Environmental Kuznets Curve (EKC) Hypothesis in Lao PDR: The Role of Globalization and Financial Development*

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Received May 20, 2020; **Revised** June 12, 2020; **Accepted** August 20, 2020

Abstract

This paper examines the cointegration and causal relationship between economic growth, carbon dioxide emission, population density, and globalization in Lao PDR for the period from 1993-2013. The empirical analysis uses an autoregressive distributed lag (ARDL). The results confirm cointegration between the variables. Our results also confirm the presence of an environmental Kuznets curve (EKC). The findings show that income, energy consumption, and financial development have become important driving factors for the increase in the emission of carbon dioxide while globalization has no significant effect on environmental degradation. The empirical findings enable policy-makers to draw some conclusions about sustainable development in Lao PDR.

Keywords: Environmental Kuznets Curve; Financial Development; Globalization.

Introduction

Global warming and climate change are the most debatable environmental issues of our times. Industrial development is the main cause of the massive damage to the environment and economic losses from natural disasters like droughts, flooding, and heatwaves. The global impacts of climate change also have extensive effects on the well-being of humans, the existence of wildlife, and the state of the ecosystem. In Lao PDR, the economy and population are dependent on natural resources and agriculture. Hence, this dependence indicates that Laos is highly vulnerable to climate change.

Laos is one of the fastest growing economies in Southeast Asia with, on average, a rate of 7.85% per year between 2009 and 2015; and CO_2 emissions per capita increased by 208%

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* The 6th Greater Mekong Sub region International Conference (GMSIC) 2019

between 2004 and 2014. As outlined in Lao PDR's eighth 5-year plan (2016-2020), the government of Lao has set a rate of 9.3% for industrial growth. This growth will increase the demand for energy that will stimulate pollution in the country. Moreover, sustainable development and environment protection are also goals (Somlith, 2016). Thus, Lao PDR faces a great challenge in accomplishing both goals of high economic growth and less environment degradation at the same time.

Since the 1980s, Lao PDR has experienced structural economic reforms because of globalization. The Lao economy has gradually become more global and has developed financially. The financial sector in Lao PDR has grown remarkably over the last decade, in particular, due to the institutions that offer services for both liabilities and assets such as microfinance institutions, saving groups, commercial banks, and insurance companies. Recent studies in Ozturk and Acaravi (2013) and Boutabba (2014) argue that financial development is an alternative source of CO_2 emission. On the other hand, Jalil and Feridun (2011) find that financial development reduces environmental pollution.

The fourth industrial revolution has increased globalization. Globalization leads to the greater integration of economies and societies (Agenor, 2002). Hence, countries around the world are more closely integrated with each other politically, economically, and culturally. Globalization enhances productivity and boosts economic activity via the transfer of technology from developed nations to developing ones. Globalization is also a significant variable that affects CO_2 emissions and the environment. Its effect on the environment is threefold: technological, scale, and compositional (Antweiler, Copeland, & Taylor, 2001). Many scholars have applied various measures to globalization to investigate its effect on environmental pollution. For instance, Shahbaz, Lean, and Shabbir (2012), Shahbaz, Kumar Tiwari, and Nasir (2013), and Boutabba (2014) show that trade openness decreases CO_2 emission due to the investment in energy-efficient technologies for production.

The remainder of this paper is organized as follows: Section 2 is a review of the literature. Section 3 presents the data and method. The empirical results are provided in Section 4 that is followed by the conclusion and policy implications in Section 5.

Lao Context

Over the last three decades, Lao PDR has experienced rapid economic growth. Before the Asian financial crisis, economic growth increased at an annual rate of 5.59% from 1986 to 1997. The average growth was about 7.82% during 2006-2016; and sectoral growth was 20.9% in agriculture, 33.2% in industry, and 45.9 % in services in 2012. Lao's economy is considered one of the fastest growing in Southeast Asia. Nonetheless, Lao PDR still has an underdeveloped infrastructure, especially in rural areas. Lao's economy has the enormous advantage of the inflows from foreign direct investment in mining and hydroelectricity (Kyophilavong, Shahbaz, Kim, & Oh, 2017).

In line with being a fast-growing economy, energy consumption has increased from 589.19 ktoe in 2013 to 613.33 ktoe in 2014 (4%). According to the report from the Ministry of Energy and Mine, the residential sector had the biggest energy use (39.68%) in 2014, followed by transportation (22.68%), commercial (9.86%), and other sectors (10.35%). In addition, CO_2 emissions increased from 0.04 metric tons per capita in 1990 to 0.29 metric tons per capita in 2014. The growth of the financial sector over the last decade raised confidence in continued foreign direct investment. Domestic credit to private sectors has been an increasing trend

(20.84% of GDP in 2010 and increased to 26.69% of GDP in 2019). A greater level of globalization in an economy can affect the emission of greenhouse gases. The globalization (measured by the KOF globalization index) of Lao PDR increased from 26.83 in 2010 to 27.07 in 2014 (26%). The KOF globalization index measured Lao's economy in 2014 as social globalization 38%, economic globalization 66%, and political globalization 26% (Dreher, 2006).

Lao PDR became a member of the Kyoto Protocol in February 2003. In order to cooperate with the Kyoto Protocol, Lao PDR must reduce the emission of greenhouse gases. While Lao PDR is not a main contributor to climate change, around 70% of its total population depends on agriculture for their livelihood. Hence, global warming and climate change can have immense impacts on people around the country from unpredictable natural disasters (UNDP, 2010). The country has concerns about the consequences of climate change to environmental sustainability, poverty reduction, human development, and economic growth.

Literature review

The existence of the environmental Kuznets curve (EKC) hypothesis has greatly attracted the attention of various scholars over the years. Studies have mostly applied the EKC hypothesis to emerging and developed countries rather than to less developed countries. The studies on EKC of different countries are presented in Table 1. To investigate whether the inverted U-shaped curve exists or not, most of the studies use different environmental degradation variables such as carbon dioxide (CO_2) emission (Ang, 2007; Iwata, Okada, & Samreth, 2010; Ozturk & Acaravcı, 2010; Marrero, 2010; Pao, Yu, & Yang, 2011), Sulfur dioxide (SO_2) emission (Llorca & Meunie, 2009), Ecological footprint (Al-mulali, Choong, Sheau-Ting, & Mohammed, 2015), and Biological oxygen demand emissions (Lee, Chiu, & Sun, 2010). Moreover, a number of variables have been applied as major determinants of environmental degradation such as GDP and GDP square (Arouri, Ben Youssef, M'henni, & Rault, 2012; Guangyue & Deyong, 2013; Shahbaz, Solarin, Mahmood, & Arouri, 2013). Studies also use other various economic indicators such as energy consumption (Ozturk & Acaravcı, 2010; Saboori, Sulaiman, & Mohd, 2012), trade openness (Halicioglu, 2009; Tiwari & Shahbaz, 2012), urbanization (Al-mulali et al., 2015), financial development (Jalil & Feridun, 2011), population growth (Ahmed & Long, 2012), and so forth. Furthermore, the empirical studies examine various countries from various regions that include the Americas (Day & Grafton, 2002; Zilio & Recalde, 2011; Hamit-Haggar, 2012; Robalino-López, García-Ramos, Golpe, & Mena-Nieto, 2014), East Asia and Pacific (Jalil & Mahmud, 2009; Lean & Smyth, 2010; Saboori et al., 2012; Chandran & Tang, 2013), Europe and Central Asia (Atici, 2009; Halicioglu, 2009; Apergis & Payne, 2010; Ozturk & Acaravcı, 2010), the Middle East and Africa (Fodha & Zaghdoud, 2010; Ozcan, 2013; Kohler, 2013; Sbia, Shahbaz, Hamdi, & Ozturk, 2014), and South Asia (Nasir & Rehman, 2011; Ahmed & Long, 2012; Tiwari & Shahbaz, 2012; Shahbaz, Lean, & Shabbir, 2012).

The studies that support the existence of an inverted U-shaped curve are presented in Table 1. In addition, they show that the EKC hypothesis commonly exists in high income and developed countries such as Canada (Hamit-Haggar, 2012), France (Ang, 2007), and Spain (Esteve & Tamarit, 2012). The upper middle-income countries such as China (Jalil & Feridun, 2011; Wang, Zhou, Zhou, & Wang, 2011), Malaysia (Shahbaz, Solarin, et al., 2013; Lau, Choong, & Eng, 2014), Tunisia (Shahbaz, Khraief, Uddin, & Ozturk, 2014; Farhani, Chaibi, & Rault, 2014), Turkey (Halicioglu, 2009; Ozturk & Acaravcı, 2010; Ozturk & Acaravcı, 2013;

Yavuz, 2014), and emerging countries (Pao & Tsai, 2010; Jayanthakumaran, Verma, & Liu, 2012; Govindaraju & Tang, 2013). On the other hand, some researchers have found that the EKC hypothesis does not support their studies such as of Llorca and Meunie (2009), Ozturk and Acaravcı (2010), Pao et al. (2011), Du, Wei, and Cai (2012), and Babu & Datta (2013). In the case of Lao PDR, there are no studies that examine the EKC hypothesis despite the phenomenal boost in its economic development. Thus, this paper is an effort to fill that gap in the EKC literature.

Table 1: Some sample studies on EKC.

Authors	**Country, period, and methodology**	**Variables use**	**EKC result**
Day and Grafton (2002)	Central and Eastern Europe 1980-2002 Fixed and random effects	CO_2, GDP, energy consumption	Yes
Ang (2007)	France 1960-2000 ARDL and VECM	CO_2, GDP, energy consumption, trade openness	Yes
Atici (2009)	Central and Eastern Europe 1980-2002 Random and fixed effect	CO_2, GDP, energy consumption, and trade openness.	Yes
Halicioglu (2009)	Turkey 1960–2005 ARDL, VECM Granger causality.	CO_2, energy consumption, GDP, trade openness	Yes
Jalil and Mahmud (2009)	China 1953-2006 ARDL, VECM	CO_2, energy consumption, GDP, financial development, trade openness.	Yes
Llorca and Meunie (2009)	China 1985–2003 Fixed effects model	SO_2, GDP, FDI, industrial output,	No
Iwata et al. (2010)	France 1960–2003 ARDL, Pair wise Granger causality.	CO_2, energy consumption, urbanization, nuclear electricity production, GDP, trade openness.	Yes
Ozturk and Acaravcı (2010)	Turkey 1968–2005 ARDL, Pair wise Granger causality.	economic growth, CO_2, energy consumption and employment	No
Marrero (2010)	Europe 1990-2006 Panel OLS, GMM and FE	CO_2, GDP, energy consumption in aggregate and disaggregate level	Yes
Lee et al. (2010)	97 countries by region. 1980-2001 Generalized Method of Moments (GMM)	Biological oxygen demand emissions, GDP, trade openness and population density.	Various

Lean and Smyth (2010)	ASEAN 1980–2006 Fisher cointegration, OLS (DOLS), VECM	CO_2, energy consumption, GDP	Yes
Apergis and Payne (2010)	Commonwealth of independent states. 1992-2004 Pedroni cointegration, OLS, and VECM	CO_2, GDP, energy consumption.	Yes
Ozturk and Acaravcı (2010)	Turkey 1968–2005 ARDL	economic growth, CO_2, energy consumption and employment	No
Pao and Tsai (2010)	Brazil, Russia, India, and China 1971–2005 Pedroni, Kao, fisher cointegration, OLS, VECM	CO_2, GDP and energy consumption	Yes
Fodha and Zaghdoud (2010)	Tunisia 1961–2004 Johansen cointegration, VECM	CO_2, SO_2, GDP	Yes
Pao et al. (2011)	Russia 1990–2007 Johansen cointegration, OLS and VECM.	CO_2, energy consumption, GDP.	No
Zilio and Recalde (2011)	Latin America and the Caribbean. 1970–2007 Pedroni cointegration	CO_2, energy supply, GDP	No
Nasir and Rehman (2011)	Pakistan 1972–2008 Johansen cointegration, VECM	CO_2, GDP, energy consumption, trade openness.	Yes
Jalil and Feridun (2011)	China 1953-2006 ARDL, VECM	CO2, energy consumption, GDP, financial development, and trade openness	Yes
Wang et al. (2011)	China 1995–2007 Pedroni cointegration and VECM	CO_2, GDP and energy consumption	No
Pao et al. (2011)	Russia 1990–2007 Johansen cointegration, OLS, VECM	CO_2, energy consumption, GDP	No
Arouri et al. (2012)	MENA 1981-2005 CCE, bootstrap panel test cointegration, and VECM	CO_2, GDP, and energy consumption.	No
Hamit-Haggar (2012)	Canada 1990–2007 FMOLS, VECM	CO_2, GDP	Yes
Saboori et al. (2012)	Malaysia	CO_2, GDP	Yes

	1980–2009 ARDL and VECM		
Ahmed and Long (2012)	Pakistan 1971–2008 ARDL	CO_2, energy consumption, GDP, trade openness, and population growth.	Yes
Tiwari and Shahbaz (2012)	India 1966–2011 ARDL and VECM	CO_2, energy consumption, GDP, and trade openness.	Yes
Shahbaz et al. (2012)	Pakistan 1971-2009 ARDL and VECM	CO_2, GDP, energy consumption, and trade openness.	Yes
Esteve and Tamarit (2012)	Spain 1857–2007 VECM	CO_2 and GDP	Yes
Jayanthakumaran et al. (2012)	China and India 971–2007 ARDL	CO_2, energy consumption, GDP, trade openness.	Yes
Du et al. (2012)	China 1995-2009 FE and GMM	CO_2, GDP, urbanization, industrial composition, energy consumption, technology progress, trade openness.	No
Guangyue and Deyong (2013)	China 1990-2007 CEDW, DF, ADF and PLS.	CO_2 and GDP	Various
Sbia et al. (2014)	UAE 1975–2011 ARDL and VECM	Electricity consumption, Growth, CO_2, urbanization.	Yes
Shahbaz et al. (2013)	Malaysia 1970-2011 ARDL and VECM	CO_2, GDP, financial development, energy consumption, trade openness.	Yes
Chandran and Tang (2013)	ASEAN 1971-2008 Johansen cointegration, VECM	CO_2, energy consumption for road transportation, GDP.	No
Ozcan (2013)	Middle East 1990–2008 Pedroni cointegration, FMOLS and VECM	CO_2, energy consumption, GDP	No
Kohler (2013)	South Africa 1960-2009 ARDL and VECM	CO_2, GDP, energy consumption, trade openness.	Yes
Ozturk and Acaravcı (2013)	Turkey 1960–2007 ARDL	Financial development, trade, economic growth, energy consumption, CO_2	Yes
Govindaraju and Tang (2013)	China and India 1965–2006 Johansen, ECM and VECM	CO_2, GDP and Coal consumption	No
Babu and Datta (2013)	Development countries 1980-2008 Fixed effect	Environmental degradation index, GDP, and population.	No

Shahbaz et al. (2014)	Tunisia 1971–2010 ARDL and VECM	CO_2, energy consumption, GDP and trade openness.	Yes
Farhani et al. (2014)	Tunisia 1971–2008 ARDL and VECM	CO_2, energy consumption, GDP and trade openness.	Yes
Yavuz (2014)	Turkey 1960–2007 Johansen cointegration, Gregory–Hansen cointegration, OLS and FMOLS model.	CO_2, energy consumption, GDP	Yes
Al-mulali et al. (2015)	99 countries classified by income level. 1980-2008 GMM and Panel	Ecological footprint, GDP, energy consumption, urbanization, trade openness, and financial development.	Yes

Model and methodology

To establish the relationship between the selected variables for Lao PDR, the following model is introduced:

$$C_t = f(E_t, Y_t, Y_t^2, F_t\ G_t) \tag{1}$$

Where C_t is CO_2 emission per capita, E_t is per capita energy consumption, Y_t is GDP per capita, Y_t^2 is GDP squared per capita, F_t defines financial development, and G_t refers to the KOF globalization index. All data are transformed into natural logarithms following Shahbaz et al. (2012) and Ozturk and Acaravci (2013). Hence, the form of our model is rewritten as follows:

$$Ln\ C_t = \beta_0 + \beta_1\ LnE_t + \beta_2\ LnY_t + \beta_3\ Ln\ Y_t^2 + \beta_4\ Ln\ F_t + \beta_5\ Ln\ G_t + \varepsilon_t \tag{2}$$

Where ε_t is the standard error term assumed to be a normal distribution.

Since the increase in energy consumption leads to higher economic activity that triggers CO_2 emissions, the sign for $\beta_1$should be positive. The EKC hypothesis displays that β_2 should be positive whereas β_3 should be negative. The sign of β_4 may be positive or negative depending on the level of economic development in the country. The expected sign for globalization is positive or $\beta_5 > 0$ if energy-efficient technology via foreign investment and trade is encouraged for domestic products otherwise $\beta_5 < 0$.

The accessibility of proper data is the most significant part of any research. We have used data on CO_2 emissions (metric tons per capita), real GDP per capita (constant 2010 US$), and the financial development indicator (domestic credit provided by financial sector, % of GDP) from World Development Indicators. The data on globalization come from the economic, social, and political globalization sub-indices that were borrowed from Dreher (2006). Moreover, the data on energy consumption per capita (kg of oil equivalent) were collected from the Ministry of Energy and Mine, Lao PDR (unpublished). This study concentrates on the period from 1990 - 2014 based on the availability of annual data. We analyze the cointegration and causal relationships between economic growth, carbon dioxide emission, energy consumption, globalization, and financial development in Lao PDR. Furthermore, we test the long-run relationships among the series by applying the ARDL bounds testing approach to cointegration.

ARDL bounds testing

The determination of the existence of cointegration among variables is considerable. The existence of cointegration among variables not only means a long-run equilibrium relationship but it also assures consistent results when the ordinary least square method is applied to the estimation of the coefficients.

The ARDL bounds testing approach of cointegration is a new method that was established by Pesaran, Shin, and Smith (2001). This approach has various advantages compared to other cointegration approaches. First, we do not have to have all variables in the system to be in the same order of integration. Second, Haug (2002) argues that this technique provides better results for small samples in comparison to other cointegration techniques such as the versions presented in Engle and Granger (1987), Johansen and Juselius (1990), and Phillips and Hansen (1990). Third, we can distinguish between the long-run as well as the short-run relationships between the independent variables and the dependent variables. In addition, it allows the variables to have various optimal lags. However, it does not allow the order of integration of any of the variables to be bigger than one such as the I(2) variable. Thus, it is essential to identify the unit root to ensure that all variables qualify the underlying assumption of the ARDL bounds testing to cointegration.

In order to apply the ARDL, we construct the Unrestricted Error-Correction Model (UECM). The UECM is used to examine long-run and short-run relationships among variables as follows in Equation (3):

$$\begin{aligned}\Delta lnC_t = \theta_0 &+ \sum_{i=1}^{n} \theta_{1i} \Delta lnC_{t-i} + \sum_{i=0}^{n} \theta_{2i} \Delta lnE_{t-i} + \sum_{i=0}^{n} \theta_{3i} \Delta lnY_{t-i} \\ &+ \sum_{i=0}^{n} \theta_{4i} \Delta \mathrm{ln} Y_{t-i}^2 + \sum_{i=0}^{n} \theta_{5i} \Delta lnF_{t-i} + \sum_{i=0}^{n} \theta_{6i} \Delta lnG_{t-i} + \delta_1 lnC_{t-1} \\ &+ \delta_2 lnE_{t-1} + \delta_3 lnY_{t-1} + \delta_4 \mathrm{n} Y_{t-1}^2 + \delta_5 lnF_{t-1} + \delta_6 lnG_{t-1} + \varepsilon_t \end{aligned} \tag{3}$$

Fundamentally, Equation (1) uses the OLS technique. Then the computed F-statistic needs to be calculated. Equation (3) shows two segments of results. The first part presents the short-run parameters for instance θ_1, θ_2, θ_3, θ_4 , θ_5, and θ_5; while δ_1, δ_2, δ_3, δ_4 , δ_5 , and δ_6 show the long-run relations among the selected variables. The "*k*" represents the number of lags, and "*t*" represents the trend variables.

The null hypothesis of no long-run cointegration for the F test is $H_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = 0$ $H_1 = \delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 \neq \delta_6 \neq 0$ that is examined against its alternative. The computed F-statistic is compared with the critical bounds in Pesaran, Shin, and Smith (2004), which are known as lower critical bounds (LCB) and upper critical bounds (UCB). The existence of cointegration among the variables can be determined if the estimated

F-statistic is greater than the UCB, which rejects the null hypothesis for no cointegration. If the estimated F-statistic is lower than the LCB, then the null hypothesis for no cointegration is accepted.

Another way to determine the presence of a long-run relationship is to replace the lagged level variables with an error-correction term (ECT) and estimates for its coefficient and statistical significance. In order to get these coefficients, the short-run error-correction model in equation (3) needs to be examined. Then the ECT can be computed as the sum of the lagged level term that applies the calculates of δ_1. After that, the lagged level term in each equation is substituted by the lagged value of formed ECT. The error-correction model (ECM) is examined one more time with the same optimal selected lags. The ECT presents the speed of adjustment and indicates how quickly the variables return to the long-run equilibrium. The AIC and SBC criteria are used to choose the optimal lag length. The expected sign of its coefficients should be negative and statistically significant. The ECM is generated in Equation (4).

$$\Delta lnC_t = \theta_0 + \sum_{i=1}^{n} \theta_{1i} \Delta lnC_{t-i} + \sum_{i=0}^{n} \theta_{2i} \Delta lnE_{t-i} + \sum_{i=0}^{n} \theta_{3i} \Delta lnY_{t-i} + \sum_{i=0}^{n} \theta_{4i} \Delta \ln Y_{t-i}^2 + \sum_{i=0}^{n} \theta_{5i} \Delta lnF_{t-i} + \sum_{i=0}^{n} \theta_{6i} \Delta lnG_{t-i} + + \psi ECT_{t-1} + \varepsilon_t \quad (4)$$

The goodness of fit for the ARDL model is also checked with the diagnostic tests such as serial correlation, normality, and heteroscedasticity. Furthermore, we also compute stability tests for the stability of long-run and short-run estimates through the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ), which are introduced by Durbin, Brown, and Evans (1975).

Empirical results and discussion

This paper uses the augmented Dickey and Fuller (Phillips & Hansen, 1990) and Phillips and Perron test (Phillips & Perron, 1987). The null hypothesis in both tests states that the variables include a unit root against the alternative of stationary. Table 2 shows the results of the ADF, and Table 3 shows the results from the PP tests of the level and first difference of the variables. The results show that none of variables is I (2) or beyond.

Table 2: ADF Unit root test results.

	Variable	**ADF test statistics**		
		None	Intercept	Trend and Intercept
Level	LnC	-2.357053**	-1.686800	-1.393700
	LnY	2.705362	5.934857	-1.068972
	LnY^2	2.582590	7.532620	-0.507142
	LnG	2.899825	-1.884308	-0.824195

	LnE	4.059185	4.048041	1.552588
	LnF	0.909214	-2.076690	-2.365478
First difference	LnC	-3.984397***	-4.502597***	-4.504989***
	LnY	0.685786	-2.152744	-4.709473***
	LnY^2	0.948262	-1.710860	-4.596922***
	LnG	-1.789903*	-4.915700***	-5.170761***
	LnE	-0.314390	-4.360697***	-4.828106***
	LnF	-3.700686***	-3.951794***	-3.808721**

Note: The ***, **, and * denote the statistical significance at the 1%, 5%, and 10% levels respectively.

Table 3: PP Unit root test results.

	Variable	PP test statistics		
		None	None	None
Level	LnC	-2.373599**	-1.393404	-1.686800
	LnY	13.11075	5.874444	-1.080210
	LnY^2	13.53576	7.485001	-0.518968
	LnG	2.915271	-1.884308	-0.824195
	LnE	3.779445	2.458860	-1.133427
	LnF	1.013319	-1.100113	-1.688023
First difference	LnC	-3.978638***	-4.502654***	-4.491987***
	LnY	0.447053	-2.995608*	-4.709473***
	LnY^2	0.665271	-2.423309	-4.596922***
	LnG	-4.005778***	-4.911359***	-5.155170***
	LnE	-2.774942***	-4.355811***	-5.927244***
	LnF	-3.602911***	-3.602911**	-3.482568***

Note: The ***, **, and * denote the statistical significance at the 1%, 5%, and 10% levels respectively.

The ARDL bounds testing requires the lag length for the variable to ensure that the classical assumptions are not violated. Based on the minimum value of the Akaike Information

Criteria (AIC), the optimum lag order is (1, 1, 1, 0, 1, 1). The result in Table 4 shows that the F-statistic is greater than the UCB. Thus, cointegration exists among the variables.

Table 4 presents the long-run cointegration results with the diagnostic tests such as serial correlation, normality, and heteroscedasticity. The results establish the existence of the EKC with positive and negative coefficients for $\ln Y$ and lnY^2.

Table 4: The results of ARDL cointegration.

Maximum lag imposed	AIC optimal lags	F-statistic at AIC-selected optimal lags	Result
1	(1, 1, 1, 0, 1, 1)	10.26841***	Cointegrated
Critical Value for F-statistics		Lower Bounds I(0)	Upper Bounds I(1)
1%		3.74	5.06
5%		2.86	4.01
10%		2.45	3.52

Note: ***, ** and * denote the statistical significance at 1%, 5% and 10% level respectively.

Specifically, the turning point of real GDP per capita is $Y^* = -\beta_2/2\beta_3$. This paper proposed that CO_2 emission per capita triggers an increase in income but after a certain level of income, which is the turning point, it begins to fall. The turning point of real GDP per capita out is 6.237, and the result is computed as a logarithm. Hence, our converted turning point is 511.322 US$.

Table 5 shows a 1% increase in GDP leads to a 203.476 % increase in CO_2 emission in the long run. The coefficient for lnE indicates that a 1% increase in energy consumption leads to a 11.961% increase in CO_2 emission. In addition, a 1% increase in financial development leads to a 0.525% increase in CO_2 emission. All the mentioned coefficients are statistically significant. However, lnG is statistically insignificant.

The short-run estimation results are also provided in Table 5. The sign of the coefficients for $\ln Y$ and lnY^2 do not support the existence of the EKC hypothesis for Lao PDR over the sample period. The coefficient for lnY indicates that a 1% increase in GDP leads to a 429.425% decrease in CO_2 emission. In addition, the coefficient for lnE indicates that a 1% increase in energy consumption leads to a 1.969% decrease in CO2 emission.

The estimate of the lagged error-correction term (ECT_{t-1}) is negative and statistically significant (-0.539) at the 1% level. This significance validates our earlier formed long-run relationship between the variables. Hence, we conclude that the adjustment from the short-run to the long-run equilibrium path is 53.9%. Our model passes all the diagnostic tests easily, and we find no evidence of serial correlation or heteroscedasticity.

Table 5: Long- and short-run analysis.

Long-run relationship			
Variable	**Coefficient**	**t-Statistic**	**Probability**
Dependent variable = C			
Constant	-699.3734	-2.693659	0.0246
LnY	203.4766	2.692730	0.0247
LnY^2	-16.31176	-2.686908	0.0249
LnG	-1.617506	-0.790379	0.4496
LnE	11.96164	2.081949	0.0671
LnF	0.525695	2.249239	0.0511
R-squared	0.987940	F-statistic	73.72595
Adjusted R-squared	0.974540	Prob(F-statistic)	0.000000
Short-run relationship			
ΔLnY	-429.4053	-10.59549	0.0000
ΔLnY^2	33.78499	10.67727	0.0000
ΔLnE	-1.969331	-2.317728	0.0457
ΔLnF	0.081306	1.627712	0.1380
ECT_{t-1}	-0.539293	-10.94523	0.0000
R-squared	0.900363	F-statistic	
Adjusted R-squared	0.873794	Prob(F-statistic)	
Diagnostic Checks			
Serial correlation LM	0.478472 (0.3004)		
ARCH test	1.477498 (0.2177)		
Normality test	0.606374 (0.738461)		
Heteroscedasticity test	1.139947 (0.3440)		
Ramsey reset test	0.003928 (0.9516)		

Moreover, due to structural changes in the Lao economy, it is likely that the macroeconomic variables may be subject to one or more structural breaks. For this reason, the stability of the short-run and the long-run coefficients are checked through the cumulative sum (CUSUM) and cumulative sum of squares (CUCUMSQ) test suggested by Durbin et al. (1975). The results of the stability test (CUSUM & CUSUMSQ) are provided in Figs. 1 and 2. We discover that our graphs are both inside the critical bounds (red lines) at the 5% level. These levels ensure that our model is reliable and consistent.

Fig.1. Plot of cumulative sum of recursive.

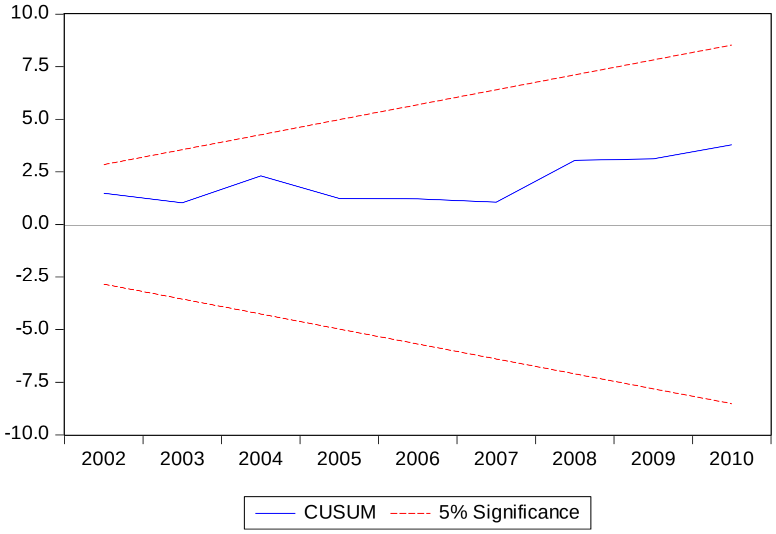
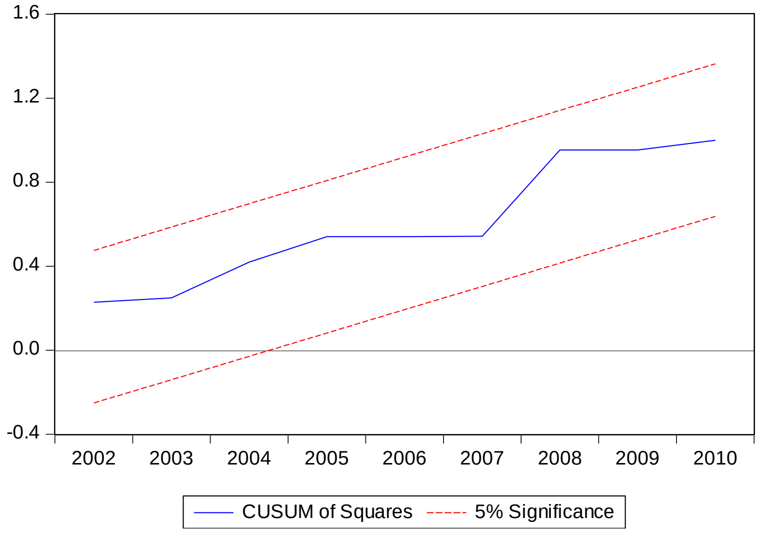


Fig.2. Plot of cumulative sum squares of recursive.



Conclusion

This paper examines the cointegration between CO2 emission, energy consumption, financial development, and globalization in Lao PDR for the period from 1990-2014. To realize the aim of this research, we use the ARDL technique introduced by Pesaran et al. (2001). The bound F-test for cointegration gives evidence of a long-term relationship among the respective variables.

The positive signs of the linear and nonlinear confirm that the existence of the EKC hypothesis supports this country only for the long run. This finding means that CO2 emission increases with income but after a certain level of income, it starts to fall as more efficient technology and energy conservation are utilized during the nation's development progress. We find that globalization has no significant impact on CO2 emission. Furthermore, the results also indicate that income, energy consumption, and financial development are important contributors to the increase in CO2 emission. These results are in line with the findings obtained for Pakistan (Javid & Sharif, 2016). This study suggests that the government of Lao PDR should plan new environmental policies to reduce environmental pollution and conserve the well-being of the Lao people.

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