing approach, and VECM Granger causality.	CO_2 emission, GDP, and GDP square.	Yes for Denmark and Italy.
Pao et al. (2011)	1990–2007	Russia	Johansen cointegration, OLS model, and VECM Granger causality.	CO_2 emission, energy consumption, GDP, and GDP square.	No
Shahbaz et al. (2013c)	1980–2010	Romania	The ARDL bounds testing approach.	CO_2 emission, energy consumption, GDP, and GDP square.	Yes
Atici (2009)	1980–2002	Central and Eastern Europe	Random and fixed effects model.	CO_2 emission, energy consumption, GDP, GDP square, and trade openness	Yes
Yavuz (2014)	1960–2007	Turkey	Johansen cointegration tests, Gregory–Hansen cointegration test, OLS and FMOLS model.	CO_2 emission, energy consumption, GDP, and GDP square.	Yes
Esteve and Tamarit (2012)	1857–2007	Spain	Threshold VECM model.	CO_2 emission, GDP, GDP square	Yes
Apergis and Payne (2010)	1992–2004	Commonwealth of independent	Pedroni cointegration, FMOLS, VECM Granger	CO_2 emission, energy consumption, GDP, GDP square.	Yes

		states.	causality.		
Studies on the Americas					
Hamit-Haggar (2012)	1990–2007	Canada	Pedroni cointegration test, fully modified OLS (FMOLS), VECM Granger causality.	CO_2 emission, GDP, and GDP square.	Yes
Apergis and Payne (2009a)	1971–2004	Central America	Pedroni cointegration, FMOLS, VECM Granger causality.	CO_2 emission, energy consumption, GDP, and GDP square	Yes
Zilio and Recalde (2011)	1970–2007	Latin America and the Caribbean	Pedroni cointegration,	Energy supply, GDP, and GDP square	No
Pao and Tsai (2011a,b)	1980–2007	Brazil	Gray prediction model (GM), and VECM Granger causality.	CO_2 emission, energy consumption, GDP, and GDP square.	Yes
Day and Grafton (2003)	1974–1997 for carbon monoxide (CO) emission. 1958–1995 For CO_2 emission. 1974–1997 for SO_2 emission. 1974–1997 for Total suspended particulate (TSP)	Canada	Johansen cointegration, OLS model, and VAR Granger causality.	CO emission, CO_2 emission, SO_2 emission, TSP, GDP, GDP square, and GDP cubic.	No
Plassmann and Khanna (2006)	1990	United States of America	Poisson regression	Carbon monoxide (CO), particulate matter (PM), GDP, GDP square, GDP cubic, population density, percentage minority, percentage unemployment, percentage employed in manufacturing, percentage voters, percentage renters, percentage below poverty, percentage female head of household, percentage older than 65, and distance from highway.	Yes
	1975–1999	Canada	Fixed effects and random effects model.	Forest area clear-cut, GDP, and GDP square.	Yes
Studies on Middle East and North Africa					
Shahbaz et al. (2014)	1971–2010	Tunisia	The ARDL bounds testing approach, VECM Granger causality.	CO_2 emission, energy consumption, GDP, GDP square, energy consumption, and trade openness.	Yes
Farhani et al. (2014)	1971–2008	Tunisia	The ARDL bounds testing approach, VECM Granger causality.	CO_2 emission, energy consumption, GDP, GDP square, and trade openness.	Yes
Fodha and Zaghdoud (2010)	1961–2004	Tunisia	Johansen cointegration test, VECM Granger causality.	CO_2 emission, SO_2 emission, GDP, GDP square.	Yes
Ozcan (2013)	1990–2008	Middle East	Pedroni cointegration, FMOLS, VECM Granger causality	CO_2 emission, energy consumption, GDP, and GDP square.	No
Studies on South Asia					
Nasir and Rehman (2011)	1972–2008	Pakistan	Johansen cointegration, VECM Granger causality.	CO_2 emission, GDP, GDP square, energy consumption, and trade openness.	Yes
Shahbaz et al. (2012)	1971–2009	Pakistan	The ARDL bounds testing approach, and VECM Granger causality.	CO_2 emission, energy consumption, GDP, and GDP square.	Yes
Tiwari et al. (2013)	1966–2011	India	The ARDL bounds testing approach, and VECM Granger causality.	CO_2 emission, energy consumption, GDP, GDP square, and trade openness.	Yes
Ahmed and Long (2012)	1971–2008	Pakistan	The ARDL bounds testing approach.	CO_2 emission, energy consumption, GDP, GDP square, trade openness, and population growth.	Yes
Studies on Sub-Saharan Africa					
Osabuohien et al. (2014)	1995–2010	Africa	Pedroni cointegration, and dynamic OLS (DOLS).	CO_2 emission, GDP, GDP square, rule of law, regulatory quality, government effectiveness, and trade openness.	Yes
Orubu and Omotor (2011)	1990–2002	Africa	OLS, fixed effects and random effects model.	suspended particulate matter (SPM), organic water pollutant (OWP)	Yes
Studies on emerging countries					
Pao and Tsai (2010)	1971–2005	Brazil, Russia, India, and China (BRIC) countries.	Pedroni, Kao, fisher cointegration tests, OLS model, VECM Granger causality.	CO_2 emission, GDP, GDP square, and energy consumption.	Yes
Jayanthakumaran et al. (2012)	1971–2007	China and India	The ARDL bounds testing approach	CO_2 emission, energy consumption, GDP, GDP square, trade openness.	Yes
Govindaraju and Tang	1965–2006	China and India	System-based test of Johansen, ECM-based	CO_2 emission, GDP, GDP square, and Coal consumption.	No

Table 1 (*continued*)

Author	Period	Country/region/organization	Methodology	Variables used in the study	EKC hypothesis
(2013)			F-test of Boswijk, ECM-based t-test of Banerjee cointegration, and VECM Granger causality.		
Pao and Tsai (2011a,b)	1992–2007	BRIC countries	Pedroni, Kao, and Fisher cointegration, OLS model, and VECM Granger causality.	CO_2 emission, energy consumption, GDP, GDP square, foreign direct investment (FDI).	Yes
Onafowora and Owoye (2014)	1970–2010	Brazil, China, Egypt, Japan, Mexico, Nigeria, South Korea, and South Africa.	The ARDL bounds testing approach, variance decomposition.	CO_2 emission, GDP, GDP square, trade openness, energy consumption, and population density.	Yes only for Japan and South Korea.
Studies on countries in different regions					
Babu and Datta (2013)	1980–2008	Developing countries	Fixed effects model.	Environmental degradation index, GDP, GDP square, GDP cubic, and population.	No
Cho et al. (2014)	1971–2000	OECD countries	Pedroni cointegration and FMOLS.	CO_2 emission, N_2 O emission, CH_4 emission, energy consumption, GDP, and GDP square.	Yes
Chow (2014)	1992–2004	132 developed and developing countries	OLS model	CO_2 emission, GDP, and GDP square.	Yes

environmental degradation will be positive until the country reaches a certain level of economic development when the relationship between income and the environmental degradation becomes negative. When the country's income quality increases, it will also increase the public demand for a better quality environment. Consequently, efforts from the government will increase to improve the environmental quality. This is evident in Vietnam as its government is continuously striving to reduce the pressure on the country's environment. Moreover, the substantially increasing income of Vietnam allowed the government to access technologies that can increase the country's energy efficiency and role of renewable energy. Hence, during the last 20 years, Vietnam's energy efficiency as well as its consumption of renewable energy increased over 50% and 45% respectively (Euromonitor database, 2013). Therefore, the inverted U-shaped relationship between Vietnam's income and its environmental damage may take place. This will, in turn, depict the existence of the EKC hypothesis.

Although numerous studies examined the existence of the EKC hypothesis in developed and developing countries, there has been no study that investigated the existence of the EKC hypothesis in Vietnam. Therefore, this paper aims to examine the environmental Kuznets curve (EKC) hypothesis in Vietnam during the period of 1981–2011. A pollution model was established using the Autoregressive Distributed Lag (ARDL) methodology to achieve the aim of this research.

2. Literature review

The validity of the environmental Kuznets curve (EKC) hypothesis has been widely examined by different scholars over the years. The empirical studies published over the period of 2003–2014 are presented in Table 1. The studies that examined the EKC hypothesis utilized different environmental degradation variables, such as carbon dioxide (CO_2) emission (Apergis and Payne, 2009a; Lean and Smyth, 2010; Du et al., 2012; Shahbaz et al., 2013b; and Tiwari et al., 2013), sulfur dioxide (SO_2) emission (Day and Grafton, 2003 and Llorca and Meunié, 2009), nitrous oxide (N_2O) emission (Cho et al., 2014), methane (CH_4) emission (Cho et al., 2014), Total Suspended Particulate (TSP) (Day and Grafton, 2003), and water waste (Haisheng et al., 2005). Moreover, these studies used different economic indicators, such as energy consumption, gross domestic product, trade openness, industrial output, urbanization, financial development, population density, and foreign direct investment (FDI). In addition, the reviewed studies investigated different countries from different regions that include East Asia and Pacific (Jalil and Feridun, 2011; Shahbaz et al., 2013a; Saboori and Sulaiman, 2013a,b; and Chandran and Tang, 2013), the Americas (Day and Grafton, 2003; Plassmann and Khanna, 2006; Apergis and Payne, 2009a; Zilio and Recalde, 2011; and Hamit-Haggar, 2012), Europe and Central Asia (Ang, 2007; Atici, 2009; Acaravci and Ozturk, 2010; Pao et al., 2011; Shahbaz et al., 2013c; and Ozturk and Acaravci, 2013) Middle East and North Africa (Fodha and Zaghdoud, 2010; Ozcan, 2013; Farhani et al., 2014; and Shahbaz et al., 2014), South Asia (Nasir and Rehman, 2011; Ahmed and Long, 2012; Shahbaz et al., 2012; and Tiwari et al., 2013), and Sub-Saharan Africa (Orubu and Omotor, 2011 and Osabuohien et al., 2014). To confirm the EKC hypothesis, most of the previous studies utilized GDP and GDP square. These two variables are incorporated to specify that if an inverted U-shaped relationship between the pollution indicator and GDP with its square is found, the EKC hypothesis exists.

The presence of the EKC hypothesis between income and pollution existed in 70% of the studies presented in Table 1. Moreover, the literature also revealed that the EKC hypothesis exists generally in high income countries such as France (Ang, 2007 and

Iwata et al., 2010), Canada (Hamit-Haggar, 2012), Spain (Esteve and Tamarit, 2012), and the United States of America (Plassmann and Khanna, 2006) and upper middle income countries such as Malaysia (Saboori et al., 2012; Shahbaz et al., 2013a; and Lau et al., 2014), China (Haisheng et al., 2005; Jalil and Mahmud, 2009; and Jalil and Feridun, 2011), Turkey (Halicioglu, 2009; Ozturk and Acaravci, 2013; Shahbaz et al., 2013b; and Yavuz, 2014), Romania (Shahbaz et al., 2013c), Tunisia (Fodha and Zaghdoud, 2010; Shahbaz et al., 2014; and Farhani et al., 2014), and Latin America and the Caribbean (Apergis and Payne, 2009a and Zilio and Recalde, 2011). This phenomenon corresponds with the EKC hypothesis. Despite that most of the studies were in accordance with the EKC hypothesis, this study found a number of gaps in the literature. Firstly, there is a lack of studies that examined the hypothesis in Vietnam despite its substantial boost in economic development in the past 30 years. Therefore, this study will examine the EKC hypothesis in Vietnam. Secondly, the previous studies joined GDP and GDP square in one regression which may cause an econometric problem due to the multicollinearity between GDP and its square. Therefore, to eliminate this limitation, Narayan and Narayan's (2010) approach, which will be explained in the methodology section, will be applied. This approach uses series data which correspond with the EKC hypothesis's time series relationship between income and environmental degradation.

3. Methodology and data treatment

In order to examine the cointegration relationship between the variables, Pesaran et al. (2001) cointegration approach was applied. In this approach, Pesaran et al. (2001) solved the non-stationary problem related to the time series data. Thus, this approach is applicable for time series data that are integrated in different orders except for time series data that are integrated in order two ($I(2)$) and above. Thus, it is not mandatory to check the integration order of the variables since the ARDL approach solves the problems resulting from non-stationary time series. Another advantage of the ARDL approach over the other cointegration approaches is that the short-run as well as the long-run effects of the independent variables on the dependent variable are assessed simultaneously to distinguish between the short run and long run effects of the variables. Moreover, the properties of the ARDL approach are more effective in analyzing small samples than the other approaches. It is proven that the ARDL based estimators for the long run coefficients are consistent with small sample size. Furthermore, all variables are assumed to be endogenous which eliminates the endogeneity problems associated with the Engle–Granger method.

The first step in the analysis was finding the Wald F-statistics for the combined significance of the coefficients. The F-statistics were compared with the tabulated critical values. For this test, Pesaran et al. (2001) formulated the critical values for large sample sizes (500–1000 observations) and Narayan and Narayan (2010) created the critical values for small sample sizes (30 observations and above). If the Wald F-statistics are higher than the upper bound critical value, cointegration is deemed to be present. On the other hand, if the Wald F-statistics are lower than the lower bound critical value, cointegration is considered inexistent. Furthermore, if the Wald F-statistics fall between the upper and lower bound critical values, the result is considered inconclusive.

Based on the EKC hypothesis, the environmental degradation is a function of GDP and square of GDP. However due to the collinearity or multicollinearity problems that may arise between GDP and square of GDP, Narayan and Narayan (2010) suggested an alternative method to examine whether developing countries have reduced carbon dioxide emission over time with the increase in their economic growth. They suggested comparing the short and long-run elasticities. If the long-run income elasticity is smaller than the short run income elasticity, then we can conclude that, over time, income leads to less carbon dioxide emission. In the light of the above discussion, following the recent empirical literatures such as Narayan and Narayan (2010) and Jaunky (2011), the following models were considered:

$$\text{Ln}\,(CO_2)_t^{ELF} = \alpha_0 + \alpha_1\,\text{Ln GDP}_t + \alpha_2\,\text{Ln CA}_t + \alpha_3\,\text{Ln LA}_t + \alpha_4\,\text{Ln EX}_t + \alpha_5\,\text{Ln IM}_t + \alpha_6\,\text{Ln ELF}_t + \varepsilon_t \quad (1)$$

$$\text{Ln}\,(CO_2)_t^{ELF} = \alpha_0 + \alpha_1\,\text{Ln GDP}_t + \alpha_2\,\text{Ln CA}_t + \alpha_3\,\text{Ln LA}_t + \alpha_4\,\text{Ln EX}_t + \alpha_5\,\text{Ln IM}_t + \alpha_6\,\text{Ln ELR}_t + v_t \quad (2)$$

In model (1), ELF stands for electricity consumption from fossil fuels sources measured in billions of Kilowatt-hours and, in model (2), ELR refers to electricity consumption from renewable sources measured in billions of Kilowatt-hours. CO_2 is per capita carbon dioxide emission from the consumption of fossil fuels measured in millions of metric tons, GDP is per capita Gross Domestic Products measured in 2000 of constant US dollars, CA is capital measured in millions of constant 2000 US dollars, LA is labor force measured in thousands of individuals, EX is export and IM is import measured in millions of constant US dollars. Additionally, ε and v represent the error term. This study will use time series data for the period of 1982–2011. The data of CO2, GDP, ELF, ELR, EX, IM, CA, and LA were retrieved from the Euromonitor database (2013). Table 2 describes the descriptive statistics for the data used in this study.

Table 2
The descriptive statistics.

	CO_2	CA	ELR	GDP	LA	EX	IM
Mean	10.43687	16.26829	22.76585	17.77918	10.43149	8.575331	8.962904
Median	10.49024	18.08656	23.12976	19.33514	10.46278	8.889556	9.318621
Maximum	11.70643	20.42956	24.12623	21.65410	10.72818	11.46397	11.55717
Minimum	9.473366	7.232950	20.92457	9.227453	10.07520	4.951593	6.011267
Std. Dev.	0.754451	4.130511	1.101568	3.723258	0.193037	1.910558	1.641872
Skewness	0.260994	−1.028964	−0.548566	−1.158292	−0.277183	−0.345804	−0.173489
Kurtosis	1.596512	2.661970	1.815578	2.989224	1.890093	2.078311	2.050700
Jarque-Bera	2.896240	5.617883	3.366797	6.931954	1.988152	1.715116	1.319521
Probability	0.235012	0.060269	0.185742	0.031242	0.370065	0.424197	0.516975
Sum	323.5430	504.3169	705.7413	551.1545	323.3762	265.8353	277.8500
Sum Sq. Dev.	17.07591	511.8337	36.40353	415.8796	1.117894	109.5069	80.87228
Observations	31	31	31	31	31	31	31

This study used per capita carbon dioxide emission as the dependent variable since it has been used by most of the reviewed studies, such as Halicioglu (2009), Fodha and Zaghdoud (2010), Ozturk and Acaravci (2010), Pao and Tsai (2011a,b), Wang et al. (2011), Tiwari et al. (2013), Lau et al. (2014), Yavuz (2014), and Osabuohien et al. (2014). The trade variables as a measure of trade openness were also used by a number of scholars such as Iwata et al. (2010), Jalil and Feridun (2011), Nasir and Rehman (2011), Du et al., (2012), Shahbaz et al. (2014), and Osabuohien et al. (2014). Furthermore, the energy consumption variable has been used by numerous studies such as Ang (2007), Atici (2009), Lean and Smyth (2010), Apergis and Payne (2010), Pao and Tsai (2011a,b), Shahbaz et al. (2013a), Chandran and Tang (2013), Saboori and Sulaiman (2013a,b), and Farhani et al. (2014). However, there are few studies that disaggregated energy consumption into non-renewable and renewable energy. Therefore, energy consumption in this study was divided into renewable and non-renewable sources as different sources of energy might have different effects on the environment. The variable GDP is utilized by all the previous studies as an indicator of economic development and to examine the EKC hypothesis. Moreover, Ghali and El-Sakka (2004), Huang et al. (2008), and Apergis and Payne (2009b) incorporated the variables labor and capital and indicated that these two variables have a significant influence on energy consumption. Therefore, labor and capital were included in both models as they might have an influence on pollution.

To employ the ARDL methodology, the following error correction models were estimated:

$$\begin{aligned}\Delta \ln (CO_2)_t^{ELF} = \; & \alpha_0 + \sum_{k=1}^{n1} \alpha_{1k} \Delta \ln (CO_2)_{t-k}^{ELF} + \sum_{k=0}^{n2} \alpha_{2k} \Delta \ln GDP_{t-k} \\ & + \sum_{k=0}^{n3} \alpha_{3k} \Delta \ln CA_{t-k} + \sum_{k=0}^{n4} \alpha_{4k} \Delta \ln LA_{t-k} + \sum_{k=0}^{n5} \alpha_{5k} \Delta \ln EX_{t-k} \\ & + \sum_{k=0}^{n6} \alpha_{6k} \Delta \ln IM_{t-k} + \sum_{k=0}^{n7} \alpha_{7k} \Delta \ln ELF_{t-k} \\ & + \delta_0 \ln (CO_2)_{t-1}^{ELF} + \delta_1 \ln GDP_{t-1} + \delta_2 \ln CA_{t-1} \\ & + \delta_3 \ln LA_{t-1} + \delta_4 \ln EX_{t-1} + \delta_5 \ln IM_{t-1} \\ & + \delta_6 \ln ELF_{t-1} + \mu_t \end{aligned} \quad (3)$$

$$\begin{aligned}\Delta \ln (CO_2)_t^{ELF} = \; & \beta_0 + \sum_{k=1}^{n1} \beta_{1k} \Delta \ln (CO_2)_{t-k}^{ELF} + \sum_{k=0}^{n2} \beta_{2k} \Delta \ln GDP_{t-k} \\ & + \sum_{k=0}^{n3} \beta_{3k} \Delta \ln CA_{t-k} + \sum_{k=0}^{n4} \beta_{4k} \Delta \ln LA_{t-k} + \sum_{k=0}^{n5} \beta_{5k} \Delta \ln EX_{t-k} \\ & + \sum_{k=0}^{n6} \beta_{6k} \Delta \ln IM_{t-k} + \sum_{k=0}^{n7} \beta_{7k} \Delta \ln ELR_{t-k} \\ & + \delta_0 \ln (CO_2)_{t-1}^{ELF} + \lambda_1 \ln GDP_{t-1} + \lambda_2 \ln CA_{t-1} \\ & + \lambda_3 \ln LA_{t-1} + \lambda_4 \ln EX_{t-1} + \lambda_5 \ln IM_{t-1} \\ & + \lambda_6 \ln ELR_{t-1} + \vartheta_t \end{aligned} \quad (4)$$

The α_0 and β_0 are the drift components in Eqs. (3) and (4) respectively. μ_t and ϑ_t are the white noise in Eqs. (3) and (4) respectively. α_1–α_6 in Eq. (3) and β_1–β_6 in Eq. (4) represent the error correction dynamics while δ_1–δ_6 in Eq. (3) and λ_1–λ_6 in Eq. (4) correspond to the long-run relationship among variables.

As mentioned earlier, the ARDL approach based on the Wald-*F*-statistics was employed to examine the existence of cointegration between the variables. The null hypotheses of no-cointegration in Eq. (3), H_{0ELF}: $\delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = 0$ and (4), H_{0ELR}: $\lambda_0 = \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = \lambda_6 = 0$ were tested against their alternatives H_{0ELF}: $\delta_0 \neq \delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 \neq \delta_6 \neq 0$ and H_{0ELR}: $\lambda_0 \neq \lambda_1 \neq \lambda_2 \neq \lambda_3 \neq \lambda_4 \neq \lambda_5 \neq \lambda_6 \neq 0$, respectively.

After testing the cointegration relationship between the variables and finding the long-run coefficients, the researchers examined the short coefficients in order to examine the existence of the EKC hypothesis. Thus, the short-run model of Eqs. (1) and (2) were formulated as follows, respectively:

$$\begin{aligned}\Delta \ln (CO_2)_t^{ELF} \; & \alpha_0 + \sum_{k=1}^{n1} \alpha_{1k} \Delta \ln (CO_2)_{t-k}^{ELF} + \sum_{k=0}^{n2} \alpha_{2k} \Delta \ln GDP_{t-k} \\ & + \sum_{k=0}^{n3} \alpha_{3k} \Delta \ln CA_{t-k} + \sum_{k=0}^{n4} \alpha_{4k} \Delta \ln LA_{t-k} + \sum_{k=0}^{n5} \alpha_{5k} \Delta \ln EX_{t-k} \\ & + \sum_{k=0}^{n6} \alpha_{6k} \Delta \ln IM_{t-k} + \sum_{k=0}^{n7} \alpha_{7k} \Delta \ln ELF_{t-k} + \psi ECT_{t-1} + \pi_t \end{aligned} \quad (5)$$

$$\begin{aligned}\Delta \ln (CO_2)_t^{ELF} = \; & \alpha_0 + \sum_{k=1}^{n1} \alpha_{1k} \Delta \ln (CO_2)_{t-k}^{ELF} + \sum_{k=0}^{n2} \alpha_{2k} \Delta \ln GDP_{t-k} \\ & + \sum_{k=0}^{n3} \alpha_{3k} \Delta \ln CA_{t-k} + \sum_{k=0}^{n4} \alpha_{4k} \Delta \ln LA_{t-k} + \sum_{k=0}^{n5} \alpha_{5k} \Delta \ln EX_{t-k} \\ & + \sum_{k=0}^{n6} \alpha_{6k} \Delta \ln IM_{t-k} + \sum_{k=0}^{n7} \alpha_{7k} \Delta \ln ELR_{t-k} + \omega ECT_{t-1} + k_t \end{aligned} \quad (6)$$

ECT indicates the Error Correction Term and shows the adjustment speed of the variables towards the long-run equilibrium. It should be noted that the ECT should have a statistically significant negative coefficient. Finally, the stability of the short and long-run models were checked by Cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ).

4. Empirical results

The first step was testing the cointegration relationship between the variables. The cointegration results are presented in Table 3. The results show that the cointegartion between the variables in both models (ELF and ELR) is supported by significant *F*-statistics and also by significant and negative coefficient obtained from the ECT_{t-1}.

The next step was examining the presence of the EKC. Following the new approach by Narayan and Narayan (2010), the short and long-run coefficients of GDP were compared. The short and long-run results related to both models are presented in Table 4. The results show that, in both models, the GDP has positive and significant coefficients. From comparing the short and long-run coefficients of GDP, it is apparent that in the both estimated models, an inverted U-shaped relationship between economic growth and CO_2 emission does not exist since economic growth has a positive effect on CO_2 emission in both the short and long-run in Vietnam. This indicates clearly that Vietnam economic development level has not reached the point where pollution can be reduced by the increase in GDP.

The long-run results show that capital increases pollution which indicates that most of the capital goes to energy intensive

Table 3
Cointegration results.

	ELF model	ELR model
F-statistics	6.608***	5.212**
ECT_{t-1}	−0.476(−3.402)***	−0.676(−3.933)***

Notes: The upper bound critical value of the *F*-statistics for cointegration is 6.21, 4.49 and 3.79 at the 1%, 5% and 10% level of significance respectively (Narayan and Narayan, 2010, p. 1988). The values in parentheses are the *t*-ratios.

** Significance at 5% level.

*** Significance at 1% level.

Table 4
The short and long-run results.

Long-run coefficient estimates	ELF model	ELR model
Ln GDP	0.96(2.908)***	1.399(6.328)***
Ln CA	0.267(4.139)***	0.231(3.035)***
Ln LA	−1.224(−1.983)*	−1.524(−2.389)**
Ln ELF	0.086(1.795)*	–
Ln ELR	–	−0.04(−0.535)
Ln EX	−0.091(−1.355)	−0.092(−0.97)
Ln IM	0.118(2.335)**	0.124(1.735)*
Constant	3.796(0.677)	4.758(0.796)
Short-run coefficient estimates		
ΔLn GDP	0.96(2.908)***	1.399(6.328)***
ΔLn CA	0.005(0.065)	−0.011(−0.126)
ΔLn LA	−1.224(−1.983)*	−1.524(−2.389)**
ΔLn ELF	0.086(1.795)*	–
ΔLn ELR	–	−0.04(−0.535)
ΔLn EX	−0.091(−1.355)	−0.092(−0.97)
ΔLn IM	0.118(2.335)**	0.124(1.735)*
ΔConstant	3.796(0.677)	4.758(0.796)

Note: The values in parentheses are the *t*-ratios.
* Significance at 10% level.
** Significance at 5% level.
*** Significance at 1% level.

and polluted industries, as indicated by Ghali and El–Sakka (2004), Huang et al. (2008), and Apergis and Payne (2009b). This result depicts the existence of the pollution haven hypothesis. In addition, imports of goods and services increase pollution since most of Vietnam's imports are energy intensive and highly polluted products. However, exports of goods and services have no effect on pollution which indicates that exports did not reach to the level where it can affect pollution. It is crucial to note that previous studies used trade openness to signify the exports and imports variables, for instance Halicioglu (2009), Jalil and Feridun (2011), Shahbaz et al. (2013a), Ozturk and Acaravci (2013), and Onafowora and Owoye (2014). This study, however, incorporated both variables in the equation instead of using the single variable of trade openness. This incorporation is intended to further elucidate the relationship between the variables (export and imports) and CO_2 emission. Renewable energy consumption is negatively correlated to pollution, but it is also insignificant which indicates that renewable energy cannot be a key solution in reducing the pollution level. Furthermore, fossil fuel energy consumption intensifies pollution by its positive effect on CO_2 emission. These results are consistent with most of the previous studies, such as Apergis and Payne (2009a), Lean and Smyth (2010), Pao et al. (2011), Nasir and Rehman (2011), Du et al., (2012), Saboori and Sulaiman (2013a,b), Shahbaz et al. (2014), and Cho et al. (2014). Moreover, labor force has a negative effect on pollution which indicates that most of the labor force is concentrated in less polluted and energy incentive sectors. This is also indicated by Ghali and El-Sakka (2004), Huang et al. (2008), and Apergis and Payne (2009b). Based on the obtained results, the EKC hypothesis was not confirmed in Vietnam since GDP has a positive effect on CO_2 emission in both the short and long run. This outcome is consistent with Zilio and Recalde (2011), Chandran and Tang (2013), Ozcan (2013), and Babu and Datta (2013). Moreover, this result indicates that the relationship between income and pollution did not reach the turning point where the relationship between the two components becomes negative.

Finally, the stability of the ELF and ELR models was checked by CUSUM and CUSUMSQ tests. In both tests, the straight lines represent critical bounds at 5% significance. The results of the CUSUM test for both models show that the models are stable in the short and long-run. The plots of Cumulative sum (CUSUM) and the

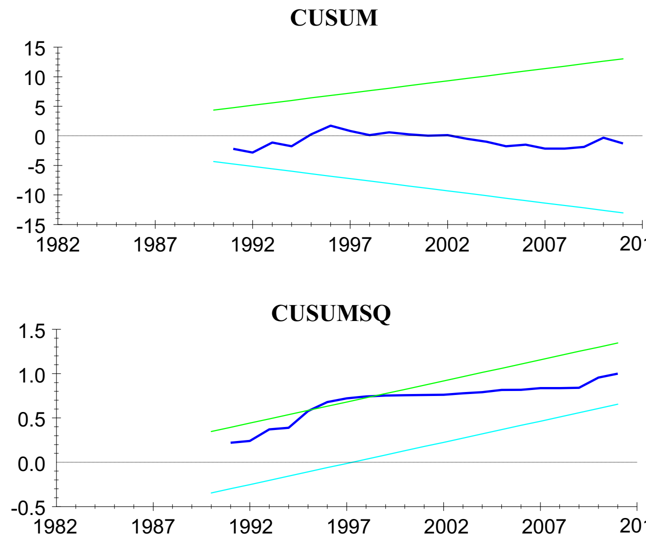

Fig. 1. The results of CUSUM and CUSUMSQ in ELF model.

plot of cumulative sum of squares (CUSUMSQ) tests are presented in Figs. 1 and 2, respectively.

5. Discussion

The results obtained from the ARDL revealed that capital has a significant positive effect on CO_2 emission. However, this variable does not have any significant effect on CO_2 emission in the short-run. This is in line with the Pollution Haven Hypothesis (PHH) which suggests that, in the long-run, countries with lesser environmental regulations will produce more pollution intensive goods than countries with more environmental rules. Basically, foreign direct investments (FDI) from the developed countries are more likely to invest in polluted intensive industries than the clean industries in the developing countries. Since industrialized countries, such as China, South Korea, Japan, Singapore, Thailand, and the United States of America represent the main trade partners to Vietnam, they regularly seek to establish factories in this country due to its cheap resources, labor, and, essentially, less stringent environmental regulations (World Factbook, 2014). As a result, capital, in the long-run, has a positive effect on environmental pollution.

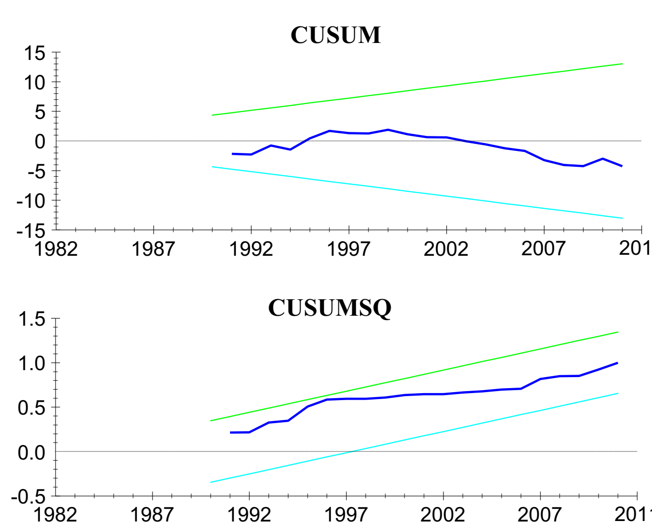

Fig. 2. The results of CUSUM and CUSUMSQ in ELR model.

Moreover, it was concluded that labor has a negative impact on CO_2 emission. This relationship is expected since over 79% of the labor force goes to the agricultural and the services sectors which are well known to be less energy intensive compared to the industrial sector (World Factbook, 2014). Although, there is evidence of moving labor force from the agricultural sector to the industrial and services sectors, this trend is still very slow.

The results indicate that fossil fuel energy consumption has a positive effect on CO_2 emission while renewable energy consumption has no significant effect in reducing pollution. The positive relationship between fossil fuel energy consumption and CO_2 emission is expected since this type of energy is well known to be the main source of greenhouse gas emission. The insignificant relationship between renewable energy consumption and CO_2 emission is predictable since renewable energy plays only 1% from the total energy consumed in Vietnam. Moreover, the results also indicate that renewable energy cannot be a key solution to reduce the pollution level in Vietnam.

Additionally, it was found that the imports of goods and services increase pollution because of its positive impact on CO_2 emission. This indicates that Vietnam's imports, which are mostly machinery and equipment, petroleum products, steel products, raw materials, electronics, plastics, and automobiles, are heavily polluted (World Factbook, 2014). However, exports of goods and services seem to have an insignificant effect on CO_2 emission which reveals that exports did not reach a level that can affect pollution.

6. Conclusion and policy implications

This research examined the validity of the EKC hypothesis in Vietnam due to its substantial economic development that the country witnessed over the past three decades. To realize the aim of this research, a pollution model was established using the ARDL method and taking the period 1981–2011.The results revealed that the pollution haven hypothesis does exist in Vietnam. Moreover, fossil fuel energy consumption increases pollution while renewable energy consumption has no significant effect in reducing pollution. Furthermore, labor force reduces pollution since most of Vietnam's labor force is in the agricultural and services sectors which are less energy intensive than the industrial sector. Finally, the EKC hypothesis does not exist because the relationship between GDP and pollution is positive in both the short and the long run.

From the results of this research, the researchers recommend Vietnam to increase the use of capital for projects that can promote energy efficiency and renewable energy. This will also help reduce the consumption of fossil fuels and increase the role of renewable energy which can result in reducing pollution. Moreover, it is also suggested that Vietnam's policy makers should increase the environmental regulations especially on the energy intensive and polluted foreign industries. As imports of goods and services increase pollution, a trade-related actions and strategies to increase the environmental protection are essential to be applied to reduce the environmental pressure induced by trade in general. Applying these suggestions by Vietnam's policy makers can help to reduce the energy consumed and the pollution produced by GDP and the other macroeconomic variables. This can boost Vietnam's economic development to reach the turning point where the relationship between GDP and pollution becomes negative.

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