An Empirical Analysis of the Environmental Kuznets Curve For CO_2 Emissions in Indonesia: The Role of Energy Consumption and Foreign Trade

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Received: August 26, 2011 Accepted: September 13, 2011 Published: February 1, 2012
doi:10.5539/ijef.v4n2p243 URL: http://dx.doi.org/10.5539/ijef.v4n2p243

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 in Indonesia for the period 1971–2007, using the Auto Regressive Distributed Lag (ARDL) methodology. 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 model is also examined. The result suggests that the estimated model is stable over the study period.

Keywords: Environmental Kuznets curve, CO_2 emissions, Energy consumption, Foreign trade

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). This would have tremendous negative impact on half of the world's population lives in coastal zones (Lau et al. 2009).

Indonesia is the world largest archipelagic state consisting of 17,500 islands and 81.000 kilometers of coastline. It is the fourth populated country in the world with a very high rate of urbanization, two-third of the population resides in Java (World Bank, 2008). It has a very high coastal population, for example around 65% of the population of Java lives in coastal regions (Note1). Indonesia houses the third largest tropical forests which support extremely high level of biodiversity (PEACE, 2007). These characteristics of Indonesia make it one of the most vulnerable countries to the climate change impacts. According to OFDA/CRED international disaster database (2007) the ten biggest disaster events in Indonesia occurred after 1990 and most of them were related to flooding, drought, forest fire and the increase of endemic diseases.

CO_2 emissions account for the largest share of total greenhouse gas emissions which are most largely generated by human activities (The World Bank, 2007). Rapid increase of CO_2 emissions is mainly the result of human activities due to the development and industrialization over the last decades. It is highly dependent to the energy consumption, which is inevitable for economic growth.

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) and Narayan and Narayan (2010). Their results differ substantially and are inconclusive.

One of the crucial elements for continuous economic growth is energy consumption. Higher is the economic growth, more the energy consumption. This highlights the importance of the link between energy consumption an economic growth. 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), 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), Mehrara (2007), 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 to examine the impact of other exogenous variables such as; environmental policies, historic experiences, development of trade relationship. 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. They examined 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) 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.

In all the research strands mentioned above, no known study has been conducted to examine the dynamic relationship among CO_2 emissions, economic growth, energy consumption and foreign trade in a single framework in Indonesia, one of the most vulnerable countries to the climate change impacts in the world.

Our investigation is based on environmental Kuznets curve hypothesis, using time series data and cointegration 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: Section 2 is explaining the data used for this study. The model and econometrics methodology are introduced in section 3. Section 4 gives the empirical results and the last part concludes the paper.

2. Data

Data for this study covers the period 1971 to 2007 and was chosen because of its availability. Data utilized for estimation are Per capita carbon dioxide (CO_2) emissions, per capita GDP, commercial energy consumption per capita and trade ratio. All data were collected from World Bank's World Development Indicators (WDI). CO_2 emissions (E) is measured in metric tones per capita, the real per capita GDP (Y) is in constant 2000 US dollars, 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.

3. 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, energy consumption and foreign trade with a view of testing the validity of the EKC hypothesis in logarithm version as follows:

$$\ln E_t = \alpha_0 + \alpha_1 \ln Y_t + \alpha_2 (\ln Y_t)^2 + \alpha_3 \ln EN_t + \alpha_4 \ln TR_t + \varepsilon_t \tag{1}$$

Where E is per capita CO_2 emissions, Y represents per capita real income, EN stands for commercial energy consumption per capita, TR is openness ratio which is used as a proxy for foreign trade and ε_t is the standard error term. Based on EKC hypothesis the sign of α_1 expected to be positive whereas a negative sign is expected for α_2. Since higher level of energy consumption leading to greater economic activity and stimulates CO_2 emissions, α_3 is expected to be positive. The expected sign of α_4 is mixed 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 imports 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 and Krueger, 1995).

various methods are available in conducting the cointegration analysis, including 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) suggested by Pesaran et al. (2001). ARDL for cointegration analysis has a number of attractive features over the other alternatives (Pesaran & Shin, 1999). First the approach avoids endogeneity problems and inability to test hypotheses on the estimated coefficients in the long-run associated with the Engle-Granger (1987). Second the short-run as well as the long-run effects of the independent variables on the dependent variable are assessed at the same time. Third all variables are assumed to be endogenous. Forth the econometric methodology does not require establishing the order of integration of the variables (unit-root test). The approach is applicable regardless of whether the underlying regressors are I(0), I(1) or fractionally integrated and finally the methodology is popular in small samples as the case of the present study .

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

$$\begin{aligned}\Delta \ln E_t = {} & \alpha_0 + \sum_{k=1}^{n} \alpha_{1k} \Delta \ln E_{t-k} + \sum_{k=1}^{n} \alpha_{2k} \Delta \ln Y_{t-k} + \sum_{k=1}^{n} \alpha_{3k} \Delta (\ln Y_{t-k})^2 + \sum_{k=1}^{n} \alpha_{4k} \Delta \ln EN_{t-k} + \\ & \sum_{k=1}^{n} \alpha_{5k} \Delta \ln TR_{t-k} + \delta_1 \ln E_{t-1} + \delta_2 \ln Y_{t-1} + \delta_3 \ln (Y_{t-1})^2 + \delta_4 \ln EN_{t-1} + \delta_5 \ln TR_{t-1} + \varepsilon_t\end{aligned} \tag{2}$$

where Δ, α_0 and ε_t are the first difference operator, the drift component and white noise, respectively. 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, H_0: $\delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = 0$ is tested against its alternative, H_1: $\delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 \neq 0$. The *F*-test is conducted to test the existing 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) (Note2). There are two sets of critical values 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 employing to select 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. A general ECM of Eq. (2) is formulated as follows:

$$\begin{aligned}\Delta \ln E_t = \alpha_0 + \sum_{k=1}^{n} \alpha_{1k} \Delta \ln E_{t-k} + \sum_{k=1}^{n} \alpha_{2k} \Delta \ln Y_{t-k} + \sum_{k=1}^{n} \alpha_{3k} \Delta (\ln Y_{t-k})^2 + \sum_{k=1}^{n} \alpha_{4k} \Delta \ln EN_{t-k} \\ + \sum_{k=1}^{n} \alpha_{5k} \Delta \ln TR_{t-k} + \theta ECT_{t-1} + \varepsilon_t\end{aligned} \tag{3}$$

The error correction term (ECT_{t-1}) 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.

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). Quattara (2004) argued that in the presence of I(2) variables the computed *F*-statistics provided by Pesaran et al (2001) are not valid. 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.

Insert Table 1 Here

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). This is confirmed by imposing up to four lags on all first differenced variables (Note3). The results are as reported in Table 2 along with the critical values at the bottom of the Table.

Insert Table 2 Here

The results confirmed that *F*-test is sensitive to the lag lengths. The calculated *F*-statistics indicate that there is no cointegration relationship. The evidence of no cointegration is attributed to the fact that the same numbers 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 (2,0,1,0,2) (Note4).

To further justify our result, we carried out the bounds test after imposing the optimum lags on each of the first differenced variable. The *F*-statistics of 6.03 was obtained which is higher than the upper bound critical value of 4.781 at 1% significant level and supports cointegration. Furthermore following Kremers et al. (1992) who argued that the significant lagged error-correction term is a more efficient way of establishing cointegration, it can be concluded that there exist a strong cointegration relationship among variables in the model because the coefficient of *ECM (-1)* is statistically significant at 1% significance level and has the correct sign. The short-run results are presented in Table 3. The short-run elasticity of CO_2 emissions, with respect to energy consumption, is 0.854. It is positive in sign and highly significant at 1% confidence level, indicating that for each 1% increase in per capita energy consumption per capita CO_2 emissions increase by 0.85%. The coefficient of trade openness is negative and insignificant. It is -0.056, suggesting that the contribution of the foreign trade to CO_2 emissions in the short-run is negligible in Indonesia during the estimated period. However the coefficient of *ECM (-1)* is fairly large, that is, -0.686. This indicates that any deviation from the long-run equilibrium between variables is corrected about 68% for each period and it takes about 1.5 periods to return to the long-run equilibrium level.

Insert Table 3 Here

The existence of cointegration among variables warrants the estimation of equation (2) by ARDL cointegration approach to get the long-run coefficients. The results are reported in Table 4 along with diagnostic test statistics.

Insert Table 4 Here

The negative and positive coefficient of $\ln Y$ and $(\ln Y)^2$ respectively, indicate 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.

The long-run elasticity of CO_2 emissions with respect to energy consumption is 1.246 and significant at 1% level which implies that 1% increase in per capita energy consumption will lead to 1.246% increase in per capita CO_2 emissions in the long run. This positive effect of per capita energy consumption on CO_2 emissions is in line with Jalil and Mahmud (2009) and Ang (2008). Similarly The coefficient of $\ln TR$ is 0.229 which is positive in sign and highly significant. 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 Halicioglu (2009) and Iwata et al. (2010). From the results it is apparent that the long-run effect of energy consumption on CO_2 emissions in Indonesia is more significant than trade openness. The estimated model also passes the diagnostic tests of functional form specification and normality. Moreover diagnostic test statistics do not suggest the presence of any serial correlation and heteroskedasticity.

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. As can be seen from Figures. 1 and 2, the plots of CUSUM and CUSUMSQ statistics are well within the critical bounds, support the stability of the coefficients in estimated model.

Insert Figure 1 Here

Insert Figure 2 Here

5. Conclusion

This paper investigated the dynamic relationship between carbon dioxide emissions and economic growth in Indonesia based on the EKC hypothesis for the period 1971–2007 by incorporating energy consumption and trade openness. Cointegration analysis was conducted using ARDL bounds testing approach developed by Pesaran et al. (2001). Negative and positive coefficient of $\ln Y$ and $(\ln Y)^2$ respectively, indicating 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. The elasticity of CO_2 emissions with respect to energy consumption is 1.246 and 0.854 in the long and short-run respectively and highly significant. This implies that for each 1% increase in energy consumption per capita CO_2 emissions will rise by 1.246% in the long-run and 0.854% in the short-run. The coefficient of trade openness is positive and significant in the long-run while it is negative and insignificant in the short-run. This is indicating that 1% increase in foreign trade will lead to 0.229% increases in per capita CO_2 emissions in the long-run while its contribution to CO_2 emissions is negligible in the short-run. Correctly signed and statistically significant coefficient of ECM (-1) supports the existence of cointegration among variables.

Additionally to check the stability of the coefficients, cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) techniques were employed. Based on both tests all the coefficients in estimated model are stable.

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Notes

Note 1. National action plane addressing climate change, republic of Indonesia 2007

Note 2. This study adopts the critical values of Pesaran et al. (2001) for the bounds F-test.

Note 3. Four is the maximum lag that can be imposed.

Note 4. This represents the ARDL model in which the variables take the lag length 2, 0, 1, 0 and 2, respectively.

Table 1. Unit root tests.

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

Note: 1. ***, ** and * are 1%, 5% and 10% 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

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

Calculated F-statistics for different lag lengths			
lag 1	lag 2	Lag3	lag 4
2.571	2.376	0.687	0.832

Note: 1. 1% CV [3.516, 4.781], 5% CV [2.649, 3.805] and 10% CV [2.262, 3.367].

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

Table 3. The result of error correction model.

Regressor	**Coefficient**	**T-Statistic**
$\Delta \ln Y$	-2.51	-2.434**
$\Delta(\ln Y)^2$	0.281	3.268***
$\Delta \ln EN$	0.854	4.692***
$\Delta \ln TR$	-0.056	-0.655
ΔC	2.937	0.871
ECT_{t-1}	-0.686	-5.14***
Diagnostic test statistic		
R-squared	0.795	
F (7, 27)	13.886***	
DW-statistic	2.382	
RSS	0.053	
ecm = $lnE+3.659*lnY-0.275*(lnY)^2-1.246*lnEN-0.229*lnTR-4.282*C$		

Note 1. ARDL (2,0,1,0,2) selected on the basis of AIC. 2. *, **, and *** represent 10%, 5% and 1% level of significance, respectively. 3. RSS stands for residual sum of squares.

Table 4. Long-run estimation results and diagnostic test statistics.

Regressors	**coefficient**	**t-values**
ln Y	-3.659	-2.177^{**}
$(\ln Y)^2$	0.275	2.150^{**}
ln EN	1.246	3.776^{***}
ln TR	0.229	4.3^{***}
c	4.282	0.835
Diagnostic test statistics	Test-stats	p-Value
Serial correlation $\chi^2(1)$	2.639	0.104
Functional form $\chi^2(1)$	0.833	0.361
Normality $\chi^2(2)$	0.574	0.751
Heteroskedasticity $\chi^2(1)$	0.173	0.678

Note: 1. ***, ** and * are 1%, 5% and10% of significant levels, respectively.2. ARDL (2,0,1,0,2) selected on the basis of AIC. 3. Diagnostic test statistics are Lagrange multiplier statistic for test of residual serial correlation, Ramsey's RESET test for functional form misspecification, Normality based on a test of skewness and kurtosis of residuals and heteroskedasticity Based on the regression of squared residuals on squared fitted values. These statistics are distributed as Chi-squared variates with degrees of freedom in parentheses.

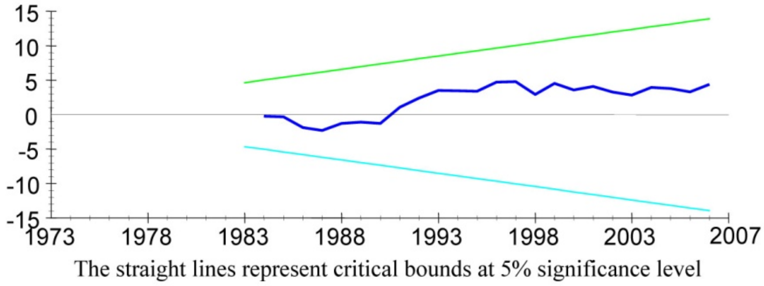

Figure 1. Plot of cumulative sum of recursive residuals.

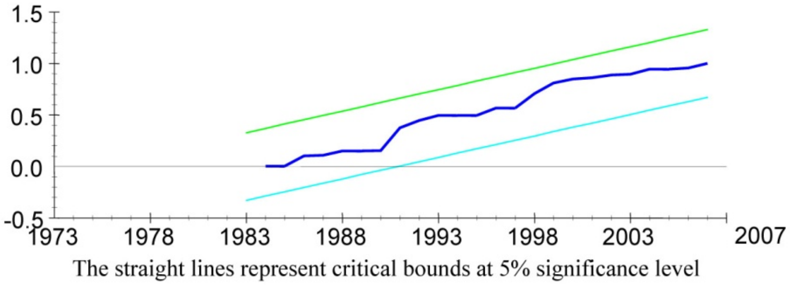

Figure 2. Plot of cumulative sum squares of recursive residuals