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ENVIRONMENTAL KUZNETS CURVE IN INDONESIA, THE ROLE OF ENERGY CONSUMPTION AND FOREIGN TRADE

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Abstract

This study examines the dynamic relationship among carbon dioxide (CO_2) emissions, economic growth, energy consumption and foreign trade based on the environmental Kuznets curve (EKC) hypothesis for Indonesia during the period 1971–2007. The Auto regressive distributed lag (ARDL) methodology is used as an estimation technique. The results do not support the EKC hypothesis, which assumes an inverted U-shaped relationship between income and environmental degradation. The long-run results indicate that foreign trade is the most significant variable in explaining CO_2 emissions in Indonesia followed by Energy consumption and economic growth. The stability of the variables in estimated models is also examined. The result suggests that the estimated models are stable over the sample period.

Keywords: Environmental Kuznets curve, CO_2 emissions, energy consumption

JEL classifications: Q43; Q51; Q53

1. Introduction

Global environmental issues are getting more attention especially the increasing threat of global warming and climate change. Higher global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level are some evidence of warming of the climate system. The intergovernmental panel on climate change (IPCC) reported a 1.1 to 6.4 °C increase of the global temperatures and a rise in the sea level of about 16.5 to 53.8 cm by 2100 (IPCC, 2007). CO_2 emissions which is a global pollutant is the main greenhouse gas that causes 58.8% of global warming and climate change (The World Bank, 2007a). Rapid increase of CO_2 emissions is mainly the result of human activities due to the development and industrialization over the last decades.

In this subject one strand of literature focuses on testing the growth and environmental pollution nexus that tests the environmental Kuznets curve (EKC) hypothesis which proposes a U-type relationship between environmental quality and economic growth. They tried to answer the question whether continued increase in economic growth will eventually undo the environmental impact of the early stages of economic development. Many related studies are available in Stern (2004) and Dinda (2004). More recent examples are those of Dinda and Coondoo (2006), Akbostanci et al. (2009), Lee and Lee (2009), Fodha and Zaghdoud (2010) and Narayan and Narayan (2010). Their results differ substantially and are inconclusive.

As one of the crucial elements for continuous economic growth is energy consumption, the second strand of the literatures is related to energy consumption and output nexus. Several studies emerged in this regard. After the pioneer seminal study of Kraft and Kraft (1978) who found a unidirectional Granger causality running from output to energy consumption for the United States, by employing different econometric methodologies for different panel of countries, Masih and Masih (1996), Yang (2000), Wolde-Rufael (2006) and Narayan et al. (2008) tested the energy consumption and economic growth nexus and found varied and sometimes conflicting results. With the development of time series econometric techniques Masih and Masih (1997), Cheng and Lai (1997), Al-Iriani (2006), Mehrara (2007), Akinlo (2008), Ghosh (2009), Tang (2008), Chandran et al. (2009) and Yoo and Kwak (2010) focused on the cointegrating relationship between output and energy consumption.

Two important points come to light from reviewing these two groups: First, as most of them consider the growth–environment nexus and growth–energy nexus in a bivariate framework, thus, suffer from omitted variables bias, hence making a study of both nexuses in a single framework is necessary. Second, as the vast majority of these investigations concentrate on using the cross-country panel data, therefore they would not allow the impact of environmental policies, historic experiences, development of trade relationship and other exogenous factors through time to be examined. However, a time series analysis for a single country may provide better framework to estimate these relationships. Therefore, studying countries individually may be necessary.

The third strand filled the gap in literature by combining these two lines of studies and examining the dynamic relationship between carbon emissions, energy consumption and economic growth in a single framework for single countries. See for example, Ang (2007, 2008), Soytas and Sari (2009), Zhang and Cheng (2009), and Ghosh (2010).

In a similar kind of study Halicioglu (2009) for Turkey, Jalil and Mahmud (2009) for China and Iwata et al. (2010) for France attempted to reduce the problem of omitted variable bias in econometric estimation by including the impacts of foreign trade into the nexus.

In this regard, they applied ARDL approach of cointegration in a log-linear quadratic equation among CO_2 emissions, energy consumption, economic growth and trade openness to test the validity of EKC hypothesis. Halicioglu (2009) found two forms of long-run relationships between variables when CO_2 emissions and income are the dependent variables. He suggested that the most significant variable in explaining the carbon emissions in Turkey is income followed by energy consumption and foreign trade. Jalil and Mahmud (2009) found a unidirectional causality running from economic growth to CO_2 emissions in China. The results of the study also indicate that the carbon emissions are mainly determined by income and energy consumption in the long run. Moreover trade has a positive but statistically insignificant impact on CO_2 emissions. Iwata et al. (2010) as well as the two previous studies supported the EKC hypothesis in the case of France. They found evidence of statistical significance for the coefficient of energy consumption just in the short run. Furthermore they concluded that foreign trade coefficient is not statistically significant in the short and long run.

This paper is an attempt to extend the literature by considering the long-run relationship between CO_2 emissions, economic growth energy consumption and foreign trade for Indonesia based on the EKC hypothesis. The issue of environmental pollutants is in a progressive trend in developing countries as they require more energy consumption for higher economic development. Consequently, they suffer from more environmental problems. Among the developing countries, Indonesia has been one of the fastest-growing open country with a rapid economic transformation, population expansion and high energy consumption with particular emphasis on city context and a significant rise in pollutant emissions, specifically CO_2 emissions. Indonesia which is an archipelagic state is vulnerable to climate change. If the current trend of global warming continues unabated, it is expected that 2000 of the 17000 islands in Indonesia will be submerged by 2030 (Lean & Smyth, 2010).

The choice of this country is also motivated by the fact that no known study has been conducted to examine the dynamic relationship between CO_2 emissions, economic growth, energy consumption and trade openness in a single framework for Indonesia.

Our investigation is based on environmental Kuznets curve hypothesis, using time series data and coitegration analysis. To conduct cointegration analysis we employ the recently developed ARDL bounds testing approach of cointegration by Pesaran and Shin (1999) and Pesaran et al. (2001). The main objective of the current study is examining the long-run relationship amongst CO_2 emissions, economic growth, energy consumption and trade openness in Indonesia during the period 1971-2007.

The rest of the paper is structured as follows: In section 2 the model and econometrics methodology are introduced while section 3 is data and section 4 gives the empirical results and the last part is the conclusion.

2. Model and Econometric Methodology

Based on EKC hypothesis, it is possible to form a linear quadratic relationship between economic growth and environmental degradation. However to eliminate the omitted variable bias Dina (2004) proposes other variables such as international trade, demography, technological progress and energy consumption as the determinant of environmental pollution. Based on this argument we take into account the effects of energy consumption and trade openness on CO_2 emissions. Following Ang (2007) and Iwata et al. (2010) we form the long-run relationship between CO_2 emissions, economic growth and energy consumption for our baseline estimation model in logarithm version as follows:

$$\ln E_t = \alpha_0 + \alpha_1 \ln Y_t + \alpha_2 (\ln Y_t)^2 + \alpha_3 \ln EN_t + \varepsilon_t \qquad (1)$$

Where E is per capita CO_2 emissions, Y represents per capita real income, EN stands for commercial energy use per capita and ε_t is the standard error term. Based on EKC hypothesis the sign of α_1 is expected to be positive whereas a negative sign is expected for α_2. Since higher level of energy consumption leads to greater economic activity and stimulates CO_2 emissions, α_3 is expected to be positive.

To date, various methods have been developed and introduced to conduct cointegration analysis, such as the residual-based approach proposed by Engle and Granger (1987), the maximum likelihood-based approach proposed by Johansen and Juselius (1990), the fully modified OLS procedures of Phillips and Hansen's (1990) and the recently developed approach, autoregressive distributed lag (ARDL) by Pesaran et al. (2001). ARDL for cointegration analysis has a number of attractive features over other alternatives (Pesaran & Shin, 1999). The main advantage of ARDL approach is that, it does not require establishing the order of integration of the variables.

In this study ARDL bounds testing approach is employed to examine the long-run relationship among CO_2 emissions, economic growth and energy consumption. ARDL framework of Eq. (1) of the baseline estimation model is as follows:

$$\begin{aligned}\Delta \ln E_t = \alpha_0 + \sum_{k=1}^{n} \alpha_{1k} \Delta \ln E_{t-k} + \sum_{k=1}^{n} \alpha_{2k} \Delta \ln Y_{t-k} + \sum_{k=1}^{n} \alpha_{3k} \Delta (\ln Y_{t-k})^2 + \sum_{k=1}^{n} \alpha_{4k} \Delta \ln EN_{t-k} + \\ \delta_1 \ln E_{t-1} + \delta_2 \ln Y_{t-1} + \delta_3 \ln (Y_{t-1})^2 + \delta_4 \ln EN_{t-1} + \varepsilon_t\end{aligned} \qquad (2)$$

In the ARDL bounds testing approach the first step is to estimate Eq. (2) by ordinary least square (OLS) method. The null hypothesis of no cointegration or no long-run relationship, H0: $\delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$ is tested against its alternative, H1: $\delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq 0$. The F-test is conducted to test the presence of long-run relationship among the variables. The critical values of the *F*-statistics in this test are available in Pesaran and Pesaran (1997) and Pesaran et al. (2001).[1] Two sets of critical values are found for a given significance level, with and without a time trend, one for I(0) variables and the other set for I(1), which are known as lower bounds (LCB) and upper bounds critical values (UCB) respectively. This provides a band covering all possible classifications of the variables into I(0) and I(1). If the computed *F*-statistic is higher than the UCB, the null hypothesis of no cointegration is rejected and if it is below the LCB the null hypothesis cannot be rejected, and if it lies between the LCB and UCB the result is inconclusive. At this stage of the estimation process the optimum lag orders of the variables can be selected on the basis of Schawrtz–Bayesian criteria (SBC) and Akaike' s information criteria (AIC). The SBC selects the smallest possible lag length, while AIC is employed for selecting the maximum relevant lag length. The long-run relationship among variables can be estimated after the selection of the ARDL model by AIC or SBC criterion, Once a long-run relationship has been established, error correction model (ECM) can be estimated.

The error correction term (ECT) indicates the speed of the adjustment and shows how quickly the variables return to the long-run equilibrium and it should have a statistically significant coefficient with a negative sign. Moreover Pesaran et al. (1999, 2001) suggested testing the stability of estimated coefficients through cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ). In this study the stability tests such as CUSUM and CUSUMSQ are conducted to check the stability of the coefficient in estimated models.

Furthermore, following Jalil and Mahmud (2009) and Iwata et al. (2010), in order to avoid the omitted variable bias, we expand the baseline equation 1 to incorporate trade openness which may have effect on CO_2 emissions. The expected sign of the coefficient of trade is mixed

[1] This study adopts the critical values of Pesaran et al. (2001) for the bounds *F*-test.

depending on a level of a country in economic development stages. It is expected to be negative for developed countries as they specialize in clean and service intensive production and instead they import the pollution-intensive products from other countries with less restrictive environmental protection laws. On the other hand it may be positive in the case of developing countries as they are likely to be net exporter of pollution-intensive goods (Grossman & Krueger, 1995).

3. Data

The current study uses the annual data spanning from 1971 to 2007 which is based on the availability of all data. For estimation, Per capita carbon dioxide (CO_2) emissions, per capita GDP, commercial energy consumption per capita and trade ratio were used. All data were collected from World Bank's World Development Indicators (WDI) online database. CO_2 emissions (E) is measured in metric tones per capita, the real per capita GDP (Y) is in constant 2000 USD, energy consumption (EN) is measured as kg of oil equivalent per capita and trade openness ratio (TR) is the total value of real import and real export as a percentage of real GDP.

4. Empirical Results

The preliminary step in this analysis is concerned with establishing the order of integration of each variable as the bounds testing approach is applicable for variables that are I (0) or I (1). The analysis begins by investigating the unit root test of variables using the augmented Dickey–Fuller (1979) ADF and Phillips-Perron (1988) PP tests. In both tests the null hypotheses of the series has a unit root is tested against the alternative of stationarity. Table 1 summarizes the outcome of the ADF and PP unit root tests on the natural logarithms of the levels and the first differences of the variables. The results suggest that all the series are stationary in their first differences, indicating that they are integrated at order one, hence validate the use of bounds testing for cointegration.

Table 1: Unit root tests.

Variable	**ADF test statistic**		**PP test statistic**	
	Constant	Constant and trend	Constant	Constant and trend
lnE	-0.7278	-1.7162	-0.8204	-1.3515
lnY	-1.2887	-1.7533	-0.9488	-1.4036
$(lny)^2$	-1.0596	-1.9621	-0.6845	-1.6323
$lnEN$	-0.3304	-1.9456	-0.0875	-1.8257
$lnTR$	-1.7138	-3.3659*	-1.9299	-2.7518
ΔlnE	-3.6148**	-3.5886**	-3.6363***	-3.6127**
ΔlnY	-3.4349**	-3.5252*	-3.5192**	-3.5365*
$\Delta(lny)^2$	-3.4791**	-3.4852*	-3.4894**	-3.4912*
$\Delta lnEN$	-3.9535***	-3.8792**	-3.9424***	-3.8679**
$\Delta lnTR$	-4.2473***	-4.3523***	-4.0903***	-4.1778**

Note: 1. *******, ****** and ***** are 1%, 5% and10% of significant levels, respectively. 2. The lag length has been chosen based on the AIC for ADF test and the bandwidth is selected using the Newey–West method for PP test.3. The maximum number of lags is set to be four.

We then proceeded with *F*-test to confirm the existence of the cointegration between variables. To follow the procedure of ARDL bounds test we set different orders of lags for the variables as evidence of previous researches reveals that the results of the *F*-test are sensitive to the lag imposed on each of the first differenced variable (Bahmani-Oskooee & Brooks, 1999). We confirm this by imposing up to four lags on all first differenced variables.[2] The results of

[2] four is the maximum lag that can be imposed.

baseline equation (2) are presented as case 1, whereas the results of the case in which baseline equation (2) is expanded to incorporate trade are provided as case 2. The results are as reported in Table 2 along with the critical values at the bottom of the Table.

Table 2: The results of *F*-test for cointegration.

	Calculated *F*-statistics for different lag lengths			
	lag 1	lag 2	Lag3	lag 4
Case 1	1.8444	2.0221	1.6347	1.7264
Case 2	2.5712	2.3760	0.68662	0.83175

Note: 1. 1% CV [3.817, 5.122], 5% CV [2.850, 4.049] and 10% CV [2.425, 3.574] for Case 1.

2. 1% CV [3.516, 4.781], 5% CV [2.649, 3.805] and 10% CV [2.262, 3.367] for Cases 2.

3. The critical values are obtained from Table CI in Pesaran et al. (2001, p. 300).

The results confirmed that *F*-test is sensitive to the lag lengths. The calculated *F*-statistics indicate that there is no cointegration relationship in both cases. The evidence of no cointegration in cases 1 and 2 is attributed to the fact that the same number of lags were imposed on each first-differenced variable arbitrarily (Bahmani-Oskooee & Kantipong, 2001).

At this stage, the optimum number of lags on the first differenced variables is usually obtained from unrestricted vector auto regression (VAR) by means of AIC and SBC. Given the number of variables and sample size in this study, we conduct optimal lag selection by setting the maximum lag lengths up to 2. Setting 2 as the maximum lag length helps to ensure that the degree of freedom is sufficient for econometric analysis. AIC has been used to find the optimum number of lags in the model. Given this, the AIC-based ARDL suggests ARDL(2,1,2,1) for the case 1 and ARDL (2,0,1,0,2) in case 2.

To further justify our result, we carried out the bounds test after imposing the optimum lags on each of the first differenced variable. In case 1, the *F*-statistics of 1.44 was obtained which is still lower than the lower bound critical value of 2.425 at 10% significant level and does not support cointegration. In the case 2 the *F*-statistics is 6.03 which is higher than the upper bound critical value of 4.781 at 1% significant level and supports cointegration. The coefficient of *ECM (-1)* is correctly signed and statistically significant at 1% significance level in both cases. Following Kremers et al. (1992) who argued that the significant lagged error-correction term is a more efficient way of establishing cointegration, we conclude the existence of a strong cointegration relationship among variables in both cases.

The existence of cointegration among variables warrants the estimation of baseline equation (2) and the expanded equation by ARDL cointegration approach to get the long-run coefficients. The results are reported in Table 3.

Table 3: estimation results using ARDL approach.

case	lnY	$(lny)^2$	$lnEN$	$lnTR$	c	$ECM\ (-1)$	F statistic	$CUSUM$	$CUSUMSQ$
1	-5.624 (-0.962)	0.414 (0.923)	1.193 (1.133)	—	11.437 (0.602)	-0.276 (-2.067) **	1.441	U	S
2	-3.659 (-2.177)**	0.275 (2.150)**	1.246 (3.776)***	0.229 (4.3) ***	4.282 (0.835)	-0.686 (-5.14) ***	6.03	S	S

Note: 1. *****, **** and *** are 1%, 5% and10% of significant levels, respectively

2. ‘‘S’’ and ‘‘U’’ stand for stable and unstable respectively.

3. The numbers in parentheses are t-ratios

The negative and positive coefficient of lnY and $(lny)^2$ respectively, in both cases, indicate the existence of a U-shape relationship between per capita CO_2 emissions and per capita real GDP. Thus confirms that CO_2 emissions declines at initial level of economic growth then reaches a turning point and increases with the higher level of economic growth.

The long-run elasticity of CO_2 emissions with respect to energy consumption is positive in both cases. It is significant at 1% level in case 2, while it is not statistically significant in case 1. This positive effect of per capita energy consumption on CO_2 emissions is in line with Jalil and Mahmud (2009) and Ang (2008). The coefficient of $lnTR$ is 0.229 which is positive in sign and highly significant. This is in line with Halicioglu (2009). It indicates that 1% increase in foreign trade will lead to 0.229% increases in per capita CO_2 emissions. The positive long-run relationship between CO_2 emissions and trade openness is in line with Iwat et al. (2010). Insignificant coefficients in case 1 may be attributed to the omitted variable bias. So as can be seen from the results in Table 3, in case 2 it has been solved with the inclusion of trade variable.

To check the stability of the coefficients cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) techniques were employed. Graphically, these two statistics are plotted within two straight lines bounded by the 5% significance level. If any point lies beyond this 5% level, the null hypothesis of stable parameters is rejected. While the result of CUSUMSQ test supports the stability of all the estimated variables in both cases, there are some signs of instability based on CUSUM test in case 1.

5. Conclusion

This paper investigated the long-run relationship between carbon dioxide emissions, economic growth and energy consumption based on the EKC hypothesis for Indonesia during the period

1971–2007. Furthermore we expanded the baseline equation by including trade openness. Cointegration analysis was conducted using ARDL bounds testing approach developed by Pesaran et al. (2001). Negative and positive coefficient of lnY and $(lny)^2$ respectively were found in both cases 1 and 2, indicating the existence of a U-shape relationship between per capita CO_2 emissions and per capita real GDP. This confirms that CO_2 emissions declines at initial level of economic growth then reaches a turning point and increases with the higher level of economic growth. Therefore our results do not support the EKC hypothesis. In case 1 the elasticity of CO_2 emissions with respect to energy consumption is positive and statistically insignificant while in case 2 it is 1.246 and significant at 1% level, implying that for each 1% increase in energy consumption per capita CO_2 emissions will rise by 1.246%. The coefficient of trade openness is positive and highly significant. It is 0.229, indicating that 1% increase in foreign trade will lead to 0.229% increases in per capita CO_2 emissions. Correctly signed and statistically significant coefficient of *ECM (-1)* in both cases once again support the existence of cointegration among variables. Additionally stability test was also conducted. Based on CUSUMSQ test all the coefficients in case 2 are stable.

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