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Economic Growth, CO_2 Emissions and Electric Consumption: Is there an Environmental Kuznets Curve? An Empirical Study for North America Countries

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ABSTRACT

The goal of this paper is validity the environmental Kuznets curve hypothesis for North America countries (Canada, United States and Mexico) over the annual period 1980-2008. Pedroni cointegration tests are applied for testing long-run relationship between the variables. Using the panel fully modified ordinary least squares (OLSs) and the panel dynamic OLSs determinate the elasticities of the long-run relationships. The results show that there is an inverted U-shape relationship. Finally, in the long-run, the results of the causality test show that there is a unidirectional causal flow from energy consumption, electricity consumption and economic growth to CO_2 emissions in North America.

Keywords: Environmental Kuznets Curve, Carbon Dioxide Emissions, Economic Growth.
JEL Classifications: C33, Q4, Q43, Q56

1. INTRODUCTION

Environmental degradation has become important in recent years. Starting for the contribution of Kuznets (1955) and following with the framework of the environmental Kuznets curve (EKC); there are many contributions trying to prove the relationship between economic growth as a source of environmental degradation Shafik (1994), Grossman and Krueger (1994), Kijima et al. (2010), Zambrano-Monserrate et al. (2016). However, there have been other contributions that consider additional aspects like globalization, education and inequality, electricity consumption, energy consumption, human capital, technology advancement, industry structure and poverty Tisdell (2001), Hill and Magnani (2002), Ang (2007), Lean and Smyth (2010), Jun et al., (2011), Ozturk and Al-Mulali (2015).

Considering the countries used in this paper; in the case of United States, Carley (2001) made a historical revision taking account the importance of the U.S. electricity sector; however, Payne (2009) found no relationship between energy consumption and output but Plassmann and Khanna (2006) proved the EKC hypothesis between household income and exposure to pollution. Narayan and Narayan (2010) considered a Mexico in his study of carbon dioxide emissions and economic grown for some developing countries. Hamit-Hagar (2012) investigated the long-run and the causal relationship between gas emissions, energy consumption and economic growth for Canadian industrial sector over the period 1990-2007.

This paper contributes the existent literature to consider the relationship between economic growth, energy consumption and electric consumption (ELC) for a panel of North America countries and try to prove the EKC hypothesis. In this area, Lean and Smyth (2010) proved the causal relationship between carbon dioxide emission, electricity consumption and economic growth within a panel error correction model for five ASEAN[1] countries consistent with the EKC. However, there was other contributions, Chandran et al. (2010) who got results with the autoregressive distributed lags (ARDLs) estimates of long-run elasticity of electricity consumption on gross domestic product (GDP). Tang (2008) found

1 Association of South East Asian Nations (ASEAN).

bidirectional causality between GDP and electricity consumption in Malaysia over the period 1972-2003 and in the case of Ghosh (2009) using an ARDL bounds testing approach found a short-run causality between GDP and electricity. The model is estimated using panel data methods in order to control the collinearity and heterogeneity among the variables Baltagi (2005).

This study used to check the presence of long-run relationships the cointegration test suggested by Pedroni (1999), Pedroni (2001a), Pedroni (2001b), Pedroni (2004). Per capita GDP, electricity consumption are the explanatory variables and CO_2 emissions is the dependent variable. The models were estimated based on two techniques namely panel fully modified ordinary least squares (FMOLS, suggested by Phillips and Hansen [1990]) and dynamic OLSs (DOLS suggested by Saikkonen [1991] and Stock and Watson [1993]). Finally, to verify the direction of causality among the variables we use the Granger causality test based on the vector error correction model (VECM).

The other sections of the paper are organized in the following way. In Section 2, we present the data. The econometrical methodology is described in Section 3. Section 4 reports the empirical results and, finally, the conclusions are provided in Section 5.

2. DATA

The data set is a balanced panel of North America countries over the annual period 1980-2008. The selected countries are Canada, United States and Mexico. The variables used are: CO_2 emissions (CO_2) measured in metric tons per capita; income (GDP) using per capita real GDP in constant 2010 US$; and ELC is expressed in terms of billion kWh. These variables are obtained from World Bank Development Indicators (World Development Indicators, 2015).

3. ECONOMETRICAL METHODOLOGY

An empirical methodology is proposed in four stages. The first step consists in use the panel unit root tests; the second step are the panel co-integration tests. The third step develops the long run relationship using panel FMOLS and panel DOLS estimators. Finally, the last step consists to estimate a panel VECM in order to study Granger causality relationships.

The approach consist in shows the long-run relationship between CO_2 emissions (CO_2), income (GDP) and electric power consumption (ELC) and is given by the following equation:

$$lnCO_{2i,t} = \alpha_0 + \alpha_1 lnGDP_{i,t} + \alpha_2 lnGDP_{i,t}^2 + \alpha_3 lnELC_{i,t} + u_{i,t} \quad (1)$$

3.1. Panel Unit Root Tests Analysis

In the present study, in order to assess the stationary of the variables three types of panel unit root test are used: Breitung (2001); Levin et al. (2002) and Im et al. (2003). This structure is employed following Farhani et al. (2014) who show that there is an inverted U-shape relationship between environmental degradation and income and used this analysis to assess the stationary of the variables.

Breitung (2001) assumes that the null hypothesis is given by $H_0 : \sum_{j=1}^{k+1} \beta_{i,j} - 1 = 0$, and the alternative hypothesis is given by $H_1 : \sum_{j=1}^{k+1} \beta_{i,j} - 1 < 0$, considered the equation $W_{i,t} = \alpha_{i,t} + \sum_{j=1}^{k+1} \beta_{i,j} \Delta X_{i,t-j} + \varepsilon_k$ and assumed that $W_{i,t}$ is stationary. Also uses the transformed vectors $W_i^* = AW_i = \left[W_{i1}^*, W_{i2}^*, \ldots, W_{iT}^*\right]'$ and $X_i^* = AX_i = \left[X_{i1}^*, X_{i2}^*, \ldots, X_{iT}^*\right]'$ for construct the next test statistic:

$$\lambda = \frac{\frac{1}{\sigma_i^2} \sum_{i=1}^{N} W_i^{*}{}' x_i^{*}{}'}{\sqrt{\frac{1}{\sigma_i^2} \sum_{i=1}^{N} x_i^{*}{}' A' x_i^{*}}} \quad (2)$$

Levin et al. (2002) considered the next equation:

$$\Delta X_{i,t} = \alpha_i + \beta_i X_{i,t-1} + \delta_i t + \sum_{j=1}^{k} \gamma_{i,j} \Delta X_{i,t-j} + \nu_{i,t} \quad (3)$$

because proposed a panel unit root based on augmented Dickey–Fuller (ADF) test. Also assumed for all panel units, cross-sectional independence and that there is homogeneity in the dynamics of the autoregressive coefficients. In the equation 3, Δ is the first difference operator, $X_{i,t}$ is the dependent variable, $\nu_{i,t}$ is a white – noise disturbance with a variance of σ^2, $i = 1,2,\ldots N$ depending of the number of countries and $t = 1,2,\ldots,T$ considering the time.(Levin, et al., 2002) Assumed that the null hypothesis is given by H_0: $\beta_i = 0$, and the alternative hypothesis is given by H_1: $\beta_i < 0$ where the statistic of test is $t_\beta = \hat{\beta} / \sigma(\hat{\beta})$, $\hat{\beta}$ is the OLS estimate of β in the equation 3 and $\sigma(\hat{\beta})$ is the standard error.

Considering the average of the $t_{\beta i}$ statistics of the Equation 3, proposed a test based on the mean group approach. Using the next $\bar{Z}$ statistic: $\bar{Z} = \sqrt{N}\left[\bar{t} - E(\bar{t})\right] / \sqrt{V(\bar{t})}$ (4), where, $\bar{t} = (1/N) \sum_{i=1}^{N} t_{\beta i}$, $E(\bar{t})$ is the mean of $t_{\beta i}$ statistics and $V(\bar{t})$ is the variance generated by simulations. Finally, $\bar{Z}$ converges to a standard normal distribution and $\bar{t} = (1/N) \sum_{i=1}^{N} t_{\beta i}$ taking account the test is based on the average of the individual unit root test.

3.2. Panel Cointegration Tests Analysis

To examine the long-run relationship between the variables included in this paper, we use the Pedroni (1999), Pedroni (2001a), Pedroni (2001b), Pedroni (2004) panel cointegration test who based on residuals of the Engle and Granger (1987) developed a number of statistics assuming a panel of N countries, T observations, m regressors (X_m) considering the next equation:

$$W_{i,t} = \propto_i + \lambda_i t + \sum_{j=1}^{m} \beta_{j.i} X_{j.i.t} + \zeta_{i,t} \quad (5)$$

Where, $W_{i,t}$ and $X_{j.i.t}$ are integrated of the order one.

Several studies used this approach in the panel cointegration tests analysis Al-Mulali and Ozturk (2015), Al-Mulali et al. (2015a), Al-Mulali et al. (2015b), Hamit-Haggar (2012). Following the recommendations of Pedroni (1999), Pedroni (2001a), Pedroni (2001b), Pedroni (2004) there are two parts of panel cointegration test (Table 1). The parts of the panel cointegration tests contains a panel cointegration tests based on the within dimension approach and a group mean panel cointegration tests based on the between dimension approach.

Following Farhani and Ben Rejeb (2012), the within dimension approach includes four statistics: Panel v-statistic, panel ρ-statistic, panel non-parametric (Phillips–Perron [PP]) t-statistic, and panel parametric (ADF) t-statistic. These four statistics take into account common tune factors and heterogeneity across countries. The between dimension approach includes three statistics: Group ρ-statistic, group non-parametric (PP) t-statistic, and panel parametric (ADF) t-statistic. These three statistics are based on the residuals for each country and the averages of the individual autoregressive coefficients.

The null hypothesis is given by H_0: $\rho_i = 0$, and the alternative hypothesis is given by H_1: $\rho_i < 0$ for all seven tests, where ρ_i is the autoregressive term of the estimated residuals, taking into account the next equation:

$$\hat{\zeta}_{i,t} = \rho_i \hat{\zeta}_{i,t-1} + u_{i,t} \tag{6}$$

According to Pedroni (1999), all seven panel cointegration tests have a standard asymptotic distribution considering,

$$\left.\frac{Z - \mu\sqrt{N}}{\sqrt{v}}\right|_{N,T\to\infty} \to N(0,1) \tag{7}$$

Where, Z is one of the seven normalized statistics, and μ and ν are calculated in Pedroni (1999) when N, $T \to \infty$ based in the independent movements in Brownian motions.

3.3. Panel FMOLS and DOLS Estimates

There are many types of problems given the presence of heterogeneity in the time series analysis and in the panel data analysis Kao and Chiang (2001). Takin account the nuisance parameters associated with the presence of serial correlation in the data, we can't use the OLS estimators because their distribution is asymptotically biased Pedroni (2001a), Pedroni (2001b).

Various techniques exist for an effective estimation, in this paper we use the FMOLS estimator suggested by Phillips and Hansen (1990) and DOLS estimator of Saikkonen (1991), Stock and Watson (1993) because these techniques led to normally distributed estimators. According to Phillips and Moon (1999) and Pedroni (2001a) the FMOLS estimator exhibit small sample bias and DOLS estimator outperform it.

According to FMOLS approach, Pedroni (2001a) Pedroni (2001b) considered the following equation to solve the problem of endogeneity between regressors:

$$W_{i,t} = \propto_i + \beta_i X_{i,t} + \sum_{k=-K_i}^{K_i} \lambda_{i,k} X_{i.t-k} + \tau_{i,t} \tag{8}$$

The FMOLS estimator will be given by,

$$\widehat{\beta^*_{FMOLS}} = \frac{1}{N}\sum_{i=1}^{N}\left[\begin{array}{c}\left(\sum_{t=1}^{T}\left(X_{i,t}-\overline{X}_i\right)^2\right)^{-1} \\ \left(\sum_{t=1}^{T}\left(X_{i,t}-\overline{X}_i\right)W^*_{i,t} - T\hat{\gamma}_i\right)\end{array}\right] \tag{9}$$

Where, $W^*_{i,t} = W_{i,t} - \overline{W}_i - \left(\hat{\Omega}_{2,1,i} / \hat{\Omega}_{2,2,i}\right)\Delta X_{i,t}$ and $\hat{\gamma}_i = \hat{\Gamma}_{2,1,i} + \hat{\Omega}^0_{2,1,i} - \left(\frac{\hat{\Omega}_{2,1,i}}{\hat{\Omega}_{2,2,i}}\right)\left(\frac{\hat{\Gamma}_{2,2,i}}{\hat{\Omega}^0_{2,2,i}}\right)$.

For the case of panel data analysis, according to(Kao & Chiang, 2001) and the panel DOLS estimator can be defined as:

$$\beta^*_{DOLS} = \frac{1}{N}\sum_{i=1}^{N}\left[\left(\sum_{t=1}^{T} Z_{i,t}Z_{i,t}'\right)^{-1}\left(\sum_{t=1}^{T} Z_{i,t}\tilde{w}_{i,t}\right)\right] \tag{10}$$

Where, $Z_{i,t} = \left[X_{i,t} - \hat{X}_i, \Delta X_{i,t-k_i,\ldots,} X_{i,t+K_i}\right]$ is vector of regressors, and $\tilde{w}_{i,t} = W_{i,t} - \overline{W}_i$.

3.4. Panel Granger Causality Test

To perform Granger-causality test a panel VECM has to be estimated Pesaran et al. (1999). To investigate the short-and long-run dynamic relationships this panel employed the two steps of Engle and Granger (1987). First, it should be estimated the long-run parameters presented in the Equation 1 in order to obtain the residuals corresponding to the deviation from equilibrium, then it should be estimated the parameters to the short-run adjustment. This is the equation used in the panel Granger causality testing:

$$\begin{pmatrix}\Delta\ln CO_{2i,t}\\ \Delta\ln GDP_{i,t}\\ \Delta\ln GDP^2_{i,t}\\ \Delta\ln ELC_{i,t}\end{pmatrix} = \begin{pmatrix}\varnothing_{i,1}\\ \varnothing_{i,2}\\ \varnothing_{i,3}\\ \varnothing_{i,4}\end{pmatrix} + \sum_{l=1}^{m}\begin{pmatrix}\theta_{1,1,k} & \theta_{1,2,k} & \theta_{1,3,k} & \theta_{1,4,k}\\ \theta_{2,1,k} & \theta_{2,2,k} & \theta_{2,3,k} & \theta_{2,4,k}\\ \theta_{3,1,k} & \theta_{3,2,k} & \theta_{3,3,k} & \theta_{3,4,k}\\ \theta_{4,1,k} & \theta_{4,2,k} & \theta_{4,3,k} & \theta_{4,4,k}\end{pmatrix}$$

$$\begin{pmatrix}\Delta\ln CO_{2i,t-k}\\ \Delta\ln GDP_{i,t-k}\\ \Delta\ln GDP^2_{i,t-k}\\ \Delta\ln ELC_{i,t-k}\end{pmatrix} + \begin{pmatrix}\gamma_1\\ \gamma_2\\ \gamma_3\\ \gamma_4\end{pmatrix} ECT_{i,t-1} + \begin{pmatrix}\omega_{1,i,t}\\ \omega_{2,i,t}\\ \omega_{3,i,t}\\ \omega_{4,i,t}\end{pmatrix} \tag{11}$$

The term Δ denotes first differences; $\varnothing_{i,j}$ (j = 1, 2, 3, 4) present the fixed country effect; l (l = 1,…,m) is the optimal lag length determined by the Schwarz Information Criterion, and $ECT_{i,t-1}$ is the estimated lagged error correction term (ECT) derived from the long-run cointegrating relationship. The term γ_j is the adjustment coefficient; and $\omega_{j,i,t}$ is the disturbance term, which assumed to be uncorrelated with zero means. To estimate the parameters related to the short-run model, it should be used the definite lagged residuals estimated in Equation 1. The lagged residuals estimated are defined in the next model as ECT:

Table 1: Pedroni (1999; 2004) panel cointegration statistics and results

I. Within-dimension (four statistics)	Between-dimension (three statistics)
Panel v-statistic	
$Z_v = \left(\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{1,1i}^{-2}\hat{\zeta}_{i,t-1}^{2}\right)^{-1}$	
Panel ρ-statistic	Group ρ-statistic
$Z_\rho = \left(\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{1,1i}^{-2}\hat{\zeta}_{i,t-1}^{2}\right)^{-1}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{1,1i}\left(\hat{\zeta}_{i,t-1}\Delta\hat{\zeta}_{i,t}-\hat{\lambda}_i\right)$	$\tilde{Z}_\rho = \sum_{i=1}^{N}\left(\sum_{t=1}^{T}\hat{\zeta}_{i,t-1}^{2}\right)^{-1}\sum_{t=1}^{T}\left(\hat{\zeta}_{i.t-1}\Delta\hat{\zeta}_{i.t}-\hat{\lambda}_i\right)$
Panel non-parametric (PP) t-statistic	Group non-parametric (PP) t-statistic
$Z_{PP} = \left(\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{1,1i}^{-2}\hat{\zeta}_{i,t-1}^{2}\right)^{-1/2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{1,1i}^{-2}\left(\hat{\zeta}_{i,t-1}\Delta\hat{\zeta}_{i,t}-\hat{\lambda}_i\right)$	$\tilde{z}_{pp} = \sum_{i=1}^{N}\left(\hat{\alpha}^2\sum_{t=1}^{T}\hat{\zeta}_{i,t-1}^{2}\right)^{-1/2}\sum_{t=1}^{T}\left(\hat{\zeta}_{i,t-1}\Delta\hat{\zeta}_{i,t}-\hat{\lambda}_i\right)$
Panel parametric (ADF) t-statistic	Panel parametric (ADF) t-statistic
$Z_{ADF} = \left(\hat{S}^{*2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{1,1i}^{-2}\hat{\zeta}_{i,t-1}^{*2}\right)^{-1/2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{1,1i}^{-2}\hat{\zeta}_{i,t-1}^{*}\Delta\hat{\zeta}_{i,t}^{*}$	$\tilde{Z}_{ADF} = \sum_{i=1}^{N}\left(\sum_{t=1}^{T}\hat{S}_i^{-2}\hat{\zeta}_{i,t-1}^{*2}\right)^{-1/2}\sum_{t}^{T}=1\hat{\zeta}_{i,t}^{*}-1\Delta\hat{\zeta}_{i,t}^{*}$

Where (i) $\hat{\lambda}_i = \frac{1}{T}\sum_{s=1}^{K}\left[1-\frac{s}{K_i+1}\right]\sum_{t=s+1}^{T}\hat{u}_{i,t}\hat{u}_{i,t-s}$ for $\hat{u}_{i,t} = \hat{\zeta}_{i,t}-\hat{\rho}_i\hat{\zeta}_{i,t-1}$

(ii) $\hat{L}_{1,1i}^{-2} = \frac{1}{T}\sum_{t=1}^{K}\hat{\eta}_{i,t}^{2}+\frac{2}{T}\sum_{s=1}^{K}\left[1-\frac{s}{K_i+1}\right]\sum_{t=s+1}^{T}\hat{\eta}_{i,t}\hat{\eta}_{i,t-s}$ for $\hat{u}_{i,t} = \Delta Y_{it}-\sum_{m=1}^{M}\hat{b}_{m,i}\Delta X_{m,it}$

(iii) $\hat{\sigma}^2 = \frac{1}{N}\sum_{i=1}^{N}\hat{L}_{1,1i}^{-2}\hat{\sigma}_i^2 = \hat{S}_i^2+2\hat{\lambda}_i$ and

(iv) $\hat{S}_i^2 = \frac{1}{T}\sum_{t=1}^{T}\hat{u}_{i,t}^2;\hat{S}_i^{*2} = \sum_{t}^{T}\hat{u}_{i,t}^{*2}$ for $\hat{u}_{i,t}^{*} = \hat{\zeta}_{i,t}-\hat{\rho}_i\hat{\zeta}_{i,t-1}-\sum_{k=1}^{k_i}\hat{\rho}_{i,k}\Delta\hat{\zeta}_{i,t-k*}$

II. Panel EKC		
Within-dimension	**Test statistic**	**P**
Panel v-statistic	3.727464*	(0.0001)
Panel δ-statistic	-2.839162*	(0.0023)
Panel PP-statistic	-4.544721*	(0.0000)
Panel ADF-statistic	-4.923718*	(0.0000)
Between-dimension		
Group δ-statistic	-1.906442**	(0.0283)
Group PP-statistic	-4.265491*	(0.0000)
Group ADF-statistic	-4.383029*	(0.0000)

The null hypothesis of Pedroni test examines the absence of cointegration. Lag selection (automatics) is based on SIC with a max lag of 5. *Statistical significance at the 1%. **Statistical significance at the 5%. Structure according to Farhani et al. (2014). SIC: SIC: Schwarz Information Criteria, ADF: Augmented Dickey–Fuller, PP: Phillips–Perron, EKC: Environmental Kuznets curve

$$ECT_{i,t} = \Delta\ln CO_{2i,t}-\hat{\alpha}_{1.i}lnGDP_{i,t}-\hat{\alpha}_{2.i}lnGDP_{i,t}^2-\hat{\alpha}_{3.i}lnELC_{i,t}$$

4. EMPIRICAL RESULTS

Table 2 shows results of Breitung (2001), Levin et al. (2002) and Im et al. (2003) unit root test, at the 1% significance level all variables are integrated of order one, i.e., I(1) as the unit root tests confirm. As all variables are stationary at the first difference, the Pedroni (1999), Pedroni (2001a), Pedroni (2001b), Pedroni (2004) cointegration test could be used.

The Part II of Table 1 shows that all variables are cointegrated, considering that all statistics are significant; and because of that the null hypothesis of no cointegration can be rejected, in that sence, there are long-run equilibrium relationship between all variable in Equation 1.

Tables 3 and 4 show the results of panel FMOLS and DOLS estimates, respectively. All variables are significant at the 1% level of significance and taking account that all a variables are expressed in natural logarithms can be interpreted as long-run elasticities. The results indicate that there are inverse U-shaped relationships between CO_2 emission per capital, percapita real GDP according to the EKC hypothesis.

The coefficients from panel FMOLS estimation are 2.014242, −0.92660 and −0.710409 for $lnGDP$, $lnGDP^2$ and $lnELC$ respectively. This means that a 1% increase in percapita real GDP increases CO_2 emissions per capita by 2.014242%; a 1% increase in GDP^2 decreases CO_2 emissions per capita by 0.92660%; and a 1% increase in electric power consumption decreases CO_2 emissions per capita by 0.710409%. However, the coefficients from panel DOLS estimation are 1.986957, -0.915566 and −0.704678 for $lnGDP$, $lnGDP^2$ and $lnELC$, respectively. This means that a 1% increase in percapita real GDP increases CO_2 emissions per capita by 1.986957%; a 1% increase in GDP^2 decreases CO_2 emissions per capita by 0.915566%; and a 1% increase in electric power consumption decreases CO_2 emissions per capita by 0.704678%.

Table 5 shows the panel short-and long-run Granger causality results following the Equation 5. The long-run causality is captured by a significant t-test on a negative coefficient of the lagged ECT. According to the coefficients on the lagged ECT, there is a long-run relationship among the variable in the Equation 1. Especifically, the finding indicate the there exists a unidirectional Granger causality between CO_2 emissions and GDP consistent to (Jaunky, 2011), whose results shows unidirectional Granger causality in some high-income countries; furthermore, there exists a unidirectional Granger causality between CO_2 emissions and electric power consumption Mark and Sul (2003).

5. CONCLUSIONS

The main goal of this study was prove the EKC hypothesis in North America countries over the annual period 1980-2008. To support that all the panel variables are integrated of order one, i.e., I(1), there different panel unit root test, Breitung (2001), Levin et al. (2002) and Im et al. (2003) were applied. To prove that all panel variables are cointegrated, the Pedroni (1999), Pedroni (2001a), Pedroni (2001b), Pedroni (2004) cointegration test was also applied.

The means of FMOLS and DOLS coefficients are 2.0005995, −0.922613 and −0.7075435 for *lnGDP*, $lnGDP^2$ and *lnELC*, respectively.

Long-run Granger causality results shows that there exists a unidirectional Granger causalitty between CO_2 emissions and GDP and there exists a unidirectional Granger causalitty between CO2 emissions and electric power consumption.

Considering that there is no a previous panel study with the methodology employed in this study, we can argue that the results

Table 2: Panel unit root test results

Test	$lnCO_2$	ΔlnGDP	lnGDP2	lnELC
Breitung				
Level	−1.49657 (0.0673)	0.49895 (0.6911)	0.55536 (0.7107)	0.35133 (0.6373)
Δ	−2.97182* (0.0015)	−2.86238* (0.0021)	−2.78024* (0.0027)	−4.80658* (0.0000)
LLC				
*t**				
Level	−2.52078* (0.0007)	−0.34558 (0.3648)	−0.35397 (0.3617)	1.04932 (0.8530)
Δ	−4.30700* (0.0000)	−4.11732* (0.0000)	−4.00176* (0.0000)	−4.23468* (0.0000)
IPS W-statistics				
Level	−2.43189 *(0.0075)	−1.16770 (0.1215)	−1.22138 (0.1110)	1.79895 (0.9640)
Δ	−3.93262* (0.0000)	−2.91738* (0.0018)	−2.88870* (0.0019)	−4.85153* (0.0000)

Δ is the first difference operator. The null hypothesis of Breitung, LLC and IPS tests examines non-stationary. Lag selection (automatic) is based on SIC. *Statistical significance at the 1% level (P values are presented in parentheses). SIC: Schwarz Information Criteria, LLC: Levin, Lin and Chu, IPS: Im, Pesaran and Shin, GDP: Gross domestic product

Table 3: Panel FMOLS results

Dependent variable: $lnCO_2$			
Variable	Coefficient	Standard error	t-statistics
Constant	−9.934011	9.146503	−1.086099*
lnGDP	2.014242	1.912646	1.053118*
$lnGDP^2$	−0.929660	0.090508	−1.027163*
lnELC	−0.710409	0.132180	−5.374578*

*Statistical significance at the 1%. GDP: Gross domestic product, ELC: Electric consumption, FMOLS: Fully modified ordinary least squares

Table 4: Panel DOLS results

Dependent variable: $lnCO_2$			
Variable	Coefficient	Standard error	t-statistics
Constant	−9.807329	1.038146	−9.446963*
lnGDP	1.986957	2.169264	9.159590*
$lnGDP^2$	−0.915566	0.103224	−8.869661*
lnELC	−0.704678	0.143347	−4.917991*

*Statistical significance at the 1%. GDP: Gross domestic product, DOLS: Dynamic ordinary least squares, ELC: Electric consumption

Table 5: Panel causality test results

Dependent variable	Short run sources of causation (independent variable)				Long run
EKC	$\Delta lnCO_2$	ΔlnGDP	$\Delta lnGDP^2$	ΔlnELC	ECT
$\Delta lnCO_2$	#	1.884692 (0.1397)	1.822704 (0.1505)	0.431185 (0.7313)	−0.130960* [−2.703918]
ΔlnGDP	0.097064 (0.9614)	#	0.700362 (0.5549)	1.534049 (0.2129)	0.055292 [1.649660]
$\Delta lnGDP^2$	0.132682 (0.9403)	0.670790 (0.5727)	#	1.566876 (0.2047)	0.995563 [1.549284]
ΔlnELC	2.707143*** (0.0514)	1.124879 (0.3437)	1.319084 (0.2747)	#	−0.017212 [−0.582356]

Short-run causality is determined by statistical significance of the partial F-statistics associated with the right hand side variables. Long-run causality is revealed by the statistical significance of the respective ECTs using a t-test. P values are listed in parentheses and t-statistics are presented in brackets. *Statistical significance at the 1%, ***Statistical significance at the 10%. GDP: Gross domestic product, DOLS: Dynamic ordinary least squares, ELC: Electric consumption, EKC: Environmental Kuznets curve are consistent with Hamit-Haggar (2012), Plassmann and Khanna (2006), Ghali and El-Sakka (2004), Narayan and Narayan (2010) Ozturk (2015) and Dávalos (2016).

The develop of renewable energy sources and foment of a friendly culture with the environmental could be the way to slow down the environmental degradation by CO_2 emissions. This study is limited considering that is focus in a few variables, future research should focus on the impact of different types of energy and include more independent variables.

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