Modelling of the Validity of Kuznets Curve of Energy Consumption in BRICS countries

نمذجة صلاحية منحنى Kuznets لاستهلاك الطاقة في دول البريكس

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Abstract: This study is to test experimentally the Kuznets curve of energy Consumption in BRICS countries during 1990-2018.The Panel Auto Regressive Distributed Lag (ARDL) method and Kao co-integration analysis methodology was used to test for cointegration in the long run. According to the results show do not support the EKC hypothesis stipulating an inverted U-shaped curb of per capita emissions as a function of per capita GDP in BRICS countries.. Additionally, development of renewable energy really limits CO2 emissions and boosts economic growth in BRICS countries. It is therefore recommended that the policymakers are required to focus on the green energy generation sector by increasing renewable energy production from the existing sources.

Keys words: **Energy Consumption, Economic growth, CO2 emissions, Panel-ARDL, BRICS countries**

JEL classification codes: **C19,Q19,O49**

ملخص: تهدف هذه الدراسة إلى اختبار منحنى Kuznets لاستهلاك الطاقة في دول البريكس خلال الفترة 1990 – 2018. تم استخدام طريقة لوحة الانحدار التلقائي الموزعة (ARDL) ومنهجية تحليل التكامل المشترك Kao لاختبار التداخل المشترك على المدى الطويل. وفقًا للنتائج، لا تدعم فرضية EKC التي تنص على كبح مقلوب على شكل حرف U لانبعاثات الفرد كدالة للناتج المحلي الإجمالي للفرد في دول البريكس بالإضافة إلى ذلك ، فإن تطوير الطاقة المتجددة يحد فعليًا من انبعاثات ثاني أكسيد الكربون ويعزز النمو الاقتصادي في البريكس بلدان. لذلك يوصى بأن يركز صانعو السياسات على قطاع توليد الطاقة الخضراء من خلال زيادة إنتاج الطاقة المتجددة من المصادر الحالية.

الكلمات المفتاحية: استهلاك الطاقة، النمو الاقتصادي، انبعاثات ثاني أكسيد الكربون، لوحة ARDL ، دول البريكس

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1-Introduction

Since the 1980s, the focus of scientific and technical discussion has been placed on the environment and its deterioration, which is a direct consequence of climate change and especially global warming,and greenhouse gas (GHG) emissions, mainly containing carbon dioxide (CO_2), represent the principal cause of climate change. and the relationship between environmental degradation and economic growth is one of the most important areas in the literature of ecological economics, both theoretically and empirically, and Environmental Kuznets curve (EKC) become an independent research issue and motivated a bulky number of studies ; (Kuznets, 1995), (Grossman & Krueger, 1991), (Shafik, 1994). EKC claims an inverted U-shaped relationship between income and CO_2; at early stage of development, environmental degradation occurs, but at certain point the increase in economic development will decrease CO_2 emission. but and there economic factors that drive changes in environmental impacts and may be responsible for rising or declining environmental degradation over the course of economic development If there were no change in the structure or technology of the economy.

The BRICS , founded in 2006, is designed to create a economic agreement between Brazil, Russia, India, China and South Africa. Those five member states in BRICS have experienced rapid increases in income, energy consumption, and trade since the establishment. Over the period 2006-2018, real GDP in BRICS countries grew at a fast compounded average annual rate of 3.3 percen. Meanwhile The value of both per capita income and per capita CO_2 are higher than the value of most countries in the world. A 2014 report estimates the economic impact of air pollution across the world's most economically developed nations, including china and India, at $3.5 trillion. The economic growth of the BRICS countries is constantly increasing as they moved to be the industrialized ones. As a result, the need of energy is also increasing in order to accommodate the demand of many sectors such as industry, transportation, economy, and others.

Also, the BRICS (Brazil, Russia, India, China, and South Africa) countries emitted more than 40% of global total CO_2 emissions in 2013. their non-renewable energy consumption also accounts for more than 35% of worldwide total .Having such higher indicators lead us to question the validity of EKC between the development and environmental degradation of the brics countries. In order to coordinate the tasks of global emission reduction to combat global warming, BRICS countries have enacted different emissions plans. Based on the above, the following problem can be raised: Is the environmental Kuznets curve (EKC) hypothesis valid in BRICS? and Is the development of renewable energy really limits CO2 emissions and boosts economic growth in BRICS?

To answer the main question, we ask the following sub-questions:

- What is the impact of the increasing Energy demand on the environmental quality in the BRICS countries?
- What is the role of the renewable Energy consumption in reducing carbon emissions in BRICS countries?
- What is the impact of the renewable energy and non-renewable on the CO2 emissions in BRICS?

1.1. The hypotheses of the study:

There are different relationships of strength and direction and significant significance between CO2 emission and the variables explained and influential.

1. 2. The approach and objectives of the study:

This study followed a quantitative approach to test the existence of effects of renewable and non-renewable energy production and energy consumption on CO2 emissions in BRICS countries during the period 1990-2018 by using the Panel Auto Regressive Distributed Lag (ARDL) method, for co- integration in order to test the long run relationship between the variables subject of study.

The rest of the paper is organized as follows. Section 2 provides a brief review of the literature. Section 3 explains the model specification, data and methodology. Section 4 discusses the empirical results. Section 5 concludes the paper.

2- Literature review

Many empirical studies have examined whether or not there exists a mutual relationship between CO2 emissions, economic growth, renewable and non-renewable energy consumption. Some empirical studies found a direct relationship that comes from renewable and non-renewable energy to stimulate the CO2 émissions of a country. Other studies viewed the relationship between these variables from another aspect; particularly that economic growth, renewable and non-renewable energy induces CO2 émissions growth. However, still other studies found inconclusive results about this relationship. This difference in results is due to different economic conditions of different countries in addition to the studied period and the used variables.

- ✓ (Tugcu & al, 2012)estimated a long run and causal relationship between renewable and non-renewable energy consumption and economic growth in G7 countries Using 1980-2009 time series period, by Using

Autoregressive Distributed Lag approach to co-integration and causal relationships between the variables. The empirical results show that non renewable energy consumption increases co2 emissions, where as renewable energy consumption decreases co2 emissions and idirectional causality is found for all countries in case of classical production function.

- ✓ (Basak & Assistant, 2016), examined the Determinants Of Renewable Energy Consumption in Balkans countries- Albania, Bosnia-Herzegovina, Bulgaria, Croatia, Montenegro, Kosovo, Macedonia, Romania, Serbia, Slovenia, Turkey, and Greece. Using 1998-2011 time series period, by Using a dynamic panel data analysis was performed through Generalized Method of Moments (GMM). The empirical results show that there is a negative and statistically significant relationship between economic growth and renewable energy consumption. On the other hand, trade openness and natural gas rents are determined to have a positive effect on renewable energy consumption in the Balkans
- ✓ (Nkengfack & Fotio, 2019), estimated a long run and causal relationship between energy consumption, economic growth and carbon emissions in Africa countries Using 1991-2015 time series period, by Using Autoregressive Distributed Lag approach to cointegration and Toda-Yamamoto Test. The empirical results show that economic growth and aggregate energy consumption, measured by primary energy consumption, have a positive and significant impact on CO2 emissions both in the long and short run, In addition, the toda-Yamamoto Granger non-causality test showed several relationships among economic growth, energy consumption and carbon emissions, each one affecting other.
- ✓ On the other hand in an analysis carried out by .(Souza & al, 2018), to analyze the impact of energy consumption (divided into renewable and non-renewable sources) and income on co2 emissions with in the environmental Kuznents Curve (EKC) model panel data analysis was conducted for Southern Common Market (Mercosur), during the period running from 1990 to 2014, The results showed that energy consumption from renewable sources had a negative impact on co2 emissions, while the energy consumption from non-renewable sources had a positive impact of economic development on co2 emissions was also seen and EKC hypothesis is valid for the (Mercosur; Argentina, Brazil, Paraguay, Uruguay, Venezuela).
- ✓ (Saidi & al, 2018),estimated a long run and causal relationship between renewable energy and economic growth in MENA countries Using 1986-2015 time series period, by Using a Panel Co-integration Approach. The empirical results show that Furthermore, we found a strong causality running from renewable energy and any institutional measure, except for

law and order, to growth. A reverse path is also observed since there is also a strong causality running from growth to renewable energy when the causal regression includes any institutional measure.

- ✓ In the same research field, (Kahia & al, 2017), examined the MENA during the 1980–2012 period and found a bidirectional causality between renewable energy use and economic growth, and between non-renewable energy use and economic growth using the panel Error Correction Model. Also, empirical results provide evidence for long-term equilibrium relationship between real Gross Domestic Product (GDP), renewable energy use, non-renewable energy use, real gross fixed capital formation and labor force.
- ✓ For a panel of five Gulf countries, (Mrabet & al, 2018), implement By using panel data over the 1980-2017 period and two alternative indicators of environmental pollution (carbon dioxide (CO2) and sulfur dioxide (SO2) emissions). The results of a recently developed panel causality test reveal one-way causality from real GDP per capita to CO2 emissions and from real GDP per capita to SO2 emissions, the results are as follows: i) we find strong evidence of a long-run inverted U-shaped relationship between real GDP per capita and both environmental indicators in the GCC region; ii) However, when SO2 emissions are used as a measure of environmental pollution, the EKC hypothesis holds for Oman, Qatar, Saudi Arabia, and the UAE iii) Country-level short-run analysis indicates that the EKC hypothesis holds for Bahrain, Kuwait, Qatar, Saudi Arabia, and the United Arab Emirates (UAE) when CO2 emissions are used as a measure of environmental pollution.

Starting from all these facts, we will try through econometric modeling to verify test the existence of environmental Kuznets curve (EKC) hypothesis in BRICS during the period 1990-2018,and Also, verify if the development of renewable energy really limits CO2 émissions and boosts economic growth in BRICS.

3- Methods and Materials:

This study analyzes the EKC hypothesis in BRICS by using an annual time series data over the period 1990-2018, The data is derived from International Energy Statistics, World Development Indicators (WDI) and Emissions Database for Global Atmospheric Research (EDGAR). for the and to investigate the causal linkages between per capita CO2 emissions (CO2), renewable and non-renewable energy consumption (REC, NREC), real GDP and international trade (TR). Following the literature (Grossman & Krueger, 1991), (Shafik, 1994), (Basak & Assistant, 2016), (Nkengfack & Fotio, 2019), (Saidi & al, 2018), (Mrabet & al, 2018), (Kuznets, 1995).

we formulated the following equation:

$$CO2 = \alpha_0 + \alpha_1 \text{REC} + \alpha_2 \text{NREC} + \alpha_3 \text{GDP} + \alpha_4 \text{TR} + \varepsilon_t \ldots..(1)$$

To reduce the variation and induce stationary in the variance-covariance matrix, the natural logarithmic form (Ln) is applied to all the variables. The log linear EKC equation to examine the long-run relationship between variables is given as follow:

$$\text{LnCO2} = \alpha_0 + \alpha_1 \text{LnREC} + \alpha_2 \text{LnNREC} + \alpha_3 \text{LnGDP} + \alpha_4 \text{LnTR} + \varepsilon_t \ldots..(2)$$

To estimate equation (2) in the long run impacts of non-renewable energy consumption and renewable energy consumption on CO2 emissions are examined by applying panel autoregressive distributed lag (ARDL) approachto cointegration. There are various reasons which make panel-ARDL model more useful than other techniques. Firstly, it can be applied irrespective of whether the series are I(0) or I(1). Also, panel-ARDL approach is more suitable and produces more valid results for small sample size (Paul, 2014).Also, The panel ARDL technique was selected to investigate the long-term and short-term cointegration correlations between the determinants and extract the ECM (error correction version) of the panel characteristics to identify the short-term dynamic. panel-ARDL approach is consists of four steps :

The first step is to check the stationarity of the variables to ensure that no variable is integrated of order two. For this study we have chosen the Im, Pesaran and Shin (IPS, hereafter), which is based on the well-known Dickey-Fuller procedure. Im, Pesaran and Shin denoted IPS proposed a test for the presence of unit roots in panels that combines information from the time series dimension with that from the cross section dimension, such that fewer time observations are required for the test to have power. Since the IPS test has been found to have superior test power by researchers in economics to analyze long-run relationships in panel data. Also,This test is based on ADF test to individual series, however overall test statistics is based on the arithmetic mean of individual series, a series may be denoted by ADF as.

$$\Delta y_{it} = \alpha_i + \rho_i y_{i,t-1} + \sum_{j=1}^{p_i} \beta_{ij} \Delta y_{i,t-j} + \varepsilon_{it}$$

IPS test allows for heterogeneity in *i* value, εit the IPS unit root test equation may be written as

$$\bar{t}_T = \frac{1}{N}\sum_{i=1}^{N} t_{i,t}(p_i)$$

Where *ti,t* is the ADF test statistics, pi is the lag order. In ADF test statistics is calculated as:

$$A_{\bar{t}} = \frac{\sqrt{N(T)}}{\sqrt{Var(t_T}}(\bar{t}_T - E(t_T))$$

The next step is to test for the existence of a long-run cointegration among CO2 emissions and the independent variables using panel cointegration tests suggested by (Kao) is the first author to suggest the test for cointegration in homogeneous panels, The Kao test statistics are calculated by pooling all the residuals of all cross-sections in the panel. It is assumed in Kao's test that all the cointegrating vectors in every cross-section are identical,The first is of a Dickey-Fuller (DF) type, which can be applied to the residuals using (Hoang, 2010) :

$$\hat{\mu} = \rho\hat{\mu}_{it-1} + \epsilon_{it}$$

The OLS estimate of ρ is:

$$\hat{\rho} = \frac{\sum_{i=1}^{N}\sum_{t=2}^{T}\widehat{\mu_{it}}}{\sum_{i=1}^{N}\sum_{t=2}^{T}\widehat{\mu_{it-1}^{2}}} \times \widehat{\mu_{it-1}}$$

The second is an Augmented-Dickey-Fuller(ADF) type test which can be calculated from:

$$\widehat{\mu_{it}} = \rho\hat{\mu}_{it-1} + \sum_{j=1}^{p}\emptyset\Delta\,\hat{\mu}_{it-j} + e_{itp}$$

where p is chosen so that the residuals e_{itp} are serially uncorrelated. The ADF test statistic here is the usual t-statistic with $\rho = 1$ in the ADF equation. The following specification of null and alternative hypotheses is used :

$$\begin{cases} H_0, & p = 1 \\ H_1, & p < 1 \end{cases}$$

The next step is to test for the existence of a long-run cointegration among CO2 emissions and the independent variables using Panel ARDL test. Pesaran et al. (1997), Peseran et al. (2004) suggested the ARDL approach for the co-integration analysis in the single equation models. The ARDL approach to co-integration involves two steps for estimating a long-run relationship. The first step is to investigate the existence of a long-run relationship among all variables.If there is a long-run relationship (co-integration) between variables, the second step is to estimate the long-run coefficients according to the ARDL model's results.The Panel ARDL model is a variety of the ARDL (p, q) model in the Pesaran et al. ARDL-UECM model for the standard log-linear functional specification of long-run relationship between variables: (Bildirici, 2014), (Blackburne & Frank, 2007), (Fazli & Abbasi, 2018).

$$\Delta y_i = \emptyset_i(y_{i,i-1} - \theta' X_{-t}) + \sum_{j=1}^{p-1} \lambda_{ij}^* \Delta y_{i-J} + \sum_{j=0}^{q-1} \delta_{ij}^* \Delta X_{i,-j} + \mu_i + \varepsilon_i$$

Where :

i = 1, 2 ...... N

$y_i = (y_{i1} \ldots .y_{iT})'$ is a beam of dimension *T x 1* for the individual variable *i*

$x_i = (X_{i1} \ldots .X_{iT})'$ is a matrix of the dimension *T x k* for observations of the explanatory variables of individual *i* whose values change for each individual *i* and also during each time t of *T*

y_{i-J} and $X_{i,-j}$ is the number of delays j for the variable y_i and X_i respectively

Where $\emptyset_i$ refers to the speed of adjustment from short to long term, and this parameter is assumed to be negative $\emptyset_i$ to ensure long-term equilibrium relationships between the variables, since the long-term relationship between y_{it} and X_{it}

Based on the study variables, the following model can be suggested:

$$\Delta LCO2_{it} = \emptyset_i(LCO2_{i,i-1} - \theta' X_{-t}) + \sum_{j=1}^{p-1} \lambda_{ij}^* \Delta LCO2_{i-J} + \sum_{j=0}^{q-1} \delta_{ij}^* \Delta LTR_{\ i,-j}$$
$$+ \sum_{j=0}^{k-1} \psi_{ij}^* \Delta LGDP_{\ i,-j} + \sum_{j=0}^{m-1} \eta_{ij}^* \Delta LNREC_{\ i,-j} \sum_{j=0}^{j-1} \eta_{ij}^* \Delta LREC_{\ i,-j}$$
$$+ \mu_i + \varepsilon_{it}$$

The parameter $\emptyset_i$ is the error-correcting speed of adjustment term. If $\emptyset_i = 0$, then there would be no evidence for a long-run relationship. This parameter is expected to significantly negative under the prior assumption that the variables show a return to a long-run equilibrium. Of particular importance is the vector θ' which contains the long-run relationships between the variables.

4-Results and Discussion:

4.1.Result of panel unit root tests

According to the results of the results of IPS panel unit root tests shown in the Table 01 confirm that LCO2, LGDP, LREC, LNREC, LTR the null hypothesis of unit root cannot be rejected for the variables in levels. We further applied the unit root test in the first differences in the variables and the results reject the null hypothesis, implying that the levels are nonstationary, and the first differences are stationary I(1). these case, the longterm relationship between the research variables is examined by Kao Residual Cointegration Test (1999).

Table 01 : Panel Unit Root Tests (est IPS)

First Difference		**Level**		
P-Values	Statistic	P-Values	Statistic	**Variables**
0,000	-6,096	0,529	0,0728	**LCO2**
0,003	-2,687	0,002	-4,178	**LGDP**
0,000	-4,161	0,279	-0,585	**LREC**
0,005	-2,535	0,059	-1,559	**LNREC**
0,000	-6,574	0,008	-5,265	**LTR**

The source : Eviews 09 output

4.2.Results of panel cointegration test

According to Kao Residual co-integration Test (1999), the hypothesis of zero non-cointegration is rejected and the existence of a long-term relationship between researches variables is confirmed (Table 2 and Fig.1). in these case We reject the null hypothesis and accept the alternative hypothesis that there is a common integration between the variables of the study. Are very similar to each other in the long term where they behave in a similar manner and the linear mix between the variables is static. These results allow us to estimate the error model of the Panel ardl. (long-term equilibrium speed)

The second step was the estimation of a basic pnel ARDL model that explains carbon dioxide emissions (CO2) and its determinants. are achievable. The first step is to determine the optimal delay and ARDL pattern form. As seen in Fig. 4, Schwartz's lowest criterion is related to ARDL (3,4,4,4,4) . Therefore, the optimal pattern is ARDL (3,4,4,4,4) .

Table 02. Results of KAO cointegration test

Kao Residual Cointegration Test

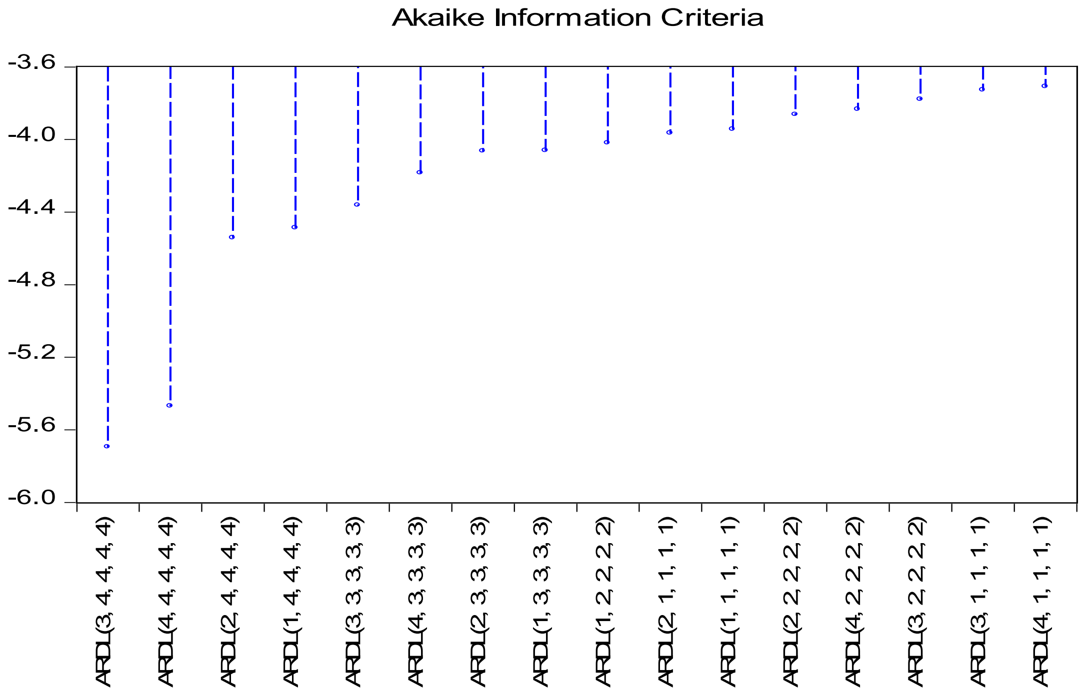
Series: LCO2 LTR LGDP LNREC LREC

Null Hypothesis: No cointegration

	t-Statistic	**Prob.**
ADF	-3.094191***	0.0010
Residual variance	0.001768	
HAC variance	0.002800	

The source : Eviews 09 output

Figure 01. Selection optimal model ARDL according to Schwarz criterion



The source : Eviews 09 output

4.3.Result of Long and short-Run relationship

Table 4.1, presents the results of the estimation of the general form of research in the framework of the ARDL (3,4,4,4,4) pattern. As can be seen coefficients obtained from the model are all significant and shows the long-run relationship of the variables. Also, Long-run results show that estimates show that increasing non-renewable energy consumption, and foreign trade and GDP increases CO2 emission, whereas renewable energy consumption has a negatively impact on CO2 emissions.This result is consistent with the finding of (Grossman & Krueger, 1991), (Shafik, 1994), (Basak & Assistant, 2016), (Nkengfack & Fotio, 2019), (Saidi & al, 2018), (Mrabet & al, 2018), (Kuznets, 1995).

The degree of renewable energy consumption has a negative and significant effect in the short term and has a negative and significant effect on CO2 emissions of BRICS countries in the long term.

Appendice 01 also presents The short run results of ARDL method of estimation is displayed in Table 05. The findings displayed a valid short run relationship between carbon dioxide emissions (CO2) and its determinats in BRICS countries . the coefficient of error term is displaying the value of around -0.71 propose that around 71% of instability is adjusted in the present year.

5. RESULTS

This paper has estimated and verify test the existence of environmental Kuznets curve (EKC) hypothesis in BRICS countries during the period 1990-2018,and Also, verify if the development of renewable energy really limits CO2 émissions and boosts economic growth in BRICS by employing Panel Auto Regressive Distributed Lag (ARDL) method. The empirical results show do not support the EKC hypothesis stipulating an inverted U-shaped curb of per capita emissions as a function of per capita GDP in BRICS countries.. Additionally, development of renewable energy really limits CO2 emissions and boosts economic growth in BRICS countries. It is therefore recommended that the policymakers are required to focus on the green energy generation sector by increasing renewable energy production from the existing sources.

Also, according to the results, the analysis demonstrates that in the long-run, show that estimates show that increasing non-renewable energy, consumption , and GDP and foreign trade increases CO2 emission, whereas renewable energy has a negatively impact on CO2 emissions. The short run results show tha relationship between carbon dioxide emissions (CO2) and its determinats in BRICS countries.

6-Appendices:

Appendice:01 ARDL model estimation results 3,4,4,4,4

Selected Model: ARDL(3, 4, 4, 4, 4)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.*
Long Run Equation				
LGDP	8.162575***	2.590179	3.151356	0.0030
LREC	-24.73592***	3.196894	-7.737485	0.0000
LNREC	16.98015***	5.364105	3.165514	0.0029
LTR	0.601863***	0.027434	21.93894	0.0000
Short Run Equation				
U_{t-1}	-0.712894*	0.383113	-1.860790	0.0700
D(LCO2(-1))	0.423254	0.250809	1.687552	0.0991
D(LCO2(-2))	0.397712	0.297479	1.336945	0.1886
D(LGDP)	-559233.3	605580.9	-0.923466	0.3612
D(LGDP(-1))	-88884.36	114980.3	-0.773040	0.4439
D(LGDP(-2))	-305658.6	288578.4	-1.059187	0.2957
D(LGDP(-3))	165071.9	176704.7	0.934168	0.3557
D(LREC)	-568992.7	616022.7	-0.923655	0.3611
D(LREC(-1))	-90688.34	116911.2	-0.775703	0.4424
D(LREC(-2))	-311261.3	293741.3	-1.059644	0.2955
D(LREC(-3))	167468.5	179115.6	0.934975	0.3553
D(LNREC)	1128207.	1221581.	0.923563	0.3611
D(LNREC(-1))	179567.6	231888.3	0.774371	0.4432
D(LNREC(-2))	616906.0	582308.2	1.059415	0.2956
D(LNREC(-3))	-332535.3	355816.3	-0.934570	0.3555
D(LTR)	20.88198	22.15373	0.942594	0.3514
D(LTR(-1))	5.100894	4.241897	1.202503	0.2361
D(LTR(-2))	12.34743	11.50794	1.072949	0.2896
D(LTR(-3))	-5.504078	3.771400	-1.459426	0.1521
C	-1.853333***	0.637640	-2.906552	0.0059

*** Significant at the level of 1%

The source : Eviews 09 output

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