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Testing Environmental Kuznets Curve (EKC) Hypothesis for Deforestation in Lao PDR[1]

Kittiya Manivong; Soudavanh Phengsavanh; Phouphet Kyophilavong;Phetsamone Pommavong; Kiengkham Khamvilvanh;Sonesana Mixayboua
Faculty of Economics and Business Management, National University of Laos

Abstract

This paper investigates the existence of Environmental Kuznets Curve (EKC) in Lao PDR. We examine for short run and long run relationship between economic growth, deforestation rate, agricultural production index, rural population and debt for period 1991 – 2015 by applying Autoregressive Distributed Lag (ARDL) approach to cointegration. The empirical result does not support an inverted U-shaped relationship (EKC) for the case of Lao PDR. However, the finding shows that agricultural production index and rural population increase deforestation which indicates that agricultural activities in rural area cause the negative impact to the forest in Lao PDR. This study provides helpful information for Lao scholars and policy-makers in order to develop and implement environmental policies of the country.

Keyword : Testing Environmental Kuznets Curve (EKC) Deforestation Lao PDR

1. Introduction

Deforestation is one of the most serious environmental issue for decades, it also has impacts on economic activities and harms the livelihood and cultural integrity (Culas, 2007). In addition, deforestation contributes to global warming and climate change.

Deforestation and woodland degradation have denuded great areas of Lao PDR since the 1940s when forests covered over 70% of the country's land area. However, forests cover conclusively reduced to less than 40 percent in the 1990s and there has been no dramatically change in this trend (FAO, 2018). The prevention of deforestation and promotion of reforestation have often been set as schemes to slow global warming and climate change (Bala et al., 2007). Lao government purposes to restore forest cover 70% by 2020 which means 8.2 million hectares of land of forests cover will be restored. On the other hand, as outlined in Lao PDR's 8th five-year plan (2016-2020), the government of Lao has set more than 7% real GDP growth target, which will require to stimulate by all sectors of the economy including agricultural, industrial and services (Somlith, 2016). Moreover, it also will increase demands for timber or alternative lands to accomplish the aim. Hence, Lao is faced with the great challenge to achieve both goals of high economic growth and less environment degradation at the same time.

In order to reduce forest degradation and to ensure sustainable economic development, it is important to better understand the linkage between economic development and environmental degradation which has been investigated widely by Environmental Kuznets Curve (EKC) hypothesis. Theoretically, the EKC hypothesis supposed the existence of an inverted U-shaped

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Email: kittiya@gmail.com

relationship between real GDP per capita and pollutant variables such as CO_2/SO_2 emission or deforestation. This paper is an achievement to fill the gap in the EKC for deforestation literature because there is lack of comprehensive studies for Laos. Single country studies provide helpful information to economists and policy-makers in making advisable policy to control forest degradation. This research contributes to the EKC for deforestation literature with a case study of Lao PDR applying time series data for the period of 1991-2015. In addition, ARDL bounds testing technique is used to investigate the existence of EKC hypothesis. The remainder of the paper is organized as follows. Section 2 reports a selected literature review related to variables. Section 3 has the data and methodology. Empirical results are provided in Section 4 followed by conclusion and policy implication in Section 5.

2. Literature review

In this study we attempt to examine the Environmental Kuznets Curve (EKC) hypothesis in Lao PDR, it postulates that Income first increases and then falls with economic growth (Kuznets, 1955). The EKC hypothesis argues relationship between environmental degradation and economic growth. In the early phase of economic developed, environmental degradation tend to increase as GDP per capita rise up to a turning point. However, the degradation will start to decrease as well as economic growth.

Since the last three decades, there has been increasing studies the association between economic growth and environment degradation using different technique. There are a number of recent studies utilized various environmental degradation variables, such as Sulfur dioxide (SO_2) emission: (Llorca & Meunie, 2009), Ecological footprint: (Al-mulali, Choong, Sheau-Ting, & Mohammed, 2015), carbon dioxide (CO_2) emission: (Ozturk & Acaravcı, 2010); (Marrero, 2010); (Pao, Yu, & Yang, 2011). GDP per capita have been connected with higher deforestation in developing countries(Kaimowitz & Angelsen, 1998), income can cause deforestation by increasing demands for timber and fuel sources, but at the later level of economic development could lead to reduction in deforestation, for instance, by enhancing the demand for restoring dreaded forests. Some studies have provided empirical results of the EKC for deforestation such as (Cropper & Griffiths, 1994) found the existence of EKC for Latin American and African countries. (Bhattarai & Hammig, 2001) also revealed the relationship between deforestation and economic development for African, Asian and Latin America countries. In addition, (Culas, 2007) discovered the validity of an EKC for deforestation in Latin America. On the other hand, (Shafik, 1994);(Koop & Tole, 1999) and (T. Azomahou & Nguyen-Van, 2007) do not find the evidence of EKC.

Some scholars have used population variables as the determinants of environmental degradation such as population growth, population density and rural population. These indicators can increase the demand for alternative land uses, agricultural products, fuelwood and timber that causes deforestation. The empirical studies shows various effects of population variables on deforestation such as population density (T. Azomahou & Nguyen-Van, 2007) and population growth (Barbier & Burgess, 2001) increased significantly on deforestation. Contrastively, (Koop & Tole, 1999) did not find the impact of population density on deforestation in Africa, Asia and Latin America. Other variable that has usually been consisted of in explanatory variable of deforestation is external debt. The devaluation would boost the exports of timber and agricultural products but with an increased rate of deforestation (Culas, 2007). However, debt could affect deforestation if the outcome in greater emphasis on the exploitation of forest resources to increase government revenues to pay interest and repay the external debt (Tacconi, 2011).

Lao PDR is included (Koop & Tole, 1999) which is a panel data study. In any event, it is extensively recognized that any practicable conclusion drawn from this cross-country study offers only a general comprehension of the relationship between the variables. Hence, it is unable to provide much information on policy implications for each country. Thus, the purpose of this study is to examine the existence of the environmental Kuznets Curve (EKC) hypothesis for deforestation in the case of Lao PDR.

Table 1: Summary of literature review for deforestation

Authors	Time period	Countries/cities	Methodology	EKC Result
(Shafik, 1994)	1972-1988	47 cities in 31 countries	FE	No
(Koop & Tole, 1999)	1961-1992	76 developing countries	Pooled regression, FE, RE	No
(Bhattarai & Hammig, 2001)	1972-1991	Africa, Asia and Latin America	FGLS estimation	Yes, for Latin America and Africa
(Culas, 2007)	1972-1994	Latin America	FE & RE	Yes
(T. Azomahou & Nguyen-Van, 2007)	1972-1994	59 developing countries	FE	No
(Chiu, 2012)	1972-2003	52 Developing countries	PSTR model	Yes
(Waluyo & Terawaki, 2016)	1962-2007	Indonesia	ARDL bounds testing	Yes
(Joshi & Beck, 2017)	1990-2007	OECD and non-OECD regions	GMM estimation	Yes, for OECD and Africa

3. The data and modeling

We have use data of deforestation rate, real GDP, debt, population growth and agricultural land. Deforestation rate calculated by $(F_{t-1} - F_t)/F_{t-1}$, where F_t is forest cover area the data on forest cover area attains from FAOSTAT released by FAO. Real GDP (constant 2010 US$), debt (% of GNI), population growth (annual %) and agricultural land (% of land) has been collected from world development indicators. The real GDP is measured as nominal GDP divided by Consumers Price Index (2010 = 100). This study examines the period 1991-2015. The estimable econometric regression line is as follows:

$$DEF_t = \beta_0 + \beta_1 GDP + \beta_2 GDP_t^2 + \beta_3 Debt_t + \beta_4 RP_t + \beta_5 API_t + \varepsilon_t \qquad (1)$$

Where DEF_t is deforestation rate, GDP_t *and* GDP_t^2 is real GDP and its square, $Debt_t$ is debt, RP_t indicates to rural population and agricultural production index is indicated by API_t. ε_t is the error term and assumed to be having normal distribution. The relationship between deforestation and economic growth inverted U-shape if $\beta_1 > 0$ and $\beta_2 < 0$. Debt, population growth and agricultural land is the determinants increase deforestation. Hence, the expected signs of β_3, β_4 *and* β_5 should be positive. Details of the variables, description, units, data sources and the expected sign with deforestation are all provided in Table 2.

Table 2: Descriptive details of variables

Variable	Unit	Description	Expected sign	Source
DEF	%	Rate of deforestation		FAO
GDP	US$	Real GDP (constant 2010 US$)	positive	WDI
GDP^2	US$	Real GDP per capita squared	negative	WDI
API	US$	Agricultural production index in the base period of 2004-2006	positive	FAO
RP	%	Rural population (% of total)	positive	WDI
Debt	%	External debt stocks (% of GNI)	positive	WDI

Note: FAO is Food and Agriculture Organization of the United Nations, WDI is World Development Indicators, World bank data.

The ARDL bounds testing approach of cointegration is introduced by (Shin & Pesaran, 1999) and (Pesaran, Shin, & Smith, 2001). The ARDL cointegration approach is used to examine for existence of the long-run equilibrium relationship between the dependent variable and explanatory variables. This method has diverse advantages in comparison with other cointegration techniques, for instance, (Engle & Granger, 1987), (Johansen, 1988) and (Johansen & Juselius, 1990) approaches: (i) the series used do not have to be the same order of integration, (ii) cointegration relationships can be determined efficiently with small sample, (iii) both the short- and the long-run relationship can be synchronously computed, (iv) different optimal lags of the variables can be allowed.

Nevertheless, it does not allow the order of integration of any of the variables is bigger than, for example an I(2) variable. Then the critical bounds presented by (Pesaran et al., 2001) and (Narayan, 2005) are not acceptable. Hence, it is crucial to test for unit root to assure that all variables qualify the underlying assumption of the ARDL bounds testing to cointegration. The unrestricted error correction model (UECM) version of the ARDL model is formed as follows:

$$\Delta DEF_t = \theta_0 + \sum_{i=1}^{n} \theta_{1i} \Delta DEF_{t-i} + \sum_{i=0}^{n} \theta_{2i} \Delta GDP_{t-i} \sum_{i=0}^{n} \theta_{3i} \Delta \ln GDP_{t-i}^2 + \sum_{i=0}^{n} \theta_{4i} \Delta API_{t-i} + \sum_{i=0}^{n} \theta_{5i} \Delta RP_{t-i} + \sum_{i=0}^{n} \theta_{6i} \Delta DEBT_{t-i} + \delta_1 DEF_{t-1} + \delta_2 GDP_{t-1} + \delta_3 GDP_{t-1}^2 + \delta_4 API_{t-1} + \delta_5 RP_{t-1} + \delta_6 DEBT_{t-1} + \varepsilon_t \quad (2)$$

In Equation (3), $\theta_1, \theta_2, \theta_3, \theta_4, \theta_5$ and θ_6 represent short-run parameter while δ_1, δ_2, δ_3, δ_4 , δ_5 and δ_6 correspond to the long-run relationship among variables, Δ is the first different operator, “t” represents trend variables, “k” refers number of lags. The optimal lag structure is chosen by the Akaike information criteria (AIC).

The cointegration analysis is delivered by examining the joint significance of the lagged levels of the variables applying the F-test. The null hypothesis of no long-run relationship suggests: $H_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = 0$. The rejection of null hypothesis: $H_1 = \delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 \neq \delta_6 \neq 0$. (Pesaran et al., 2001) generated two sets of critical value (lower and upper critical bounds), the decision of cointegration is depended on the calculated F-statistic. The upper critical bounds (UCB) assumes that regressors are I(1). The lower critical bounds (LCB) assumes that regressors are I(0). If the F-statistic passes UCB, we conclude that there is a long-run relationship. If the F-statistic is lower LCB, we cannot reject the null hypothesis of no cointegration. If the computed F-statistic falls between UCB and LCB, then the result will be inconclusive. In addition, we have carried out the stability tests to examine the stability of ARDL bounds testing computes by using CUSUM and CUSUMSQ test proposed by (Durbin, Brown, & Evans, 1975).

Once a long-run relationship has been formed the error correction model (ECM) is computed for the selected ARDL presentation. The lagged level variables are substituted by an error-correction term (ECT) and estimates for its coefficient and the statistically significance. The ECT shows the speed of adjustment and suggest how quickly the variables return to the long-run equilibrium. A general ECM of Equation (3) is established as follows:

$$\Delta DEF_t = \theta_0 + \sum_{i=1}^{n} \theta_{1i} \Delta DEF_{t-i} + \sum_{i=0}^{n} \theta_{2i} \Delta GDP_{t-i} \sum_{i=0}^{n} \theta_{3i} \Delta GDP_{t-i}^2 + \sum_{i=0}^{n} \theta_{4i} \Delta Debt_{t-i} + \sum_{i=0}^{n} \theta_{5i} RP_{t-i} + \sum_{i=0}^{n} \theta_{6i} \Delta API_{t-i} + \psi ECT_{t-1} + \varepsilon_t \qquad (3)$$

where ψ is speed adjuster parameter and ECT_{t-1} the residuals that are obtained from the computed cointegration model of Equation (1). The results of the ECM then allow measuring how quickly variables converge to equilibrium and it should have a negative sign and a statistically significant coefficient.

4. Empirical result

Table 2 gives unit roots tests in level and first different of the variables: DEF_t, GDP_t, GDP_t^2, $Debt_t$ and API_t applying (Dickey & Fuller, 1981) and (Phillips & Perron, 1987). The null hypothesis in both test suggests that the series include unit root against the alternative of stationary.

Table 2: results of unit root tests.

	Variable	ADF test statistic			PP test statistic		
		None	Intercept	Trend and Intercept	None	Intercept	Trend and Intercept
Level	DEF	-0.497743	-0.888498	-1.970270	-0.497743	-0.843920	-1.970270
	Y	-1.717753*	-2.164346	-2.053318	-1.354836	-1.380567	-1.079122
	Y^2	-2.039887**	-2.124154	-2.419939	-1.441092	-1.326588	-1.464496
	API	6.382577	3.266087	1.147745	7.290079	3.976388	0.905203

	RP	-10.81862***	-2.200574	-8.213208***	-6.644760***	3.252773	-6.822597***
	DEBT	-1.242167	-1.875248	-2.633631	-1.521424	-1.867048	-2.633631
First difference	DEF	-4.733690***	-4.993942***	-4.884656***	-4.733690***	-5.009825***	-4.897021***
	Y	-2.130698**	-2.134342	-3.752516**	-2.284561**	-2.294465	-2.361910
	Y^2	-2.303608**	-2.320086	-5.201550***	-2.303608**	-2.459414	-2.494130
	API	0.498374	-0.674746	-4.823630***	-0.544730	-3.077454**	-4.936484***
	RP	-0.568487	-2.315877	-1.288819	0.867365	-2.177199	-0.753833
	DEBT	-5.189085***	-5.204956***	-5.082693***	-5.344716***	-5.592559***	-5.393949***

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

The results of ARDL bounds testing approach to cointegration are presented in Table 3. Our estimated F-statistic exceeds upper critical bound at 1% significance level. This confirms the presence of cointegration between the variables over the period 1991-2015. This refers that economic growth, agricultural production index, rural population, debt and deforestation are cointegrated for long-run relationship in case of Lao PDR.

Table 3: ARDL cointegration analysis

Maximum lag imposed	AIC optimal lags	F-statistic at AIC-selected optimal lags	Result
3	(3, 2, 1, 1,0, 0)	8.5036775***	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.

The results are reported in Table 4 indicating that agricultural production index has positive and statistically significant effect on deforestation. This refers that This shows that a 1 US$ rise in agricultural production index is linked with a 0.022% increase in deforestation. The relationship between rural population and deforestation is also positive and it is significant at 1 % level. Keeping other things same, a 1% increase in rural population raises deforestation by 0.208%.
The result provides the absence of EKC, it identifies negative and positive coefficients of GDP and GDP^2 and they are also statistically insignificant.

The short run results illustrated that economic growth has a negative impact on deforestation and it is statistically significant at 1% level of significance. Rural population is positively related to deforestation and significantly at 1% level of significance. It is found that rural population is a major contributor to deforestation in short run.

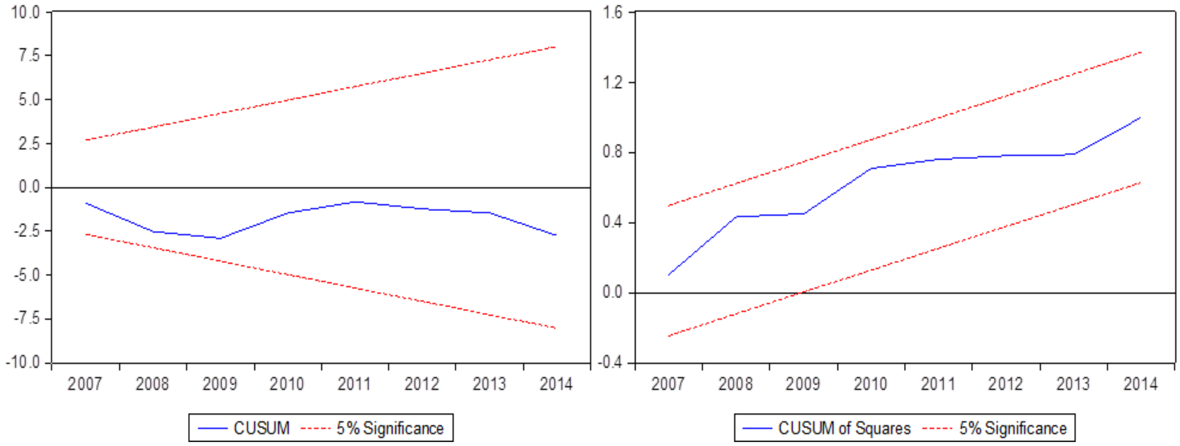
The error correction term ECT_{t-1} indicates the speed of adjustment of deforestation to its long-run equilibrium following a shock. The coefficient of -2.15 is significant at the 1% level with a negative sign expected, suggesting that a deviation from the long-run equilibrium level of deforestation in 1 year is corrected by 215% over the following year. Furthermore, a significant error correction approves the existence of a stable long-run relationship between the dependent variables to the dependent variable.

In addition, due to structural changes in Lao economies it is likely that macroeconomic series maybe subject to one or multiple structural breaks. Thus, the stability of short-run and long-run coefficients are checked through the cumulative sum (CUSUM) and cumulative sum of squares (CUCUMSQ) test suggested by (Durbin et al., 1975). The result of CUSUM and CUSUMSQ are provided in Figs 1. The results referred that CUSUM and CUSUMSQ are and CUSUMSQ statistics are well within the critical bounds, suggesting that all coefficients in the our model are stable.

Table 4: Results of long-run and short-run cointegration

Long run relationship			
Variable	**Coefficient**	**t-Statistic**	**Probability**
Dependent variable = DEF			
Constant	-18.06589	-6.436264	0.0002
Y	-0.001129	-0.299086	0.7725
Y^2	8.12E-06	0.561939	0.5896
API	0.022661	6.067654	0.0003
RP	0.208887	5.597378	0.0005
DEBT	-0.000401	-0.135491	0.8956
R-squared	0.984830	F-statistic	43.27910
Adjusted R-squared	0.962074	Prob(F-statistic)	0.000006
Short run relationship			
ΔGDP	-0.009479	-5.098598	0.0009
ΔGDP^2	-6.38E-06	-0.771212	0.4627
ΔAPI	0.013542	4.354458	0.0024
ECT_{t-1}	-2.154439	-10.20637	0.0000
R-squared	0.884537		
Adjusted R-squared	0.835052		
Diagnostic Checks			
Serial correlation LM		0.203309 (0.5135)	
ARCH test		0.031911 (0.8508)	
Normality test		2.635563 (0.267729)	
Heteroscedasticity test		0.436733 (0.7603)	
Ramsey reset test		0.498670 (0.6305)	

Fig.1: Plots of CUSUM and CUSUMSQ of recursive residuals.



5. Conclusion and policy implication

The purpose of this study is to investigate the cointegration relationship between economic growth, agricultural production index, rural population, debt and deforestation over the period 1991-2015, by employing the ARDL bounds testing approach. Diagnostic tests and the stability of the model are also checked.

Our finding suggested that the Environmental Kuznets Curve (EKC) does not support in the case of Lao PDR. Our results confirmed that all the variables are cointegrated for long run relationship. Agricultural production index is the main contributor to deforestation in both short term and long term. A rise in economic growth increases demand for agricultural production that stimulates forest degradation. Rural population also has positive impact on deforestation in long run. Our results indicated that agricultural activities in rural area cause the negative impact to the forest in Lao PDR. Our finding also gives helpful information for Lao scholars and policy-makers in order to develop and implement environmental policies of the country.

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