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Environmental Kuznets Curve for Deforestation in Indonesia: An ARDL Bounds Testing Approach

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The main objective of this study is to empirically demonstrate the inverse U-shaped relationship, which is generally called the environmental Kuznets curve (EKC), between economic development and deforestation rate in Indonesia. For this purpose, we analyzed time-series data for Indonesia over 46 years from 1962 to 2007 with the autoregressive distributed lag (ARDL) bounds testing approach to cointegration. Results support the long-run inverted-U relationship, which implies that, while the deforestation rate increases at the initial stage of economic growth, it declines after a threshold point. The income turning point of the EKC was calculated to be US$ 990.4. These findings derived solely from the time-series data for Indonesia provide helpful information for the Indonesian government and policy-makers in the sense that it explicitly indicates the specific tendency for that country.

1. Introduction

A "grow first, clean up later" approach, which means that only the economic growth is targeted with little regard for its environmental impact, is the basic strategy that have been taken by many developing countries. Unfortunately, the rapid economic growth in this strategy has often caused unprecedented environmental degradation in an early stage of the growth especially. Tropical deforestation is one of the examples. Since the forestry sector is a major contributor to the economy in the developing countries most part of whose land is covered in forest, the initial economic growth in those countries have naturally a direct and negative impact on the forest ecosystem. Flood damage occurring in all parts of the world will be one piece of clear evidence showing the fact. There is no doubt that it is one of the greatest concerns of many

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developing countries to know whether "grow first, clean up later" is a costly strategy in a long-run view, and whether it can be a threat against the sustainability of growth itself.

Indonesia, which has the most extensive forest area in the ASEAN nations, has also suffered from massive and rapid destruction of the forests for the last few decades, while the country has experienced the economic growth acceleration by extracting natural resources in its "grow first, clean up later" strategy. The Food and Agriculture Organization of the United Nations (FAO) shows that about 30 % of the forest cover area in Indonesia had been lost during the period 1962-2007, although the GDP per capita had increased by five times and more during the same time. However, such a negative correlation between these two economic and environmental indicators is not always applied. The inverse U-shaped relationship between them, which is generally called "environmental Kuznets curve (EKC)", is a key concept in understanding the impact of economic growth on deforestation. The evidence of the existence of EKC for deforestation would encourage developing countries facing the problem of serious forest loss to advance their economic development.

The main objective of this study is to empirically demonstrate the inverse U-shaped relationship between economic development and deforestation rate in Indonesia. We also figure out the turning point at which the increase in income level does not lead to the increase in deforestation rate. For these purposes, time-series data for Indonesia over 46 years from 1962 to 2007 was analyzed with the autoregressive distributed lag (ARDL) bounds testing approach to cointegration, developed by Pesaran and Shin (1998) recently. Although many relevant previous studies have so far tested the EKC hypothesis for deforestation with cross-country or panel data (Shafik and Bandyopadhyay, 1992; Koop and Tole, 1999; Bhattarai and Hammig, 2001; Culas, 2007), to our knowledge, no study exists as yet that has shown the existence of the EKC on deforestation by using the data for a single country. The findings derived solely from the time-series data for Indonesia would provide helpful information for the Indonesian government and policy-makers in the sense that it explicitly indicates the specific tendency for that country.

The paper consists of six sections. Following this introduction, the second section provides the literature review on previous EKC studies. The third section explains the empirical model specified in this study and the data employed for the analysis. The ARDL bounds testing procedure will be described in the forth section. The fifth section discusses the results and discussion. The key findings are summarized in the sixth section, and then we conclude this paper with further discussion.

2. Literature review on the EKC

The environmental Kuznets curve is a theoretical concept that describes the relationship between income growth and environmental degradation. The term is named for Simon Kuznets (1955) who proposed that a connection between economic growth and income equality is shaped as an inverted U. This inverted U-shape hypothesis for environmental indicators were first examined by Grossman and Krueger (1991). They found in their study that the concentrations of two air pollutants out of three (sulfur dioxide and “smoke”) increases at a low level of national income and decreases at a higher level of income by analyzing the data for 42 countries. Studies on the EKC following Grossman and Krueger (1991) have exhibited an inconsistent tendency. Panayotou (1995) and Song et al. (2008) showed that the EKC hypothesis was supported for all the pollutants employed in those studies in common, while Grossman and Krueger (1995), Akbostanchi et al. (2009), Shaw et al. (2010) demonstrated that the inverted U is not necessarily described for all the environmental indicators. More recently, it is reported that the inverse U-shaped relationship regarding carbon dioxide was accepted for China (Jalil and Mahmud, 2009; Jalil and Feridun, 2011) and for France (Iwata et al., 2010), but it was rejected for Turkey (Akbostanchi et al., 2009; Ozturk and Acaravci, 2010) and for Russia (Pao et al., 2011). We also have to note that these inconsistent results could be caused by the other factors, such as model specification and employed variables (Stern, 2004).

The EKC studies regarding deforestation have also produced various findings. In the two pioneering papers, mixed results are reported. Shafik and Bandyopadhyay (1992) failed to explain the EKC relationship between income and two types of deforestation indicators (annual deforestation and total deforestation). In Panayotou (1995)[1], on the contrary, an inverse U-shaped relationship appeared to hold between forest area and GDP per capita from the cross-sectional data covering 68 countries. The income turning point was estimated to be about US$ 800 in his research. Several studies that investigated the existence of the EKC for each continent also do not show regular patterns. While Bhattarai and Hammig (2001) suggested that there was a strong evidence of the EKC relationship between income and deforestation for all the three continents of Latin America, Africa, and Asia, Cropper & Griffiths (1994) indicated that the EKC hypothesis was supported for Latin America and Africa, but not for Asia. In the more recent research by Culas (2007), the inverted-U shape was statistically accepted only for Latin America. The existence of the EKC for Africa or Asia did not result in being significant in that study. In addition, Koop and Tole (1999) were unable to reject the hypothesis that the country-specific coefficients of GDP and GDP squared were vary across the countries for each of Latin America, Africa, and Asia. This implies the necessity of estimating an individual EKC with the data for each single country, as well as the difficulty of obtaining a single EKC relationship among all the countries in a region.

3. Model specification and data

This study estimates the deforestation equation that describes the factors affecting deforestation in Indonesia, by using time-series data for that country over 46 years from 1962 to 2007. The empirical model is specified as

$$(1) \qquad DEF = \alpha + \beta_1 GDP_t + \beta_2 (GDP_t)^2 + \beta_3 POPGRW_t + \beta_4 RPOP_t + \beta_5 AGI_t + \beta_6 AGL_t + \beta_7 RWOOD_t + \beta_8 FOREXP_t + u_t,$$

where *DEF* is the annual rate of deforestation, *GDP* is gross domestic product per capita, *POPGRW* is population growth, *RPOP* is rural population, *AGI* is agricultural index, *AGL* is agricultural land area, *RWOOD* is roundwood production, *FOREXP* is forest products export,

[1] The original paper was published in 1993 (Panayotou, 1993).

and u_t is a stochastic error term. The subscript *t* refers to year *t*. The *DEF*, which is the dependent variable in equation (1), is calculated as

(2) $DEF = (F_{t-1} - F_t) / F_{t-1}$

where *F* is forest cover area. The data on forest cover area comes from FAOSTAT released by FAO. For the *GDP*, which is the most important data in the explanatory variables, we employ the real GDP per capita converted into US dollars that is obtained from World Bank. The EKC hypothesis for deforestation in Indonesia would be accepted, when the coefficient of *GDP* is positive and the coefficient of GDP^2 is negative in equation (1).

As carried out by many previous EKC studies on deforestation, we also include variables other than income as explanatory variables, because the causes of deforestation are considered to be complex and interlinked. In our analysis, the significances of population, agricultural, and forestry factors, as well as income, are inspected. First, the variables of population growth (*POPGRW*) and rural population (*RPOP*) are included in the model to examine the impact of population pressure on deforestation. Those variables have been widely used in previous empirical studies (Cropper and Griffiths, 1994; Bhattari and Hammig, 2001; Barbier and Burgess, 2001; Culas, 2007). We obtained the data on population growth from World Bank, and the data on rural population from FAOSTAT. Population pressure can increase the demand for forest products or alternative land uses that causes deforestation, but it might also work so as to reduce the deforestation, inducing technological progress or institutional changes in agricultural or forestry sector (Culas, 2007). Second, we add the variables of agricultural land area (*AGL*) and agricultural production index[2] (*AGI*) to the list of explanatory variables. The purpose of adding them is to illustrate how the deforestation in Indonesia is connected with the increase in agricultural production. The two major strategies to promote agricultural production are the expansion of agricultural land into forests and technological improvement in agriculture. The *AGL* and *AGI* are employed as proxy variables for them, respectively. Third, the model comprises roundwood

[2] This index shows the relative level of the aggregate volume of agricultural production for each year in comparison with that of the base period of 1999-2001.

production (*RWOOD*) and forest products export (*FOREXP*) as the variables expressing the forestry factors of deforestation. These can be the direct determinants that raise the deforestation rate. The sources of data on agricultural and forestry variables are all FAOSTAT.

4. The ARDL bounds testing procedure

The ARDL bounds testing approach to cointegration developed by Pesaran and Shin (1998) is often applied by EKC studies in recent years (Jalil and Mahmud, 2009; Shahbaz et al., 2010; Iwata et al., 2010; Jalil and Feridun, 2011). While many macroeconomic variables are integrated of order zero (I(0)) or one (I(1)), this approach is applicable, even in the case that explanatory variables have different orders of integration, as long as it is less than two. In addition, it is argued that the ARDL approach to cointegration gives better results for small sample data, as compared to other techniques, such as Engle and Granger (1987) and Johansen and Juselius (1990) (Haug, 2002).

The first step of this ARDL approach is to establish the long-run relationship among variables by estimating an unrestricted error correction model. In this study, the model is specified as

$$
\begin{aligned}
\text{(3)} \quad \Delta DEF_t &= \alpha + \beta_0 DEF_{t-1} + \beta_1 GDP_{t-1} + \beta_2 (GDP_{t-1})^2 \\
&+ \beta_3 POPGRW_{t-1} + \beta_4 RPOP_{t-1} + \beta_5 AGI_{t-1} \\
&+ \beta_6 AGL_{t-1} + \beta_7 RWOOD_{t-1} + \beta_8 FOREXP_{t-1} \\
&+ \sum_{i=1}^{p} \delta_i \Delta DEF_{t-i} + \sum_{i=1}^{p} \theta_i \Delta GDP_{t-i} \\
&+ \sum_{i=1}^{p} \mu_i \Delta (GDP_{t-i})^2 + \sum_{i=1}^{p} \pi_i \Delta POPGRW_{t-i} \\
&+ \sum_{i=1}^{p} \rho_i \Delta RPOP_{t-i} + \sum_{i=1}^{p} \sigma_i \Delta AGI_{t-i} \\
&+ \sum_{i=1}^{p} \tau_i \Delta AGL_{t-i} + \sum_{i=1}^{p} \varphi_i \Delta RWOOD_{t-i} \\
&+ \sum_{i=1}^{p} \omega_i \Delta FOREXP_{t-i} + u_t,
\end{aligned}
$$

where α is the drift component, and u_t is the white noise error component. The null hypothesis that there is no cointegration among the variables is expressed as $\beta_0 = \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = \beta_8$. We can conclude that there is a cointegration relationship among them, if the calculated F-statistics is more than the upper critical bound given by Pesaran et al., (2001). If the F-statistics is lower than the lower critical bound, then it is judged that there is no cointegration. The decision regarding cointegration will be inconclusive, when the F-statistic lies within the upper and lower critical bounds.

Once a cointegration relationship among the variables is established, the next step is to obtain the long-run equilibrium equation for deforestation and its determinants. We can derive the reduced-form solution from equation (3) as

$$\begin{aligned} (4) \qquad DEF_t = {} & \lambda_0 + \lambda_1 GDP_t + \lambda_2 (GDP_t)^2 + \lambda_3 POPGRW_t \\ & + \lambda_4 RPOP_t + \lambda_5 AGI_t + \lambda_6 AGL_t + \lambda_7 RWOOD_t \\ & + \lambda_8 FOREXP_t + u_t, \end{aligned}$$

where $\lambda_0 = -\alpha/\beta_0$, $\lambda_1 = -\beta_1/\beta_0$, $\lambda_2 = -\beta_2/\beta_0$, $\lambda_3 = -\beta_3/\beta_0$, $\lambda_4 = -\beta_4/\beta_0$, $\lambda_5 = -\beta_5/\beta_0$, $\lambda_6 = -\beta_6/\beta_0$, $\lambda_7 = -\beta_7/\beta_0$, and $\lambda_8 = -\beta_8/\beta_0$. On the other hand, the short-run dynamics is described in the form of an error correction model (ECM) as

$$\begin{aligned} (5) \qquad \Delta DEF_t \\ = {} & \sum_{i=1}^{p} \delta_i \Delta DEF_{t-i} + \sum_{i=1}^{p} \theta_i \Delta GDP_{t-i} \\ & + \sum_{i=1}^{p} \mu_i \Delta (GDP_{t-i})^2 + \sum_{i=1}^{p} \pi_i \Delta POPGRW_{t-i} \\ & + \sum_{i=1}^{p} \rho_i \Delta RPOP_{t-i} + \sum_{i=1}^{p} \sigma_i \Delta AGI_{t-i} \\ & + \sum_{i=1}^{p} \tau_i \Delta AGL_{t-i} + \sum_{i=1}^{p} \varphi_i \Delta RWOOD_{t-i} \\ & + \sum_{i=1}^{p} \omega_i \Delta FOREXP_{t-i} + \psi\, ECT_{t-1} + u_t, \end{aligned}$$

where the *ECT* is an error correction term.

To evaluate the goodness of fit of the model, we use several criteria. These include classical assumption test, R-squared and adjusted

R-squared, lowest standard error of regression, lowest AIC, lowest SIC, and model stability test. The technique employed to test model stability is cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ). If the plots of CUSUM and CUSUMSQ statistics stay within the critical bounds of 5 % level of significance, the null hypothesis that all of the coefficients in the given regression are stable cannot be rejected.

5. Results and discussion

5.1. Preliminary Examination

This study performs the conventional Augmented Dicky Fuller (ADF) test and the Philip-Perron (PP) test to ensure that none of the variables are I(2) or beyond. Table 1 shows the results of these unit root tests for each variable. In the ADF test, the Swarchz Baysian Criterion (SBC) was used to determine the optimal lag length. As shown in Table 1, the results of ADF tests indicate that most of the variables are non-stationary and have a unit root, while only the population growth (*POPGRW*) and rural population (*RPOP*) are stationary at level. The results of PP tests are also consistent with those of ADF tests. We can conclude from these results that there is only a mixture of I(0) and I(1) among underlying regressors. Hence, the ARDL bounds testing approach to cointegration can be applied in this analysis (Duasa, 2007).

Table 1. Results of Unit Root Tests

Variable	ADF test at level			ADF test at first difference		
	None	**Intercept**	**Trend and intercept**	**None**	**Intercept**	**Trend and intercept**
DEF	0.8275	0.8311	0.0825	0.0001***	0.0008***	0.0046 ***
GDP	1.0000	0.9984	0.3002	0.0008 ***	0.0003 ***	0.0012 ***
GDP²	0.9999	0.9998	0.8206	0.0004 ***	0.0008 ***	0.0011 ***
POPGWR	0.0003***	0.2921	0.3893	0.2443	0.0672 *	0.6523
RPOP	0.0001***	0.0014***	0.5224	0.1673	0.9972	0.2186
AGI	1.0000	1.0000	0.8896	0.3503	0.0000 ***	0.0000 ***
AGL	0.9606	0.9575	0.6402	0.0000 ***	0.0000 ***	0.0002 ***
RWOOD	0.0000***	0.9868	0.7543	0.0155 **	0.0000 ***	0.0000 ***
FOREXP	0.9625	0.9396	0.2940	0.0000 ***	0.0000 ***	0.0000 ***
	PP test at level			**PP test at first difference**		
DEF	0.9184	0.9025	0.4585	0.0001 ***	0.0016 ***	0.0096 ***
GDP	1.0000	0.9984	0.4418	0.0010 ***	0.0004 ***	0.0015 ***
GDP²	0.9997	0.9995	0.8903	0.0004 ***	0.0007 ***	0.0014 ***
POPGWR	0.0372 **	0.9916	0.1150	0.3569	0.5262	0.8978
RPOP	0.9429	0.0342**	1.0000	0.3358	0.9925	0.1833
AGI	1.0000	1.0000	0.8701	0.0012 ***	0.0000 ***	0.0000 ***
AGL	0.9505	0.9410	0.6402	0.0000 ***	0.0000 ***	0.0003 ***
RWOOD	0.0000 ***	0.9906	0.7626	0.0001 ***	0.0000 ***	0.0000 ***
FOREXP	0.9769	0.9590	0.3034	0.0000 ***	0.0000 ***	0.0000 ***

Note1: Reported values are *p*-values for testing the null hypothesis that the variable has unit root.
Note 2: The symbols ***, **, and * indicate 1, 5, and 10 percent of significance, respectively.

The step of discovering the long-run relationship among explanatory variables requires an adequate lag length of them in order to remove any serial correlation. The optimum lag length of vector autoregressive (VAR) is usually selected based on AIC, SBC, and likelihood ratio (LR) test statistic. From the values of each criterion presented in Table 2, we can choose order 2 in this study. Pesaran and Shin (1998) and Narayan (2005) also have suggested that we should choose 2 as the maximum order of lags for annual data in the ARDL.

Table 2. Selection Criteria for Lag Length

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-2847.4	NA	4.04E+46	132.8558	133.2244	132.9918
1	-2445.04	617.5763	1.41E+40	117.9088	21.5951*	119.2682
2	-2307.94	3.0454*	1.73e+39*	5.2994*	122.3032	17.8822*

Note 1: The symbol * indicates the lag order selected by the criterion.
Note 2: LR: Sequential modified LR test statistic (each test at 5% level); FPE: Final prediction error; AIC: Akaike information criterion; SC : Schwarz information criterion; HQ: Hannan-Quinn information criterion

Table 3. Test Results of Granger Causality

Null Hypothesis	F-Statistic	Prob.
GDP does not Granger Cause *DEF*	6.45599	0.0038
DEF does not Granger Cause *GDP*	0.31788	0.7296
GDP^2 does not Granger Cause *DEF*	3.80436	0.0309
DEF does not Granger Cause GDP^2	0.79056	0.4607

A major concern in the analysis of EKC hypothesis is whether the GDP has an impact on the deforestation or the contrary. We therefore conducted the Granger causality tests to ascertain the direction of causality, before testing the cointegration. As presented in Table 3, the results indicate that GDP per capita Granger causes deforestation rate in the long run at the 1 % level of significance. The same results were also observed for GDP per capita squared at the 5 % level.

5.2. Results of bounds testing

The F-statistic calculated under equation (3) for testing whether the variables are cointegrated or not was 1.515 as shown in Table 4. This value is lower than the lower bound critical value at the 10 % level of significance given by both Pesaran et al. (2001) and Narayan (2005), which implies that null hypothesis of no cointegration cannot be rejected. Hence, it is concluded that *DEF* is not cointegrated with *GDP*, GDP^2, *POPGRW*, *POPDEN*, *AGI*, *AGL*, *RWOOD*, *FOREXP*.

Table 4. Result of Cointegration Test (including all the variables)

Equation	*DEF = f (GDP, GDP*^{2}*, POPGRW, RPOP, AGI, AGL, RWOOD, FOREXP*)			
Lag structure	ARDL (2,2,2,2,2,2,2,2,2)			
F-statistic	1.515425			
Significance level	Bound critical values of Case III (Unrestricted intercept and no trend)			
	Pesaran *et al*. (2001)		Narayan (2005)	
	I(0)	I(1)	I(0)	I(1)
1%	3.41	4.68	4.030	5.598
5%	2.62	3.79	2.922	4.268
10%	2.26	3.35	2.458	3.647

Since no evidence of cointegration was detected among all the variables, we next attempted to narrow the variables down.We finally selected the variables of RPOP, AGI, and RWOOD, as well as GDP and GDP2, based on the statistical significance of those variables. The F-statistic calculated again (=3.564) was higher than the upper bound critical value provided by Pesaran et al. (2001) at the 10 % level of significance. This implies that the null hypothesis of no cointegration can be rejected at the 10 % level, but it has not been supported yet according to the Narayan's critical values.

Then, we eliminated insignificant variables, except for the level variables and the intercept, with the general-to-specific approach (Krolzig and Hendry, 2001). The results are displayed in Table 5. The F-statistic (=4.183) is higher than the upper critical value at the 5 % level of significance given by Pesaran et al. (2001), and at the 10 % level by Narayan (2005). It suggests that the variables are cointegrated, and confirms the existence of long-run relationship among them.

Table 5. Result of Cointegration Test (excluding *POPGRW*, *AGL*, *FOREXP*)

Equation	$DEF = f\,(GDP, GDP^2, RPOP, AGI, RWOOD)$			
Lag structure	ARDL (2,1,1,1,1,0)			
F-statistic	4.182707			
Significance level	Bound critical values of Case III (Unrestricted intercept and no trend)			
	Pesaran *et al*. (2001)		**Narayan (2005)**	
	I(0)	I(1)	I(0)	I(1)
1%	3.41	4.68	4.030	5.598
5%	**2.62**	**3.79**	2.922	4.268
10%	**2.26**	**3.35**	**2.458**	**3.647**

5.3. Long-run and short-run coefficient estimates

The estimated long-run coefficients are presented in Table 6. All the explanatory variables included in this equation significantly affect the deforestation rate. The positive coefficient of *GDP* and the negative coefficient of GDP^2 support the existence of the inverse U-shaped relationship between economic growth and deforestation rate. This finding is consistent with the empirical evidence of Panayotou (1995) and Bhattarai and Hammig (2001). The income turning point (ITP) is calculated to be US$ 990.4 from these coefficient estimates. This value lies within the range of the GDP data set employed in this analysis, which suggests that the ITP has already been reached in Indonesia. This result is in line with several previous studies showing that ITP for deforestation is placed within the sample range (Panayotou, 1995; Kallbekken, 2000; Bhattarai and Hammig, 2001). Panayotou (1995) also found that the ITP for deforestation in developing countries was US$ 823. The value of ITP obtained in this research is extremely close to the Panayotou’s finding.

The coefficient relating rural population to deforestation rate was negative and significant at the 1% level. This suggests that an increase in rural population in Indonesia tends to decrease the deforestation rate. The same tendency was also found in several previous studies. In Cropper and Griffiths (1994), and Bhattarai and Hammig (2001), rural population density had a negative effect on the deforestation in Asian region. In addition, Reis and Guzman (1994) obtained the negative sign of the coefficient of rural population in the case of Amazon deforestation. Culas (2007) also detected a negative coefficient of population density. Templeton and Scherr (1999) noted that population pressure on forest resources will increase at first, but it will change along with efficiency in production processes into the direction of the conservation of the remaining forest resources. This result might be related to the technological or institutional innovation induced from population pressure.

As to the agricultural indicators, the *AGI* significantly affects the deforestation rate in a negative way. This implies that an increase in agricultural production does not promote the conversion of forest lands to agricultural lands, and that the increase has been led by improving technology in agriculture. Technological progress in agriculture must reduce the pressure on land demand and slow down the speed of deforestation.

Roundwood production was also significantly connected to the deforestation rate in Indonesia. This negative coefficient of *RWOOD* indicates that the deforestation rate decreases with increasing log production. Allen and Barnes (1985) that examined the effect of wood use on forest area change over 1968-78 in developing countries, also found a negative coefficient of wood use variable. This result may be closely associated with that the data on roundwood production used in this study is legally reported one. The roundwood products reported legally are probably the ones that come from the forest managed sustainably, and thus they cannot be a cause of deforestation. Unfortunately, many log products have not been officially reported and some of them are illegally produced. There is also evidence that large amounts of timber traded in the world market are harvested illegally (Hembery et al., 2007). The increase in illegal logs may decrease the production of legal logs, and may cause higher deforestation at the same time.

Table 6. Estimation Results of Long-run Model

Dependent Variable = *DEF*				
Variable		Coefficient	T-statistic	Prob.
Intercept		8.7418016	4.010585***	0.0003
GDP		0.0266419	4.066877***	0.0003
GDP^2		-1.345E-05	-3.404278***	0.0018
RPOP		-0.0001057	-3.582405***	0.0011
AGI		-0.0332558	-2.893453***	0.0068
RWOOD		-2.092E-08	-3.141136***	0.0036
Diagnostic Checks				
Jarque-Bera			1.2114 (0.5457)	
Serial Correlation LM			0.5612 (0.5764)	
Heterocedasticity Test			0.9185 (0.5349)	

Note1: ARDL (2,1,1,1,1,0) was selected on the basis of AIC.
Note2: The symbol *** indicates 1 percent of significance.

The three diagnostic tests of LM test, normality test of residual term, and White heteroscedasticity test was also conducted in this step. The results show that the long-run model has passed all the diagnostic tests successfully. This indicates that there is no serial correlation, the residual term is normally distributed, and there is no evidence of White heteroscedasticity.

The results of short-run dynamics are presented in Table 7. The signs of coefficients of *GDP* and GDP^2 support the EKC hypothesis at the 1 % level of significance. Only roundwood production variable was insignificant, which implies that the change in log production does not affect the change in deforestation in the short run. The coefficient of lagged ECT is statistically highly significant, and its sign and size are also reasonable, since it is generally required to be greater than -1 and less than 0. The coefficient estimate of that variable suggests that deviation from long-run equilibrium is corrected by nearly 57 % within a year.

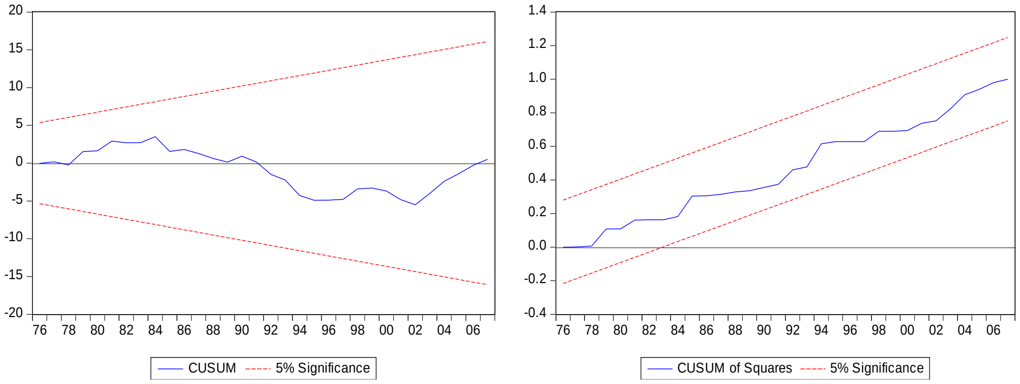
Table 7. Estimation Results of Short-run Model

Dependent Variable = Δ ***DEF***				
Variable		Coefficient	T-statistic	Prob.
Intercept		0.463402	4.046573***	0.0002
ΔGDP		0.014194	3.554423***	0.0010
ΔGDP^2		-7.52E-06	-3.168890***	0.0030
$\Delta RPOP$		0.000505	5.236923***	0.0000
ΔAGI		-0.029510	-3.919570***	0.0004
ECT(-1)		-0.568800	-5.676490***	0.0000
Diagnostic Checks				
Jarque-Bera		0.8867 (0.6418)		
Serial Correlation LM		0.7740 (0.4689)		
Heterocedasticity test		0.9760 (0.4634)		

Note1: ARDL (2,1,1,1,1,0) was selected on the basis of AIC.
Note2: The symbol *** indicates 1 percent of significance.
Note3: ECT = DEF - 0.0266419*GDP + 1.345E-05*GDP^2 + 0.0001057*RPOP + 0.0332558*AGI + 2.092E-08*RWOOD - 8.7418016

The last stage of ARDL bounds testing approach is to check the stability of parameter estimates included in the model. In order to test the stability, cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests are generally performed. Figure 1 exhibits the plots of CUSUM and CUSUMSQ, respectively. We can see from this figure that the statistics are well within the critical bounds, which means that all the parameter estimates in the model are stable.

Figure 1. Plots of Cumulative Sum (CUSUM) and Cumulative Sum of Squares (CUSUMSQ) of Recursive Residuals



6. Conclusion

Out results support the long-run inverted-U relationship between economic growth and deforestation rate in Indonesia. It implies that, while the deforestation rate increases at the initial stage of economic growth, it declines after a threshold point. Regarding previous study conducted by several researchers (Shafik & Bandyopadhyay, 1992; Cropper & Griffiths, 1994; Koop & Tole, 1999; Bhattarai & Hammig, 2001; Barbier & Burgess, 2001; Culas, 2007), the results of EKC for deforestation in Asia are still debatable due to variety of data and methodology. All of them used cross-country analyses and panel data analyses. In addition, some studies used relatively small sample size that might made the EKC hypothesis was not supported in some studies in Asia. The income turning point of the EKC was calculated to be US$ 990.4. This estimated ITP lies within the range of the data on GDP employed in this analysis, which means that the ITP has already been reached in Indonesia. In addition, we found that rural population, agricultural index, and roundwood production have a negative and significant impact on the deforestation. These results suggest in order that (1) the deforestation might be restrained by technological or institutional innovation in agricultural or forestry sectors induced from population pressure in rural area, (2) technological progress in agriculture reduce the pressure on land demand, and then would slow down the speed of deforestation, and (3) there is a possibility that the increase in “illegal” logs, which are not reported officially, cause higher deforestation. The analysis of short-run dynamics also reveals that the deviation from the long-run equilibrium is quickly adjusted.

While the EKC results obtained from cross-country information clearly shows an inverse U-shaped relationship as a whole between economic development and environmental degradation, they would be insufficient for each developing country facing the issue of whether the development of the country is sustainable or not to be optimistically confident that “grow first, clean up later” strategy will work well in that country. As described above, several previous studies analyzing these data, in fact, have revealed that there exist different EKCs among continents. In terms of practical policy-making on sustainable development, it would be necessary to test the existence of the specific EKC for each country. This study definitely demonstrates the usefulness of adopting the ARDL approach in the evaluation of EKC hypothesis for a single country.

Due to data restriction, it was not possible to use provincial data in this study. Using provincial data would provide a more valuable insight into policy making, because they can introduce the effect of region to the model. Another weakness of this study is that there is no policy variable in the empirical model. Policy variables that could be included are, for example, international environmental agreement, enforcement of environmental legislation, and green project policy (e.g. forest and land rehabilitation movement). The addition of these variables would facilitate explaining what kinds of policies can reduce deforestation.

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