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# Bounds Testing Approach to Analyze the Existence of an Environmental Kuznets Curve in Ecuador

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**ABSTRACT**

This paper provides empirical evidence of a long-run environmental Kuznets curve (EKC) for Ecuador from 1971 to 2011. Using the autoregressive distributed lag bounds testing approach, we do not just estimate the effect of economic growth on carbon dioxide emissions but also the effect of energy consumption on this one. The effects of all variables have the expected signs. In addition, we test for granger causality among the variables using an error correction model. Only gross domestic product granger causes energy consumption in the short-run. The results have several policy implications that are consistent with the recent environmental policy of the government.

**Keywords:** Environmental Kuznets Curve, Ecuador, Energy Matrix
**JEL Classifications:** C32, O52, Q43, Q50

## 1. INTRODUCTION

The first evidence of human impact on the climate were presented at the First World Climate Conference, held in Geneva in 1979, which recognized climate change as a major problem (WMO, 1979). This phenomenon is mainly generated by the increase in greenhouse gases (GHG), especially carbon dioxide ($CO_2$). In fact, according to Ozturk and Acaravci (2010) $CO_2$ emissions are the most important anthropogenic GHGs, which are responsible for more than 60% of the greenhouse effect. Moreover, the main part of the increase in $CO_2$ emissions can be attributed to energy consumption especially, fossil fuels burning such as oil, gas and coal (Saboori and Sulaiman, 2013).

Ecuador has been characterized by the production of primary goods for the international market, with little or no mechanization and high levels of concentration of profits. These features are what have given the pattern of primary specialization of exporter, which the country has been unable to overcome since its republican era. This is why the current government seeks the transformation of the productive matrix, to generate wealth based not only on the exploitation of natural resources, but in using the skills and knowledge of the population. In this context it also promotes the transformation of the energy matrix to move from expensive and polluting energy, based on hydrocarbons (power plants), to a cheaper and cleaner energy generated by eight hydroelectric plants that are under construction and would start to operate in 2016 (National Secretary of Planning and Development, 2015).

In this paper, the hypothesis of environmental Kuznets curve (EKC) is analyzed, which states that there is a strong relationship between economic growth and environmental degradation. In the short term, higher growth leads to more pollution, but in the long run the degradation will begin to decrease, forming an inverted U-shaped curve. There are also other variables such as energy consumption that would be explaining the behavior of the emission of pollutants. In fact, Shahbaz et al. (2014) state that energy consumption, pollutant emissions and economic growth may be closely interrelated.

The methodology used is an autoregressive distributive lag (ARDL) bounds testing approach to cointegration, and the study period is 1971-2011. This is the first study for Ecuador applying that uses this methodology to make the results robust. The results show an EKC in Ecuador for the long term, but not in the short term. Therefore, the results should be interpreted with caution in the sense that Ecuador is currently in the growing stage of the Kuznets curve. The primary energy use is statistically significant, and this reinforces the idea that the country is still dependent on fossil fuels, even though there have been great advances in environmental policy. In addition, conserving energy consumption may be the most direct way of managing the emissions problem, this reduction at the expense of economic growth may not be a desirable outcome (Lotfalipour et al., 2010).

The rest of the paper is organized as follows: Section 2 describes the economic situation of Ecuador and its relationship with the environment. Section 3 shows the literary review. Section 4 defines the theoretical model. Section 5 presents the methodology to be used. Section 6 shows the empirical results. Section 7 concludes.

## 2. ECUADORIAN CONTEXT

Ecuador is a South American country and has a population of 15.74 million (WDI, 2014). Its economy is the eighth largest in Latin America and its growth average rate of real gross domestic product (GDP) per capita was 7.98% between 1971 and 2011 (Figure 1). In human development it has a score of 0.724 (UNDP - United Nations Development Program, 2013) and about 35% of its population live under the Poverty threshold (Index Mundi, 2012).

In the Ecuador Concern for the environment started in the early 70s. However, it was not until 1996 that the Ministry of Environment was established which is the public agency responsible for regulating environmental practices in the country. This organization has submitted two environment national communications, in particular on GHG. With these reports it was possible to present the official publication of the national inventory of GHG, which systematizes sectoral inventories of the years 1990, 1994, 2000 and 2006, with emphasis on nitrous oxide, $CO_2$ and methane.

$CO_2$ is the second[1] GHG emitted more frequently and their emissions have doubled since 1990-2006. (Ministry of Environment, 2015). Their emission level is low (2.34 metric tons per capita) compared to other countries in the region (e.g., Venezuela, Argentina, and Chile) (WDI, 2014); despite this, the country has signed international agreements on responsibility and commitment with the environment. Thus, in 1990 it joined the Vienna Convention (1985) and the Montreal Protocol (1987), both agreements with commitment to reduce GHG emissions generated, as well as create environmental policies for the care of the ozone layer and climate change. In 1999 the country joined the Kyoto Protocol, which refers to the quantification, limitation and reduction of GHG during the years 2008 - 2012 (United Nations, 1998). Other agreements signed were the Millennium Development Goals in 2000, and the Bali Action Plan in 2007, this latter one would allow the full implementation of the Framework Convention of the United Nations Climate Change.

On the other hand, the emission of GHG increased by 54.6% from 1990 to 2006, being the energy sector the highest growth with a variation of 110% in that period (Ministry of Environment, 2015). Currently, the energy accounting shows that domestic production, which accounts for 90% of the total energy supply, is concentrated 96% on crude oil and natural gas, being renewable energy (hydropower and biomass) relegated to a 4% of the domestic production. In contrast, the second component of the energy supply, imports, corresponds to 90% of the petroleum products (LPG, diesel, high octane gasoline and others), moreover, depending on the circumstances, Electricity is imported and other not energy products (e.g., lubricants). Regarding the energy demand, exports are the major component (64% of the total), while domestic demand is barely 28% of the total, and the remaining 8% is lost by transformation. On the other hand, 90% of exports are crude oil, the remaining 9% of low value-added derivatives (mainly fuel oil) and the rest (1%) corresponds to vegetable oils. The domestic demand is mainly composed of petroleum (79%), electricity (13%), firewood - biomass, bagasse and others (5%) and the rest (2%) non-energy products such as fuels and others. The domestic demand by sector is concentrated in the transport (52%), industry (21%) and residential (19%), the rest (8%) corresponds to the sectors: Trade and services (4%), and other sectors of the economy (4%). (National Secretary of Planning and Development, 2015).

Given this current scenario, Ecuador currently holds a process of change in its energy matrix, including electricity generation based on renewable sources for obtaining clean energy. To achieve this goal, imports of petroleum products must be reduced to a minimum, which can be achieved through the construction of the Pacific Refinery, a project that is under way and that would ensure the provision of oil products for domestic consumption.

Also, Figure 1 shows a positive correlation between $CO_2$ emissions alongside GDP and energy consumption. In fact, you may notice a growing trend in the last 15 years, especially in energy consumption[2]. For this reason a direct and strong relationship of causality between energy use and environmental degradation is expected, given that the main supply source is the exploitation of oil.

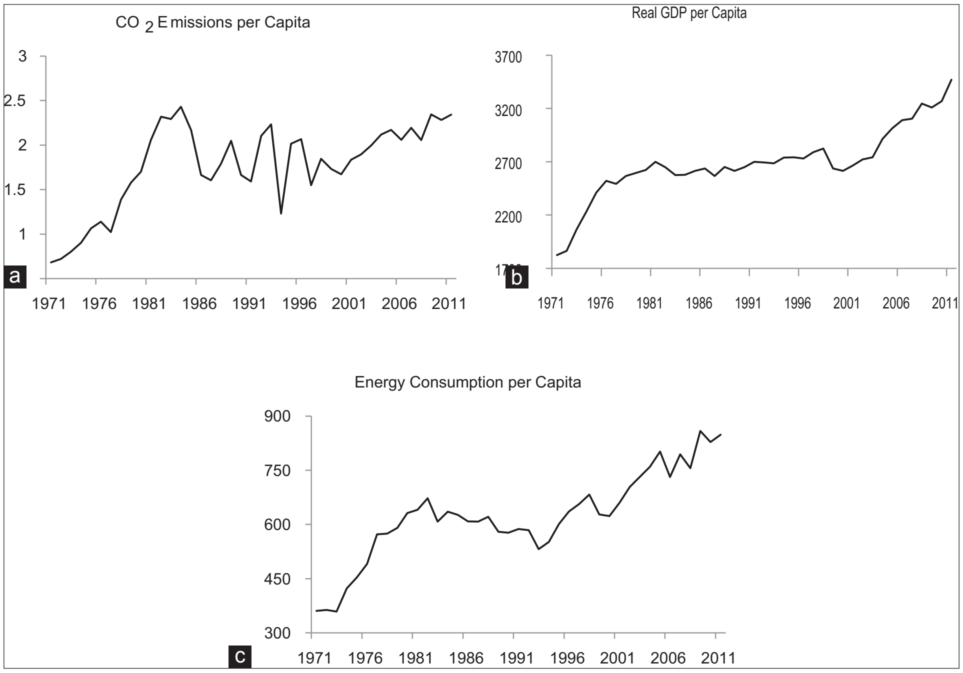
## 3. LITERATURE REVIEW

Several studies explore the relationship between pollution levels and income per capita, though there is much debate around

1 The first is nitrous oxide.

2 Energy consumption refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport (WDI, 2014).

**Figure 1:** Trends in energy consumption, carbon dioxide ($CO_2$) emissions and real gross domestic product (GDP). (a) $CO_2$ emissions per capita, (b) Real GDP per capita, (c) Energy consumption per capita




the issue. The hypothesis of the EKC proposes an inverted U relationship between these two variables. In other words, it refers that there are levels of income per capita in which air pollution levels are rising, but there is also a level of income in which each increase in income per capita translates into a decrease in the level of contamination. The first empirical work that tested the EKC was conducted by Grossman and Krueger (1991, 1993).

It is noteworthy that there are several studies that prove the EKC hypothesis for different indicators. These could be classified as indicators of air quality (sulfur dioxide, suspended particulate matters, $CO_2$ and nitrous oxides, etc.), indicators of water quality (concentration of pathogens in water, amount of heavy metals, toxic chemicals in water discharge by human activities) and other indicators (municipal solid wastes, urban sanitation, access to safe drinking water, energy use and traffic volumes, etc.). The most common indicators are those who are related to air quality where the EKC hypothesis remains for sulfur dioxide, however, when the indicator of environmental degradation are the emissions of carbon dioxide, it produces mixed results. Hill and Magnani (2002), Dinda (2004) and Stern (2004) provide a good review of this extensive research on the EKC.

Dinda (2004) claims biased in the literature since it is difficult to find an EKC for $CO_2$ emissions. Recently, researchers have reported an ever-increasing EKC for carbon emissions. For example, Atici (2009) made it for Central and Eastern Europe, Jalil and Mahmud (2009) for China, Marrero (2010) for Europe, Saboori and Sulaiman (2013) for Malaysia, Wang (2012) for 98 different developed and developing countries, Kohler (2013) for South Africa, and Farhani, Chaibi, and Rault (2014) for Tunisia.

An important framework documented in the literature is the energy consumption and economic growth nexus[3]. There are several studies that use energy consumption and economic growth in a multivariate model to explain $CO_2$ emissions. For example, Soytas et al. (2007) examine the effect of energy consumption and GDP on carbon emissions in the United States, including labor and investment in fixed capital. They employ Toda and Yamamoto (1995) procedure to test for long run Granger causality. Additionally, they use generalized impulse response functions and variance decompositions in a multivariate setting. They find that income doesn't Granger cause carbon emissions in the US in the long run, but energy use does. Hence they conclude that income growth by itself may not become a solution to environmental problems. Ang (2007) analyzes the dynamic causality relationship among $CO_2$ emissions, energy consumption, and GDP for France over the period 1960-2000 using ARDL bounds testing approach for the cointegration and a multivariate Vector Error Correction Model (VECM). His results indicate that increases in energy use rise $CO_2$ emissions; and $CO_2$ emissions and GDP have a quadratic relationship in the long run. Later, Apergis and Payne (2009) extend the work of Ang (2007) using Pedroni cointegration, fully modified OLS (FMOLS) model, and a VECM Granger causality for six Central American countries over the period 1971-2004. In this study the energy usage has a positive and statistically significant impact on emissions whereas $CO_2$ and real GDP exhibits a quadratic relationship.

Pao and Tsai (2011a) and Pao and Tsai (2011b) proved the existence of Environmental Kuznets Curve for Brazil and BRIC

3 See a detailed literature survey on the energy-growth nexus in the study of Ozturk (2010).

(Brazil, Russian Federation, India, China) countries over the period 1980-2007, respectively. Pao and Tsai (2011a) employ Johansen cointegration analysis, OLS model, and VECM to test the effect of GDP and energy consumption over the $CO_2$ emission. They found that an increase in real GDP may actually reduce both emissions and energy consumption in Brazil, since the demand for environmental quality increases as these economies grow. Pao and Tsai (2011b) use a panel cointegration framework to examine the relationship between GDP, energy consumption, FDI and $CO_2$ emission. Their results about energy consumption are congruent with the literature, nevertheless something interesting is that contrary to the general perception, FDI doesn't cause the growth of GDP, the FDI-led-growth hypothesis doesn't seem to be applicable for BRIC developing countries.

Shahbaz et al. (2015) apply the ARDL bounds testing approach to cointegration developed by Pesaran and Pesaran (1997), Pesaran et al. (2000, 2001) to examine the long run relationship between $CO_2$ emissions, energy consumption, economic growth, international trade and urbanization for Portugal over the period 1971-2008. They found a positive and significant impact of energy consumption and urbanization on $CO_2$ emissions. In addition, some authors as Soytas et al. (2007), Saboori and Sulaiman (2013), and others recommend to estimate the disaggregate energy usage, due to the fact that this one may provide more insights regarding the link between GDP and environmental degradation.

There are few studies that test the hypothesis of EKC for Ecuador. For example, Robalino-López et al. (2014) used Stock and Watson (2010) cointegration approach to prove the existence of an EKC in Ecuador. Furthermore, Al-mulali et al. (2015) proved the existence of EKC in Latin American countries, included Ecuador, through the FMOLS and VECM Granger causality approaches. This paper differs from previous works because it is the first one to explore the nexus between environmental degradation, income and energy consumption through ARDL methodology which have some advantages over traditional procedures.

## 4. THEORETICAL AND MODELING FRAMEWORK

This paper follows the theoretical and modeling framework of recent empirical literatures such as Ang (2007), Apergis and Payne (2009), Saboori and Sulaiman (2013) and Shahbaz et al. (2015) to estimate an environmental degradation equation. We propose a relationship between the $CO_2$ emissions growths and the energy consumptions growth because the $CO_2$ is the second GHG emitted more frequently and their emissions have doubled since 1990-2006 (Ministry of Environment, 2015). In addition, the emission of GHG increased by 54.6% from 1990 to 2006, being the energy sector the greatest growing with a variation of 110% in that period. For this reason, we suggest that $CO_2$ emissions ($CO_2$) in Ecuador depend on GDP, square of GDP ($GDP^2$) and the use of energy (E), in per capita terms.

$$CO_2 = f(GDP, GDP^2, E)$$

We established a log-linear functional form due to that this specification provides more appropriate and efficient results as compared to functional form of the simple linear model. The model is presented below:

$$\ln CO_2 = \beta_0 + \beta_{GDP} \ln GDP + \beta_{GDP}{}^2 + \beta_E \ln E + u$$

$\ln CO_2$ is the log of $CO_2$ emissions stemming from the burning of fossil fuels and the manufacture of cement. They include $CO_2$ produced during consumption of solid, liquid, and gas fuels and gas flaring in per capita metric tons. ln GDP is the log of GDP in constant terms for 2005 US$ as an indicator of per-capita income, it refers to the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. $\ln GDP^2$ is the square of lnGDP. Moreover, ln E is the log of the use of energy (measured in kg of oil equivalent per capita), it refers to the use of primary energy before the transformation to other end-use fuels, and u is an error term.

The EKC hypothesis suggests $\beta_{GDP} > 0$, $\beta_{GDP}{}^2 < 0$. Following existing literature, we can hypothesize that economic activity is positively stimulated by an increase in energy use and provokes an increase in environmental pollutants or carbon emissions, hence we might expect that $\beta_E > 0$. All the data mentioned above was taken from World Development Indicators (WDI) for the period 1971-2011.

## 5. METHODOLOGY

### 5.1. ARDL Bounds Testing of Cointegration

The main objective of this paper is to test the long-run relationship between $CO_2$ emissions, GDP and energy consumption. The ARDL cointegration approach developed by Pesaran and Shin (1999) and Pesaran et al. (2001) have some advantages over traditional procedures, such as Engle and Granger (1987), Johansen and Juselius (1990) and Phillips and Hansen (1990). For instance, ARDL allows to estimate the long run relationship regardless of the integration order, and it is more efficient in small samples such as in our case. Indeed, most of the recent studies about EKC hypothesis such as Ozturk and Acaravci (2010), Saboori and Sualiman (2013), Shahbaz et al. (2014) and Shahbaz et al. (2015) use the ARDL methodology.

ARDL estimation can be performed in two steps. The first step consists of estimating an unrestricted error correction model, which is modeled as follows:

$$\begin{aligned}\Delta \ln CO_{2t} &= \alpha_0 + \beta_{CO_2} \ln CO_{2t-1} + \beta_{GDP} \ln GDP_{t-1} \\ &+ \beta_{GDP^2} \ln GDP^2_{t-1} + \beta_E \ln E_{t-1} + \sum_{i=1}^{p} \alpha_{1i} \Delta \ln CO_{2t-i} \\ &+ \sum_{j=0}^{q} \alpha_{2j} \Delta \ln GDP_{t-j} + \sum_{k=0}^{m} \alpha_{3k} \Delta \ln GDP^2_{t-k} \\ &+ \sum_{l=0}^{n} \alpha_{4l} \Delta \ln E_{t-1} + u_t \end{aligned} \quad (1)$$

The null hypothesis of no cointegration is H0: $\beta_{CO_2} = \beta_{GDP} = \beta_{GDP2} = \beta_E = 0$, while the alternative hypothesis is that at least one $\beta_k$ is zero, i.e., $H_1$: $\beta_k \neq 0$ for some *k*. Based on this, one can construct an F-statistic and continue to the next step, which consists in comparing the calculated F-statistic with the upper and lower critical bound values from Pesaran et al. (2001). However, we have decided to use critical values reported by Narayan (2005) because these critical values are more appropriated for small samples. If the calculated F-statistic is above the upper critical bound then there exists evidence of a cointegration relationship among variables. If the calculated F-statistic is under the lower critical bound, we cannot reject the null hypothesis of no cointegration. Finally, the results are inconclusive if the F-statistic lies between the two critical bound values. If there exists evidence of cointegration, the equation (1) has an error correction representation which captures the short-run dynamics of the variables, and it can be expressed as:

$$\Delta \ln CO_{2t} = \delta_0 + \sum_{i=1}^{p}\delta_{1i}\Delta \ln CO_{2t-i} + \sum_{j=0}^{q}\delta_{2j}\Delta \ln GDP_{t-j} + \sum_{k=0}^{m}\delta_{3k}\Delta \ln GDP^2_{t-k} + \sum_{l=0}^{n}\delta_{4l}\Delta \ln E_{t-1} + \theta ECT_{t-1} + \varepsilon_t \quad (2)$$

where $ECT_{t-1}$ is the lagged error correction term which is calculated as the residuals of the long-run regression (equation 3).

$$\ln CO_{2t} = \pi_0 + \pi_{GDP} \ln GDP_t + \pi_{GDP^2} \ln GDP_t^2 + \pi_E \ln E_t + v_t \quad (3)$$

### 5.2. Causality Analysis

ARDL methodology doesn't determine the direction of causality among the variables. In order to find this, it is necessary to specify a reduced form VAR model and to test the significance of the lagged variables in each equation of the VAR. However this model is misspecified in the presence of cointegrated variables, and the correct one must be a VECM. For this purpose, we test Granger-causality following two step procedure of Engle and Granger (1987). The first step consists of estimating the residuals of the long-run model (equation 3) as a proxy of the error correction term. Finally, the second step is to estimate a VECM as follows:

$$\begin{bmatrix} \Delta \ln CO_{2t} \\ \Delta \ln GDP_t \\ \Delta \ln GDP_t^2 \\ \Delta \ln E_t \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \end{bmatrix} + \begin{bmatrix} \varphi_{11,1} & \varphi_{12,1} & \varphi_{13,1} & \varphi_{14,1} \\ \varphi_{21,1} & \varphi_{22,1} & \varphi_{23,1} & \varphi_{24,1} \\ \varphi_{31,1} & \varphi_{32,1} & \varphi_{33,1} & \varphi_{34,1} \\ \varphi_{41,1} & \varphi_{42,1} & \varphi_{43,1} & \varphi_{44,1} \end{bmatrix} \begin{bmatrix} \Delta \ln CO_{2t-1} \\ \Delta \ln GDP_{t-1} \\ \Delta \ln GDP_{t-1}^2 \\ \Delta \ln E_{t-1} \end{bmatrix} + \begin{bmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \\ \omega_4 \end{bmatrix} ECT_{t-1} + \begin{bmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \\ e_{4t} \end{bmatrix}$$

Where the vector of $e_t$'s is white noise, and ECT is the error correction term. The $\omega_k$ have the interpretation of speed of adjustment parameters and represents the response of the dependent variable to deviations from the long-run equilibrium.

VECM allows to test two forms of causality: Short-run and long-run causal relationships. If the lagged differenced explanatory variables are significant, we can say there exists a short-run granger-causal relationship, whereas if the lagged error correction term is significant, then there exists long-run granger-causal relationship (Masih and Masih, 1996).

## 6. EMPIRICAL RESULTS

One assumption in ARDL methodology is that all variables are at most I (1). For this reason, it is necessary to test that all variables are I (0) or I (1). We apply Augmented Dickey-Fuller and Phillips-Perron tests to prove that the variables are at most integrated of order one. Results in Table 1 suggest that all variables in levels have unit roots but are stationary after differencing once, i.e., I (1).

ARDL bounds testing results are sensible to the choice of lag order. The maximum lags are selected based on the Schwarz Bayesian Criterion. This criterion is preferred over Akaike Information Criterion due to the small sample used in this study. The estimated parameters for the selected model are reported in Table 2. The model doesn't present evidence of a serial correlation and heteroskedasticity, moreover stability tests have been employed to investigate the parameter stability. Figures 2 and 3, show the

**Figure 2:** Plot of cumulative sum of recursive residuals

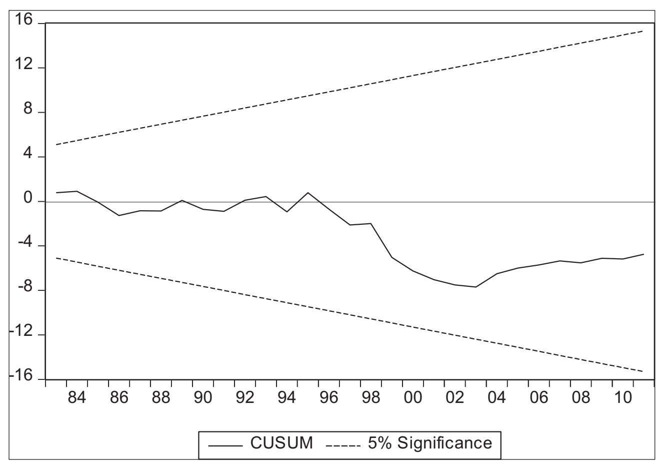



**Figure 3:** Plot of cumulative sum of squares of recursive residuals

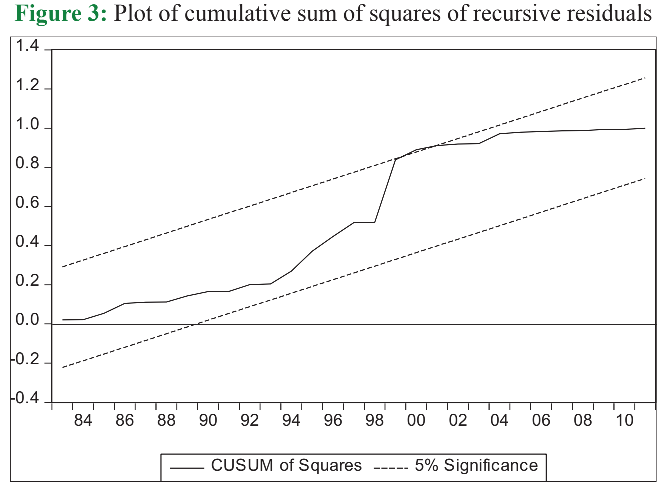


**Table 1: Unit root tests**

| Variable | T statistic | P value | | T statistic | P value |
|---|---|---|---|---|---|
| ADF test at level with intercept and trend | | | PP test at level with intercept and trend | | |
| $\ln CO_{2t}$ | −2.958026 | 0.1563 | | −2.842943 | 0.1913 |
| $\ln E_t$ | −2.543168 | 0.307 | | −2.543168 | 0.307 |
| ln GDP | −3.013651 | 0.1413 | | −2.995442 | 0.1461 |
| $\ln GDP_t^2$ | −2.877525 | 0.1802 | | −2.897559 | 0.174 |
| ADF test at first difference with intercept and trend | | | PP test at first difference with intercept and trend | | |
| $\ln CO_{2t}$ | −7.412382 | 0 | | −8.603 | 0 |
| $\ln E_t$ | −6.408043 | 0 | | −6.409695 | 0 |
| $\ln GDP_t$ | −4.039051 | 0.0154 | | −4.11182 | 0.0128 |
| $\ln GDP_t^2$ | −4.070355 | 0.0142 | | −4.144558 | 0.0118 |

**Table 2: Cointegration tests result**

| Bounds testing to cointegration | |
|---|---|
| Optimal lag structure | (1, 0, 0, 0) |
| F-statistics | 4.721064** |
| Diagnostic check | |
| R | 0.450509 |
| Adjusted-$R^2$ | 0.303978 |
| F-statistics (P) | 3.074499 |
| J-B Normality test 0.5802 | 2.7557 |
| Breusch-Godfrey LM test [2] | 0.853744 |
| ARCH LM test [2] | 1.266228 |
| Ramsey reset | 0.000087 |
| CUSUM | Stable |
| CUSUMSQ | Stable |

**Significant at 5% level. The optimal lag structure is determined by Bayesian information criterion, CUSUM: Cumulative sum of recursive residuals

plots of cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of recursive residuals (CUSUMSQ).

The calculated F-statistic is larger than the upper bound critical value reported by Narayan (2005) at 5% of significance, suggesting the existence of a long-run relationship among the variables. The estimated long-run coefficients (Table 3) are statistically significant at 5% and have the expected sign. However, Lagrange-multiplier test suggests that there exist a serial correlation. For this reason standard errors have been estimated using a robust method proposed by Newey and West (1987). This ensures the consistence of the estimated standard errors in the presence of both autocorrelation and heteroskedasticity. This new standard errors indicate that all coefficients are significant at 1%. The estimated long-run elasticities reveal the existence of an EKC in Ecuador: $CO_2$ emissions rise when income increases, until a turning point and then decrease as income increases. The long-run elasticity between $CO_2$ emissions and energy consumption is 1.11. This means that a 1% rise in energy consumption rises $CO_2$ emissions by 1.11%.

The short-run estimates are shown in Table 4. Only the error correction term is significant at 1%, confirming the existence of the cointegrating equation. The estimated coefficient of the lagged error correction term is about –0.6 and has the expected sign and magnitude. This indicates that deviations from the long-run equilibrium among the variables are corrected by 60% within the year.

**Table 3: Long run estimates**

| Dependent variable | $\ln CO_{2t}$ | |
|---|---|---|
| Variable | Coefficient | T-statistic |
| $\ln GDP_t$ | 35.86371* | 3.122468 |
| $\ln GDP_t^2$ | −2.271069* | −3.073759 |
| ln Et | 1.110552* | 2.801292 |
| Constant | −148.1916* | −3.319002 |
| Diagnostic checks | | |
| $R^2$ | 0.7719 | |
| Adjusted-$R^2$ | 0.7535 | |
| F-statistics | 41.7463* | |
| Durbin-Watson | 1.2287 | |
| Serial correlation LM | 3.0817*** | |
| ARCH LM test | 3.2903 | |
| Normality test | 0.5537 | |
| Ramsey reset test | 0.574 | |

*,*** 1%, 10% level of significance

**Table 4: Short run estimates**

| Dependent variable | $\Delta\ln CO_{2t}$ | |
|---|---|---|
| Variable | Coefficient | T-statistic |
| $\Delta\ln CO_{2t-1}$ | −0.055694 | −0.395133 |
| $\Delta\ln GDP_t$ | 35.50953 | 1.198225 |
| $\Delta\ln GDP_t^2$ | −2.257189 | −1.188558 |
| $\Delta\ln E_t$ | −0.139492 | −0.33621 |
| Constant | 0.032439 | 1.222127 |
| $ECT_{t-1}$ | −0.686341* | −4.555161 |
| Diagnostic checks | | |
| $R^2$ | 0.450272 | |
| Adjusted-$R^2$ | 0.36698 | |
| F-statistics | 5.405939* | |
| Durbin-Watson | 1.95557 | |
| Serial correlation LM | 0.844776 | |
| ARCH LM test | 0.919876 | |
| Normality test | 2.937 | |
| Ramsey reset test | 0.00402 | |

*1% level of significance

Table 5 shows the results of granger-causality tests. GDP does not Granger cause $CO_2$ emissions in the short term. However,

**Table 5: Granger causality test results**

| Null hypothesis | Chi-square statistic | P value |
|---|---|---|
| $GDP_t$ does not granger cause $CO_{2t}$ | 0.342847 | 0.8425 |
| $CO_{2t}$ does not granger cause $GDP_t$ | 0.330636 | 0.5653 |
| $GDP_t$ does not granger cause $E_t$ | 8.568509 | 0.0138 |
| $E_t$ does not granger cause $GDP_t$ | 0.300504 | 0.5836 |
| $CO_{2t}$ does not granger cause $E_t$ | 1.316162 | 0.2513 |
| $E_t$ does not granger cause $CO_{2t}$ | 0.342133 | 0.5586 |
| $ECT_{t-1}$ does not granger cause $CO_{2t}$ | 9.982813 | 0.0016 |

Note: In order to prove that $GDP_t$ does not granger cause any variable, we test the null that $\ln GDP_t$ and $\ln GDP_t^2$ does not granger cause such variable

there exists a long-run causal relationship from GDP and energy consumption to $CO_2$ emissions. Furthermore there exists a causal relationship from GDP to energy consumption in the short term.

## 7. DISCUSSION AND POLICY IMPLICATION

In Ecuador environmental studies are scarce. For this reason the present paper addresses the theory of EKC applied to this country. $CO_2$ emissions is used as the dependent variable, and GDP, $GDP^2$ and use of primary energy as explanatory variables. The ARDL bounds testing approach to cointegration is applied to test the long run relationship and VECM to detect the direction of causality among the variables.

The presence of an EKC in the long term is evident, but not in the short term. This means that Ecuador is still in the rising part of the curve, so that environmental policies should be implemented effectively. On this, the Ministry of Environment has been working with the national government for the creation of environmental policies designed to achieve sustainable development. One of them is the change of the productive matrix.

The change of the productive matrix involves moving from a pattern of extractive-primary export-specialization, to the one that privileges diversified, eco-efficient and higher value-added production and services based on the knowledge economy and biodiversity. This change will not only generate wealth based on the exploitation of natural resources, but in using the skills and knowledge of the population.

On the other hand, changing the productive matrix is based on the change in the energy matrix. The change of the energy matrix consists in increasing in an optimal and sustainable manner, primary energy sources and at the same time changing consumption patterns in the transport sector, residential, commercial, for rational efficient use. In this regard Ecuador is currently developing eight hydroelectric projects to increase national capacity to 7.873 MW installed. The aim is that by 2016 the State participation would be 90% in the renewable electricity generation matrix. This percentage should be increased up to 100% (National Secretary of Planning and Development, 2015). Furthermore, it would promote the generation of institutional frameworks that encourage non-conventional energy sources such as wind, solar, geothermal and biofuels.

Finally, the use of energy as a determinant of $CO_2$ emissions is significant in the long run. This implies that the hydrocarbons sector must be exploited efficiently and effectively, as their over-exploitation could cause severe environmental pollution problems in Ecuador and thereby compromise the concept of sustainable development.

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