# Environmental Kuznets Curve (EKC): Times Series Evidence from Portugal

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## Abstract

The paper provides empirical evidence of an EKC – a relationship between income and environmental degradation for Portugal by applying autoregressive distributed lag (ARDL) to times series data. In order to capture Portugal's historical experience, demographic changes, and international trade on CO2 emissions, we assess the traditional income-emissions model with variables such as energy consumption, urbanization, and trade openness in time series framework. There is evidence of an EKC in both the short and long-run approaches. All variables carry the expected sign except trade openness which has the wrong sign and is statistically insignificant in both the short-run and long-run. Despite the success of Portugal in containing CO2 emissions so far, it is important to note that in recent years, emissions have risen. In order to comply with the 1992 Kyoto Protocol on CO2 emissions, there is need for policies that focus on the top five sectors responsible for about 55 percent of CO2 emissions are due to the extraction of crude petroleum, manufacturing of refined products, electricity distribution, construction, land transport and transport via pipeline services.



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*Keywords*: Cointegration; Causality; Environmental Kuznets Curve

## Introduction

Empirical evidence on the EKC hypothesis varies from country to country. The results tend to be mixed when CO2 emissions is the dependent variable, evidence in this paper points to an inverted U relationship for Portugal. Major contributions of this paper in testing the EKC hypothesis are threefold. Firstly, we investigate the issue based time series data for Portugal. (Jalil et al. 2010) suggest that a time series analysis for a single country may provide better framework to study the relationship. Secondly, the paper employs the ARDL method which is amenable for short time series data as in this paper. Thirdly, we provide empirical evidence of the EKC by augmenting the standard GDP variable by trade relationship, demographic factors, and energy consumption (Stern et al. 1996). Most of the existing literature have used pooled panel data of a group of countries on the emissions-growth nexus, energy-growth nexus, and emissions-urbanization nexus. These studies still provide mixed results which is the reason for keeping the problem unresolved.

This paper contributes to the debate on environmental degradation by estimating an EKC for CO2 emissions for Portugal. The rational for selecting Portugal for our analysis is that it has implemented a variety of programs and policy initiatives that encompass all of the augmented variables stated above, given that it faces challenges on the environmental front. Portugal has made great strides in terms of economic growth since its accession to the EU in 1986. The linkages of energy consumption, trade, urbanization, and economic growth to CO2 emissions have been made to a greater extent by the 2012 CO2 targets specified under the Kyoto Protocol. As a result, Portuguese policy makers have focused on reducing greenhouse gas emissions, especially CO2 in the five sectors identified above. Portugal's EKC appears to be in focus on CO2 emissions.

Portuguese economy experienced with 0.90% economic growth rate over the last 2008 year. However, growth has been associated with structural changes such as the decline in agriculture, rapid urbanization of coastal areas, and environmental degradation. Despite this impressive growth, the Portuguese economy faces the challenges in achieving balanced environmental development. Therefore, the appropriate utilization of resources is important for the environmental protection. Given this background, Portuguese policymakers have made significant investments and achieved positive results regarding environmental quality along with the economic growth. These developments motivate the researchers to investigate the relationship between economic growth and environmental quality as environmental concerns are making their way into main public policy agenda.

Economists model the relationship between environmental quality and economic growth in a variety of emissions-income equations. The objective in these studies is to test the Environmental Kuznets Curve hypothesis (EKC). The EKC hypothesis suggests that - environmental degradation increases at initial level of economic growth and then starts to decrease at a higher level of economic growth. This relationship between measure of environmental degradation, for example $CO_2$ emissions, and measures of economic growth, for example per capita GDP, is the inverted U-shaped curve.

The objective of present article is to investigate the EKC for the Portuguese economy over the period of 1971-2008. In addition to GDP variable, we also include energy consumption, trade and the urbanization. The rest of the paper consists of: Section II reviews a selected literature encompassing the EKC and the variables listed above, Section III has the theoretical and the econometric model including the ARDL estimation strategy. The empirical results are reported in section IV followed by the conclusion and policy implications.

**II. Literature Review**

An interesting debate prevails over the relationship between environmental degradation and economic growth in the relevant literature. Most of the studies document the existence of an inverted-U shaped relationship between economic growth and environmental performance. This is especially so when other measures of environmental degradation are used. However, when CO2 emissions are the dependent variable, various tests of the hypothesis have produced mixed results. The growth-environmental performance nexus has been tested by various researchers following the work of Grossman and Krueger (1991, 1993) and Douglas and Selden (1995). Their work offers empirical evidence that environmental degradation increases at initial level of economic growth and then starts to decline at a higher level of economic growth[1].

It is worth mentioning here that the different studies tested the EKC hypothesis for different indicators of environmental degradation, such as deforestation, carbon emissions and municipal waste. However, sulfur dioxide has been among the most commonly used environmental degradation indicators and EKC hypothesis has been shown to hold mostly for sulfur dioxide emissions in the literature (Jalil and Mehmud 2009). Generally, it is difficult to find an inverted-U form relation for the CO2 emission. A number of studies working on $CO_2$ emissions find an ever-increasing positive correlation between $CO_2$ and economic growth for example Chang (2010) for China, Ozturk and Acaravci (2010) for Turkey and Pao and Tsai (2010) for Russia. However,

[1] Also see Lucas et al. (1992), Suri and Chapman, (1998), Heil and Selden (1999), Friedl and Getzner (2003), Stern (2004), Nohman and Antrobus (2005), Dinda and Coondoo (2006), Coondoo and Dinda (2008) and Managi et al. (2008).

various studies that employ panel data methods report an inverted U-shaped function for $CO_2$ emissions[2].

Furthermore, the role of energy consumption in $CO_2$ emission should not be neglected while discussing the environmental performance and economic growth nexus. A substantial volume of research has been devoted towards analyzing the energy consumption and economic growth nexus[3]. Therefore, researchers think that it will be more fitting if economic growth and energy consumption is analyzed simultaneously in a single multivariate model (Jalil and Mehmud 2009). This approach is utilized by Ang (2007), Soytas et al. (2007), Halicioglu (2009), Jalil and Mahmud (2009) and Shahbaz et al. (2010c) to test both nexus in a single framework.

The next strand in investigating the emission dynamics is to test the relationship between the dynamics of demographic factors and environmental performance. Shi (2003) and Cole and Neumayer (2004) found a positive link between $CO_2$ emissions and a set of other explanatory variables including population, urbanization rate and energy intensity. In addition, few studies have discussed population density as an additional explanatory variable in the EKC framework (Cole et al. 1997 and Panayotou 1993, 1995). More recently, Dhakal (2009) examines the relationship between urbanization and CO2 emissions. In China, evidence indicates that around 40 percent contribution in CO2 emissions is due to an 18 percent increase in population. Shahbaz et al. (2010c) investigate the relationship between CO2 emissions, energy consumption, economic

[2] Heil and Selden (1999), Martinez-Zarzoso and Morancho (2004), Cole (2003), Vollebergh et al. (2005), Galeotti et al. (2006) and Apergis and Payne (2010b).

[3] See for example Kraft and Kraft (1978), Masih and Masih (1997), Yang (2000), Asafu-Adjaye (2000), Aqeel and Butt (2001), Narayan and Singh (2007), Narayan and Smyth (2007), Reynolds and Kolodzieji (2008), Wolde-Rufael (2009), Abosedra et al. (2009), Chandran et al. (2009), Yoo and Kwak (2010), Narayan and Narayan (2010), Apergis and Payne (2010a) and Yoo and Lee (2010).

growth and trade openness for Pakistan. Their results support the EKC hypothesis when energy consumption and trade openness variables are added to the standard GDP variable. Furthermore, they find a one-way causal relationship running from income to CO2 emissions. Energy consumption increases CO2 emissions both in the short and long run, whereas, trade openness reduces CO2 emissions in the long run.

**III. Theoretical and Modeling Framework**

The paper follows the framework in Ang (2007, 2008), Soytas et al. (2007), Halicioglu (2009), Jalil and Mehmud (2009) and Shahbaz et al. (2010c) in estimating an environmental degradation equation. These studies estimated the emissions-growth nexus and energy-growth nexus in a single equation model. In addition, we include urbanization as variable to proxy for demographic changes reflecting the rapid movements of young people from rural and small farms into large cities and coastal areas in search of jobs. We also include trade openness as a controlling variable. In equation 1, we suggest that $CO_2$ emission ($CO_2$) in Portugal depend on energy consumption (*ENC*), gross domestic product (*GDP*), square of gross domestic product ($GDP^2$), trade openness (*TR*), and urbanization (*URB*).

$$CO_2 = f(ENC, GDP, GDP^2, TR, URB) \quad (1)$$

We convert linear specification of model into log-linear specification. It is noted that log-linear specification provides more appropriate and efficient results as compared to simple linear functional form of model (Cameron, 1994 and Ehrlich 1975, 1996). Furthermore, logarithmic form of variables gives direct elasticities for interpretations. Therefore, we specify estimable equation in log linear form:

$$LCO_2 = \beta_1 + \beta_{ENC} LENC + \beta_{GDP} LGDP + \beta_{GDP^2} LGDP^2 + \beta_{TR} LTR + \beta_{URB} LURB + \mu_t \quad (2)$$

Where $\mu$ stands for residual or error term, we hypothesize that economic activity is positively stimulated by an increase in energy use resulting in an increase in environmental pollutants or energy emissions. This leads us to expect $\beta_{ENC} > 0$. The EKC hypothesis suggest that $\beta_{GDP} > 0$ and $\beta_{GDP^2} < 0$. The sign of $\beta_{TR} < 0$ if production of pollutant intensive items is reduced due to environment protection laws and imports such items from the other countries where environmental laws are flexible. The expected sign of trade openness is negative, $\beta_{TR} < 0$. Frankel and Rose (2005) posit that foreign investors come with advanced technology and innovative managerial skills from their parent country for the advantage of host countries. This tends to increase the use of energy efficient approaches which further increases welfare. Moreover, trade openness increases in the demand of environmental quality and cleaner product as trade openness offers a set of available varieties to consumers (Eskeland and Harrison, 2002). On the contrary, Grossman and Helpman (1995) and Halicioglu (2009) argue that sign of $\beta_{TR}$ is positive if industries of developing economies are busy to produce heavy share of CO2 emissions with production. Finally, *URB* indicates urbanization proxies by urban population as share of total population. Urbanisation is a variable indicating the demographic growth on environment. A rise in population encourages people to move to urban areas for better education and job opportunities. This rise in urban population leads to the enhanced energy demand which in turn, creates more atmospheric pollution. Therefore, we expect $\beta_{URB}$ > 0.

The data on all variables comes from World Development Indicators (WDI, CD-ROM, 2009). CO2 emissions is proxied by CO2 emissions (Corban dioxide metric tons per capita), and ENC is for energy use (kilograms of oil equivalent per capita). Real GDP per capita (GDP) is used to capture the impact of economic growth on CO2 emissions. TR is for trade openness, which is proxied by the ratio of exports plus imports to GDP while URB is the urbanisation population as the share of total population.

**IV. Estimation Strategy**

This paper applies the ARDL bounds testing approach to cointegration developed by Pesaran and Pesaran (1997), Pesaran et al. (2000) and latter on by Pesaran et al. (2001) to examine long run relationship between CO2 emissions, energy consumption, economic growth, international trade and urbanisation. The autoregressive distributive lag model can be applied without investigating the order of integration (Pesaran and Pesaran, 1997). Haug (2002) has argued that an ARDL approach to cointegration provides better results for small sample data set such as in our case, compared to traditional approaches to cointegration, that is, Engle and Granger (1987), Johansen and Juselius (1990) and Philips and Hansen (1990). (Laurenceson and Chai, 2003) state that another advantage of ARDL bounds testing is that the unrestricted model of ECM has sufficient flexibility to accommodate lags that captures the data generating process in a general-to-specific framework of specification. In addition, Pesaran and Shin, (1999) state that, "appropriate modification of the orders of ARDL model is sufficient to simultaneously correct for residual serial correlation and problem of endogenous variables". The unrestricted model is stated as

$$\begin{aligned}\Delta LCO_2 &= \alpha_1 + \alpha_{ENC} LENC_{t-1} + \alpha_{GDP} LGDP_{t-1} + \alpha_{GDP^2} LGDP^2_{t-1} + \alpha_{TR} LTR_{t-1} + \alpha_{URB} LURB_{t-1} \\ &+ \sum_{i=1}^{p} \alpha_i \Delta LCO_{2\,t-i} + \sum_{j=0}^{q} \alpha_j \Delta LENC_{t-j} + \sum_{k=0}^{m} \alpha_k \Delta LGDP_{t-k} + \sum_{l=0}^{n} \alpha_l \Delta LGDP^2_{t-l} + \sum_{l=0}^{o} \alpha_m \Delta LTR_{t-m} \ldots (3) \\ &+ \sum_{l=0}^{r} \alpha_n \Delta LURB_{t-n} + \mu_t\end{aligned}$$

The ARDL bounds testing approach to cointegration depends upon the tabulated critical values by Pesaran et al. (2001) to make a decision about cointegration among the variables. The null hypothesis of no cointegration in the model is $\alpha_{ENC} = \alpha_{GDP} = \alpha_{GDP^2} = \alpha_{TR} = \alpha_{URB} = 0$. The alternative hypothesis of cointegration among variables is $\alpha_{ENC} \neq \alpha_{GDP} \neq \alpha_{GDP^2} \neq \alpha_{TR} \neq \alpha_{URB} \neq 0$. The next step is to compare the calculated F-statistics with lower critical bound and upper critical bound critical values from Pesaran and Pesaran (1997) or Pesaran et al. (2001)[4]. There is cointegration among variables if calculated value of F-statistics is more than upper critical bound. If the lower critical bound is more than computed F-statistics then there is no cointegration. However, if the calculated F-statistics is between lower and upper critical bounds then decision about cointegration is inconclusive. In such a situation, we rely on the significance of the lagged error correction term (ECT) for cointegration to investigate the long run relationship. If a long run relationship among variables exists, the short run behavior of variables is investigated by the following VECM model:

[4] For small samples Turner (2006) has assembled critical values for F-statistics that are suitable for the short data series employed in this paper.

$$\Delta LCO_2 = \delta_1 + \sum_{j=0}^{p} \delta_2 \Delta LENC + \sum_{k=0}^{q} \delta_3 \Delta LGDP_{t-k} + \sum_{l=0}^{o} \delta_4 \Delta LGDP_{t-l}^2 + \sum_{r=0}^{m} \delta_5 \Delta LTR_{t-r} + \sum_{s=0}^{n} \delta_6 \Delta LURB_{t-s} + \eta ECM_{t-1} + \varepsilon_t \quad \ldots (4)$$

The existence of an error correction term implies the changes in dependant variable. These changes are a function of both the levels of disequilibrium in the cointegration relationship and the changes in the other explanatory variables. This indicates the deviation in dependant variable from a short span of time to the long-run equilibrium path (Masih and Masih, 1997). The relevance of the ARDL model is checked through stability tests such as cumulative sum of recursive residuals (**CUSUM**) and cumulative sum of squares of recursive residuals (**CUSUMSQ**).

## IV. Empirical Interpretation

Ouattara (2004) states that if a variable is integrated at I(2) then the computation of F-statistics for cointegration becomes inconclusive as Pesaran et al. (2001) critical bonds are based on the assumption that such variables should be stationary at I(0) or I(1). Thus, we apply unit root tests to ensure that no variable is integrated at I(2) or beyond. We have used the ADF unit root test to check for stationarity. The results in Table 1 indicate that all variables are non-stationary at their level form and stationary at their first differences.

The two step procedure in ARDL bound testing by Pesaran et al (2001) requires adequate lag length in variables to remove serial any correlation. The order of lag length has been selected by estimating first difference of the conditional error correction version of ARDL. The selection of lag order is based on minimum value of Akaike Information Criteria (AIC). There is evidence that the calculation of ARDL F-statistics is sensitive to the selection of lag order in the model[5]. Table 2 shows a maximal of lag more than 2 in the data. The appropriate selection of lag order is necessary for unbiased and reliable results.

| **Table 1: Unit Root Estimation** | | |
|---|---|---|
| ADF Test at Level with Intercept and Trend | | |
| Variable | T-Statistics | Prob-Value* |
| *LCO2* | -0.2961 | 0.9871 |
| *LENC* | -2.3993 | 0.3741 |
| *LGDPC* | 0.4353 | 0.9987 |
| $LGDPC^2$ | -0.1559 | 0.8918 |
| *LTR* | -0.9626 | 0.9365 |
| *LURB* | -2.2018 | 0.4715 |
| ADF Test at First Difference with Intercept and Trend | | |
| *ΔLCO2* | -6.8985 | 0.0000 |
| *ΔLENC* | -6.7119 | 0.0000 |
| *ΔLGDPC* | -6.8691 | 0.0009 |
| $\Delta LGDPC^2$ | -6.7551 | 0.0000 |
| *ΔLTR* | -5.7913 | 0.0002 |
| *ΔLURB* | -3.3051 | 0.0825 |
| Note: *MacKinnon (1996) one-sided p-values | | |

| **Table-2: Lag Length Selection Criteria** | | | | | | |
|---|---|---|---|---|---|---|
| VAR Lag Order Selection Criteria | | | | | | |
| Lag | LogL | LR | FPE | AIC | SC | HQ |
| 0 | 140.581 | NA | 7.31e-09 | -7.382 | -7.209 | -7.321 |
| 1 | 339.1163 | 343.4125 | 3.82e-13 | -17.25 | -16.379 | -16.943 |
| 2 | 375.646 | 55.290* | 1.30e-13* | -18.359* | -16.791* | -17.807* |
| * indicates lag order selected by the criterion | | | | | | |
| 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 | | | | | | |

[5] Shahbaz et al. (2010a, b) and Feridun and Shahbaz (2010)

The next step is to calculate F-statistics by ARDL bound test using unrestricted OLS following equation 3. The results presented in Table 3 indicate a high calculated value of an F-statistic which is greater than the upper critical bound of 6.198 from Turner (2006)[6] at 5% significance. We conclude that CO2 is cointegrated with ENC, GDP, GDP$^2$, TR and URB when CO2 emissions are the dependent variable.

| **Table 3: The Results of Cointegration Tests** | |
|---|---|
| **Bounds testing to cointegration** | |
| Estimated Equation | $CO_2 = f(ENC, GDP, GDP^2, TR, URB)$ |
| Optimal lag structure | 2 |
| F-statistics | 7.3827** |
| **Diagnostic Check** | |
| $R^2$ | 0.9436 |
| Adjusted- $R^2$ | 0.8085 |
| F-statistics (Prob. | 6.9817 |
| J-B Normality test | 0.5802 |
| Breusch-Godfrey LM test [2] | 0.2588 |
| ARCH LM test [2] | 1.3766 |
| Ramsey RESET | 1.1583 |
| CUSUM | Stable |
| CUSUMSQ | Stable |
| Note: The asterisks ** denote the significant at 1 per cent level. The optimal lag structure is determined by AIC. | |

The long run estimates are reported in Table 4. The results reveal that an increase in energy consumption increases energy emission or CO2 emissions. For example, a 1 percent increase in energy consumption raises CO2 emissions by 0.87 percent. This finding is similar to many other studies on CO2 emissions and energy consumption[7]. Both linear and non-linear terms of GDP per

[6] We have used Tuner (2006) critical values instead of PSS (2001) and Narayan (2005). Turner (2006) produced better critical bounds for small sample data sets.
[7] See Hamilton and Turton (2002), Friedl and Getzner (2003), Liu (2005), Say and Yücel (2006), Ang (2008), Halicioglu (2009), Jalil and Mehmud (2009) and Shhabaz et al. (2010c).

capita show the existence of inverted-U relationship between economic growth and CO2 emissions. The coefficients of linear and non-linear terms are 10.25 and -0.57 respectively and are highly significant.

| **Table 4: Long Run Estimates** | | | |
|---|---|---|---|
| Dependent Variable = *LCO2* | | | |
| Variable | Coefficient | Std. Error | T-Statistic |
| *Constant* | -50.9189 | 9.6869 | -5.2564* |
| *LGDP* | 10.2513 | 2.1511 | 4.7655* |
| $LGDP^2$ | -0.5736 | 0.1169 | -4.9059* |
| *LENC* | 0.8754 | 0.1379 | 6.3438* |
| *LURB* | 0.6020 | 0.1380 | 4.3615* |
| *LTR* | 0.0024 | 0.0642 | 0.0380 |
| **Diagnostic Checks** | | | |
| R-Squared | 0.9948 | | |
| Akaike info Criterion | -3.7678 | | |
| Schwarz Criterion | -3.5030 | | |
| F-Statistic | 1154.062 | | |
| Durbin-Watson | 1.8136 | | |
| Serial Correlation LM | 0.3202 | | |
| ARCH Test | 0.3661 | | |
| Normality Test | 1.0471 | | |
| Heteroscedisticity Test | 1.0063 | | |
| Ramsey RESET Test | 2.6249 | | |

Note: * shows a 1 percent level of significance.

The results indicate that a 1 percent rise in per capita income will increase energy emissions by 10.25 percent while the negative sign of squared term corroborates the delinking of energy emissions and real GDP per capita at high level of income per capita in the country. The evidence confirms that CO2 emissions increase in the initial stage of economic growth, and eventually decline after reaching the threshold of GDP. These findings are consistent with various studies that examine the relationship between GDP growth and CO2 emissions[8]. The coefficient on trade openness (TR) shows a positive impact on CO2 emissions. The coefficient of TR on CO2 is positive and statistically insignificant. It indicates that a 1 percent increase in international trade results in a 0.002 percent increase in emissions. Fossil energy resources are not much available in Portugal and country imports most of the energy consumed such as oil products due its consumption structure. Further more, considering domestic demand, both exports and imports are imputed with CO2 emissions (Cruz, 2004). The coefficient of TR on CO2 is positive, very small and statistically insignificant. Finally, the impact of urbanization on CO2 emissions is positive and significant. Urbanization increases energy consumption and hence high energy emissions, resulting in high CO2. On the basis of empirical evidence, a 1 percent increase in urban population results in a 0.60 percent increase in CO2 emissions.

**Table-5: Granger Causality Test**

| **Null Hypothesis:** | **F-Statistic** | **Pro. Value** |
|---|---|---|
| *LGDP* does not Granger Cause *LCO2* | 5.06828 | 0.03075 |
| *LCO2* does not Granger Cause *LGDP* | 0.19584 | 0.66082 |
| $LGDP^2$ does not Granger Cause *LCO2* | 4.48858 | 0.04129 |
| *LCO2* does not Granger Cause $LGDP^2$ | 0.18862 | 0.66673 |

All variables are I (1), therefore Granger-Causality test can be used to examine the direction of causality between GDP and energy emissions. The results reported in Table-5 indicate that the GDP ($GDP^2$) affects the CO2 emissions in the long run. These results also confirm the existence of Environmental Kuznets Curve (EKC). The evidence is in line with the findings of Zhang and Cheng (2009) and Jalil and Mahmud (2009) for China, Ghosh (2010) for India, and Shahbaz et al. (2010c) for Pakistan.

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[8] See He, (2008), Song et al. (2008), Halicioglu (2009), Jalil and Mehmud (2009), Fodha and Zaghdoud, (2010), Lean and Smyth (2010) and Shahbaz et al. (2010c).

The short run dynamics results are reported in Table 6. Evidence indicates that an increase in energy consumption in the short run leads to increases CO2 emissions. For example, a 1 percent rise in energy consumption increases CO2 emissions by 0.85 percent. The signs of coefficients of GDP and $GDP^2$ support the EKC hypothesis and are significant at 10% level of significance respectively. The impact of a rise in urban population is positive and statistically significant at 5% level of significance. It implies that a 1 percent increase in urban population will raise CO2 emissions by 0.12 percent. The short run effect of international trade is positive but statistically insignificant.

| **Table 6: Short Run Estimates** | | | |
|---|---|---|---|
| Dependent Variable = $\Delta LCO2$ | | | |
| Variable | Coefficient | Std. Error | T-Statistic |
| *Constant* | -0.007970 | 0.017272 | -0.461450 |
| $\Delta LGDP$ | 11.32968 | 5.986932 | 1.892402*** |
| $\Delta LGDP^2$ | -0.636843 | 0.344594 | -1.848099*** |
| $\Delta LENC$ | 0.859039 | 0.134972 | 6.364573* |
| $\Delta LURB$ | 0.120681 | 0.055179 | 2.187077** |
| $\Delta LTR$ | 0.070053 | 0.060762 | 1.152896 |
| $ECM_{t-1}$ | -0.108312 | 0.023200 | -4.668681* |
| **Diagnostic Checks** | | | |
| R-Squared | 0.8123 | | |
| Akaike info Criterion | -4.0230 | | |
| Schwarz Criterion | -3.7183 | | |
| F-Statistic | 21.6410 | | |
| Durbin-Watson | 1.9832 | | |
| Serial Correlation LM | 0.2401 | | |
| ARCH Test | 0.3234 | | |
| Normality Test | 2.2756 | | |
| Heteroscedisticity Test | 0.5759 | | |
| Ramsey RESET Test | 0.2774 | | |

Note: *, **, *** shows a 1%, 5%, 10% level of significance.

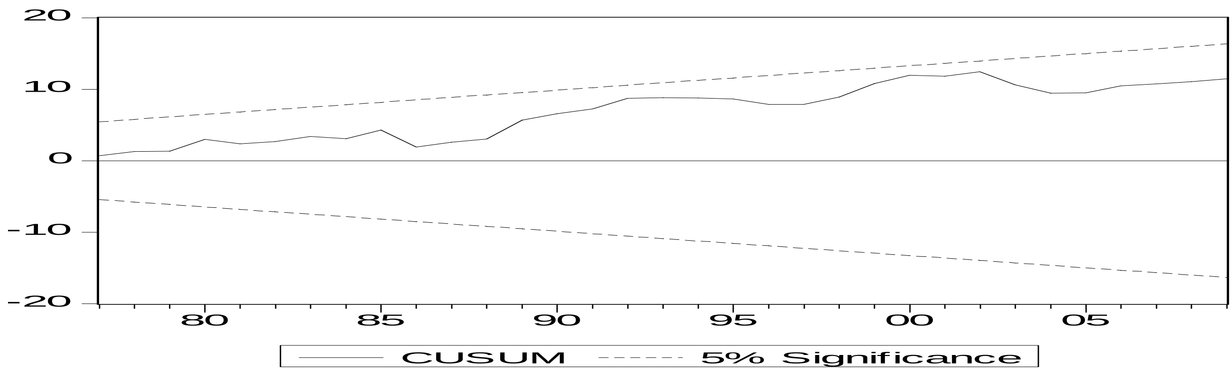
The sign of coefficient of lagged ECM term is negative and significant at 1% level of significance. This corroborates the established long run relationship among the variables. Furthermore, the value of lagged ECM term is significant and shows that deviations in CO2 emissions away from long run equilibrium are corrected by 10.83 percent within a year.

**Sensitivity Analysis and Stability Test**

The diagnostic tests such as the LM test for serial correlation, normality of the residual term and White heteroscedisticity test in the short-run model have also been conducted. The results are reported in Table 4. The relevant statistics show that the short-run model passes all diagnostic tests. The evidence indicates no serial correlation and the residual term is normally distributed. There is no evidence of autoregressive conditional heteroscedisticity and the same holds for White heteroscedisticity. Model specification is well constructed.

Figure **1**

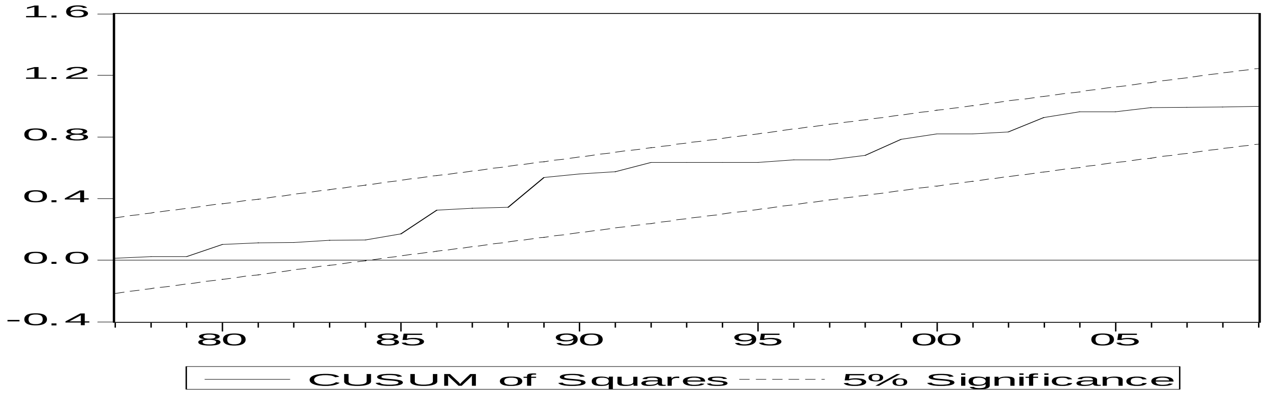
**Plot of Cumulative Sum of Recursive Residuals**




The straight lines represent critical bounds at 5% significance level.

Figure **2**

**Plot of Cumulative Sum of Squares of Recursive Residuals**




The straight lines represent critical bounds at 5% significance level.

The stability tests are used to investigate the stability of long and short run parameters. In doing so, cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests have been employed. Pesaran et al. (2000, 2001) suggest that CUSM and CUSMSQ tests are adequate in testing for stability of coefficients in such models. The graph of CUSUM is significant at 5% significance levels indicating the stability of parameters.

**V. Conclusion and Policy Implications**

In this present paper, we investigated the relationship among energy consumption, economic growth, urbanization and energy emissions for Portugal over the period of 1971-2008. The Environmental Kuznets Curve's (EKC) hypothesis has been tested by applying ARDL model. The results suggest that a long run relation exists among energy consumption, economic growth, international trade, urbanization and energy emissions. The existence of an EKC in Portugal included additional variables that capture demographics (URB), international trade (TR), and energy consumption (ENC), through which we find a positive and significant impact of energy consumption and urbanization on CO2 emissions. Trade openness has positive and significant impact on CO2 emissions in the long-run.

Since the EKC hypothesis holds in Portugal, we heed Stern's (1996) warning not to conclude that economic growth is the means to environmental improvement. Instead, one looks at the trade-offs among three objectives that have been central in Portugal's energy policy since its accession to the EU in 1986; economic growth, environmental protection and energy security. Portugal has made great strides in terms of economic growth since its accession to the EU in 1986. There is a need for further policies that address the issue of the total CO2 emissions, 55 percent of which are due to the top five sectors responsible for CO2 emissions.

However, the 2010 forest fires might have undermined Portugal's ability to meet 2012 goals. De Queirozo (2010), reports that The Quercus National Association for Nature Conservation (ANCN) says that the fires released 1.1 million tones of CO2 this year which they argue reduces "the capacity of forested areas to absorb carbon, and is a stain on Portugal's performance under the Kyoto Protocol." Similar concerns have been raised about 2010 forest fires by Off7 (a private firm that certifies emissions). They suggest that a "3% loss of absorptive capacity by forests is equivalent to 100,000 tonnes of CO2 emissions that the forests were unable to prevent." If one considers the fact that in 2008, Portugal's forest areas absorbed 4.42 million tones of CO2, the concerns of ANCN and Off7 are significant. Portuguese policy makers need a forestry policy that has major components namely, zoning, maintenance, management, and regulation of pulp-making companies. Overall, Portugal's EKC reflects structural changes of an economy that will have more information-based industries and services and with adequate technologies should experience a decline in CO2 emissions. However, Portugal must have clear policies on clean technologies, forestry management and increasing rates of urbanization.

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