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Renewable Energy Consumption and Economic Growth in Argentina: A Multivariate Co-integration Analysis

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ABSTRACT

This paper applied the ARDL bounds test approach and the VECM test technique to examine the long run relationship and direction of causality between renewable energy consumption and economic growth in Argentina. Quarterly time series data was employed in this study covering a period between 1990 and 2018. Trade openness, capital and employment were included in the study to form a multivariate framework. The results established that there is a long run relationship between the variables. The VECM test technique confirmed a unidirectional causality flowing from economic growth to renewable energy consumption. This implies that energy conservation policies may not harm the economic growth. The study, therefore, suggest that an appropriate and effective energy policy should be implemented in the long run.

Keywords: Renewable Energy Consumption, Economic Growth, Causality, Argentina
JEL Classifications: D04, C32, Q47, Q42, Q01

1. INTRODUCTION

Climate change and global warming have been a major concern worldwide and has attracted much attention of the energy economists and environmentalists. Many studies have investigated the causal relationship between energy consumption, carbon dioxide emissions and economic growth in trying to come up with important energy policies. It has been observed that energy consumption is a driver for economic growth and also economic growth stimulates energy consumption (Khobai and Le Roux, 2017). Ozturk and Acaravci (2010) established that higher levels of carbon dioxide emissions are accounted for by the increase in energy consumption. This implies that since high levels of economic growth require high levels of energy consumption, this is responsible for high levels of carbon dioxide emissions. This notion has attracted much attention where energy economist aimed to come up with energy policies that will enhance economic growth while at the same time reducing the emissions of carbon dioxide.

Most studies that argued that economic growth should not be sustained at the expense of the environment focused on the policies that would pursue an energy mix that includes clean and renewable energy. This led to studies investigating the linkage between economic growth and other sources of energy such as renewable energy (Sebri and Ben-Salha, 2014). A vast majority of the studies that aimed to examine this relationship established mixed results. Some studies revealed a unidirectional causality flowing from renewable energy consumption to economic growth (Khobai and Le Roux, 2017; Apergis and Payne, 2011); whereas other studies confirmed a unidirectional causality running from economic growth to renewable energy consumption (Ocal and Aslan, 2013; Ziramba, 2013). Most studies affirmed a bidirectional relationship between renewable energy consumption and economic growth (Sebri and Ben-Salha, 2014; Apergis and Payne, 2014; Sadorsky, 2009; Apergis and Payne, 2010). This led to the current study examining the causal relationship between renewable energy consumption and economic growth in Argentina.

The choice of Argentina is motivated by the fact that the country's domestic oil industry is a major driver to export growth. The majority of energy export from Argentina is accounted for by crude oil (US Department of Energy, 2003). It was also established that since 1990, the total energy usage in Argentina has increased by more than 40% and this accounted mostly by natural gas (46%) followed by oil (38.4%) (US Department of Energy, 2003). Energy economics has supported the fact that burning of fossil fuels such as oil are the major causes of carbon dioxide emission. In this accord, this serves to empirically investigate the causal linkage between renewable energy consumption and economic growth in Argentina covering the period between 1990 and 2014.

The main objective of this study is to determine whether the implementation of environmentally friendly policies on economic growth in Argentina will have a positive or negative effect on the country's economic growth and development. This is achieved by applying the Autoregressive Distributed Lag (ARDL) bounds testing approach to establish whether there is a long run relationship among the variables and the usage of the Vector Error Correction Model (VECM) technique to determine the direction of causality between the variables. The findings of this study will assist in determining whether the energy conservation policies have a positive or negative effect on growth by affecting energy consumption

The remainder of the study is structured as follows: Section two discusses the review of the literature between renewable energy consumption and economic growth. Section three outlines the methodology, data sources and the model specification. The empirical results are presented in section four followed by the conclusion and policy recommendations in section five.

2. LITERATURE REVIEW

The literature review shows that the linkages between economic growth and renewable energy consumption can be broadly classified into two research clusters. Firstly, the empirical work focuses on the relationship between economic growth and energy consumption using the co-integration approaches and the Granger-causality techniques. Secondly, analyses focus on economic growth and other disaggregated renewable energy (such as hydroelectricity) consumption nexus. Nevertheless, for Argentina, a limited number of studies are available.

Numerous studies have investigated the relationship between economic growth and renewable energy consumption using the co-integration techniques and Granger-causality frameworks; these studies include those by Apergis and Payne (2011) Khobai and Le Roux (2017), Inglesi-Lotz (2013); Apergis and Payne (2010) and Sadorsky (2009).

Ivanovski et al. (2020) contributed the most recent studies on renewable energy consumption – economic growth nexus. Employing non-parametric model, the results suggested that non-renewable energy consumption has a positive impact on economic growth across OECD nations. It further portrayed that both renewable and non-renewable energy consumption enhance economic growth in non-OECD countries. Shahbaz et al. (2020) examined the impact of renewable energy consumption and economic growth for 38 countries. The findings from dynamic ordinary least squares (DOLS) and Fully modified ordinary least squares (FOMLS) confirm the existence of a long run relationship between renewable energy consumption and economic growth. Specifically, renewable energy consumption has a positive impact on economic growth for 55% of the sample countries.

Haseeb et al. (2018) investigated the renewable energy consumption – economic growth nexus. This Malaysian study revealed that renewable energy have a positive and significant effect on economic well-being both in the short and long run. Can and Korkmaz (2018) focused on Bulgaria to in investigating the relationship between renewable energy consumption and economic growth. The finding from the ARDL model showed no existence of a long run relationship but Toda-Yamamoto causality results posited that renewable energy consumption and renewable electricity output causes economic growth.

Khobai and Le Roux (2017) established that there is a positive long run relationship between renewable energy consumption and economic growth in South Africa. The study employed the ARDL model and the VECM technique covering the period from 1990 to 2014 for South Africa. The VECM model validated a unidirectional causality flowing from renewable energy consumption to economic growth.

Another research that focused on a single country was conducted by Ocal and Aslan (2013). The study purposed to examine the relationship between renewable energy consumption and economic growth in Turkey for the period 1990-2010. The results from the ARDL bounds testing approach validated a presence of a negative relationship between renewable energy consumption and economic growth in Turkey. The Granger-causality test by Toda-Yamamoto evidenced a unidirectional causality flowing from economic growth to renewable energy consumption.

Sebri and Ben-Salha (2014) established the same results of a long run positive relationship between renewable energy consumption and economic growth but for a bigger group, Brics countries. The study employed the ARDL bounds testing approach and the VECM technique for the period between 1970 and 2010. The VECM model results confirmed bidirectional causality flowing between renewable energy consumption and economic growth.

Another study focused on a larger group was undertaken by Apergis and Payne (2014) who explored the relationship between renewable energy consumption and economic growth for seven Central American countries. The study validated that there is existence of a long run positive relationship between renewable energy consumption and economic growth. Apergis and Payne (2012) also affirmed a long run relationship between economic growth and renewable energy consumption for 80 countries. Moreover, the study detected bidirectional causality flowing between renewable consumption and economic growth.

One of the current studies was done by Ozcan and Ozturk (2019) to examine the relationship between renewable energy consumption and economic growth in 17 emerging countries and only established a growth hypothesis for Poland and a neutral hypothesis for the remaining 16 emerging countries. Liu and Liang (2019) served to investigate the relationship between energy consumption, biodiversity and economic growth for China and five countries (Cambodia, Laos, Myanmar, Thailand and Vietnam). The ARDL model results posits that the fossil fuels have more effect on economic growth than renewable energy as such renewable energy is an alternative for fossil fuels. In exploring West Africa, Maji and Sulaiman (2019) established that renewable energy consumption has an adverse effect on economic growth. This could be attributed to the fact that in West Africa, wood biomass is mostly used as the source of renewable energy.

Sadorsky (2009) carried a study for eighteen emerging countries and established that renewable energy consumption per capita and real income per capita have a long run relationship. Using a panel error correction model over the period 1994-2003, it was confirmed that renewable energy consumption and economic growth Granger-cause each other for the eighteen emerging countries. Apergis and Payne (2010) studied the causal relationship between economic growth and renewable energy consumption for panel of 20 OECD countries. Covering the period between 1985 and 2005, the study established that there is long run relationship between economic growth and renewable energy consumption. The Granger-causality tests suggested bidirectional causality flowing between renewable energy consumption and economic growth.

Another OECD study that investigated the causal relationship between renewable energy consumption and economic welfare was conducted by Inglesi-Lotz (2013). Employing panel co-integration techniques, Inglesi-Lotz affirmed that renewable energy consumption has a positive and significant impact on economic welfare. Apergis and Payne (2011) studied the six Central American countries in investigating the relationship between renewable energy consumption and economic growth. Using annual data for the period between 1980 and 2004, this study established that there is a presence of a long run relationship between economic growth and renewable energy consumption. It was also found that energy consumption Granger-causes economic growth both in the short run and long run.

Tagcu, Ozturk and Aslan investigated the causal relationship between economic growth and renewable energy consumption using the ARDL bounds testing approach and the recent developed Granger-causality test by Hatemi-J (2012). Their findings validated existence of a long run relationship between economic growth and renewable energy consumption. The Hatemi-J causality test suggested bidirectional causality flowing between economic growth and renewable energy consumption.

Instead of aggregated renewable energy consumption, Ziramba (2013) focused on hydroelectricity consumption and economic growth linkages for Algeria, Egypt and South Africa. Using data for the period 1980-2009, this study established a unidirectional causality flowing from economic growth to hydroelectricity in South Africa, a feedback hypothesis in Algeria and a neutrality hypothesis in Egypt.

3. METHODOLOGY

3.1. Model Specification

Based on the economic growth literature, the hypothesized model specification is as follows:

$$GDP_t = f(RE_t, TR_t, EM_t, K_t) \quad (3.1)$$

All the series are expressed in log-linear form and equation 3.1 now becomes;

$$LGDP_t = \alpha + \beta_1 LRE + \beta_2 LTR + \beta_3 LEM_t + \beta_4 LK_t + \mu \quad (3.2)$$

Where *LGDP* is the natural logarithm of economic growth and is measured by real *GDP* per capita. *LRE* represents the natural logarithm of renewable energy consumption. *LTR* denotes the natural logarithm of trade openness (the sum of imports and exports of goods and services). *LEM* represent the natural logarithm of employment and *LK* is the natural logarithm of capital formation.

3.2. Data Collection

In tracing the linkages between economic growth and renewable energy consumption in Argentina, the study employs quarterly data covering the period from 1990 to 2018. In doing so, the Gross domestic product (GDP) per capita at 2010 constant prices is used as an indicator for economic growth. Trade openness is the combination of exports and imports. Commercial, agricultural and manufacturing employments are used as proxy for Employment. Capital is measured as gross capital formation (constant 2010 US$). The data for Gross domestic product, capital and employment was extracted from the World Development Indicators (WDI) published by the World Bank (WB, 2016). The data for trade openness was sourced from United Nations and Trade Development (UNCTAD). The data for renewable energy consumption was obtained from International Energy Agency (IEA).

3.3. Unit Root

The first step in examining the long run relationship between the variables is to test whether the variables are stationary or non-stationary. To examine the non-stationarity property of the series variables both in the levels and in the first difference, the Augmented Dickey Fuller (ADF) test has been employed. This test is the modification of the Dickey Fuller (DF) test and the lagged values of the dependent variables are added in the estimation of an equation as follows:

$$\Delta Z_t = \theta + (\rho - 1)Z_{t-1} + \gamma T + \delta \Delta Z_{T-1} + \varepsilon_{2t} \quad (3.3)$$

The Phillips and Perron (PP) test is also employed in the empirical analysis. This is on account that the ADF tests does not consider cases of heteroscedasticity and non-normality which are mostly realized in raw data of economic time series variables. The PP test also has power when the time series of interest has serial correlation and there is structural breaks. The PP test is based on the following form of equation:

$$\Delta Z_t = \theta + (\rho - 1)Z_{t-1} + \gamma(t - \tfrac{T}{2}) + \delta \Delta Z_{T-1} + \varepsilon_{3t} \quad (3.4)$$

The ADF and the Phillips-Perron tests have been criticised for their low power when variables are stationary but with a root close to non-stationary boundary (Brooks, 2014). Elliot et al. (1996) argue that the Dickey Fuller Generalised Least Squares (DF-GLS) test has more power in the presence of an unknown mean or trend compared to the ADF and the Phillips-Perron tests. On this accord, the DF-GLS is also employed in this study to test for stationarity among the variables.

3.4. Co-integration Test

In order to investigate the linkage between economic growth and renewable energy consumption in Argentina, the study applies the ARDL bounds testing approach to co-integration developed by Pesaran et al., (2001). This model has become more popular in recent studies. In simple form, the ARDL model involves estimating the following conditional error correction models:

$$\begin{aligned}\Delta LGDP_t &= \alpha_1 + \alpha_T T + \alpha_{GDP} LGDP_{t-1} \\ &+ \alpha_{RE} LRE_{t-1} + \alpha_{TR} LTR_{t-1} + \alpha_{EM} LEM_{T-1} + \alpha_K LK_{t-1} \\ &+ \sum_{i=1}^{p} \alpha_i \Delta LGDP_{t-i} + \sum_{j=0}^{q} \alpha_j \Delta LRE_{t-j} + \sum_{k=0}^{r} \alpha_k \Delta LTR_{t-k} \\ &+ \sum_{l=0}^{s} \alpha_L \Delta LEM_{t-l} + \sum_{m=0}^{t} \alpha_m \Delta LK_{t-m} + \varepsilon_{1t} \quad (3.5)\end{aligned}$$

$$\begin{aligned}\Delta LRE_t &= \alpha_2 + \alpha_T T + \alpha_{GDP} LGDP_{t-1} \\ &+ \alpha_{RE} LRE_{t-1} + \alpha_{TR} LTR_{t-1} + \alpha_{EM} LEM_{T-1} + \alpha_K LK_{t-1} \\ &+ \sum_{i=1}^{p} \alpha_i \Delta LGDP_{t-i} + \sum_{j=0}^{q} \alpha_j \Delta LRE_{t-j} + \sum_{k=0}^{r} \alpha_k \Delta LTR_{t-k} \\ &+ \sum_{l=0}^{s} \alpha_L \Delta LEM_{t-l} + \sum_{m=0}^{t} \alpha_m \Delta LK_{t-m} + \varepsilon_{2t} \quad (3.6)\end{aligned}$$

$$\begin{aligned}\Delta LTR_t &= \alpha_3 + \alpha_T T + \alpha_{GDP} LGDP_{t-1} + \alpha_{RE} LRE_{t-1} \\ &+ \alpha_{TR} LTR_{t-1} + \alpha_{EM} LEM_{T-1} + \alpha_K LK_{t-1} \\ &+ \sum_{i=1}^{p} \alpha_i \Delta LGDP_{t-i} + \sum_{j=0}^{q} \alpha_j \Delta LRE_{t-j} + \sum_{k=0}^{r} \alpha_k \Delta LTR_{t-k} \\ &+ \sum_{l=0}^{s} \alpha_L \Delta LEM_{t-l} + \sum_{m=0}^{t} \alpha_m \Delta LK_{t-m} + \varepsilon_{3t} \quad (3.7)\end{aligned}$$

$$\begin{aligned}\Delta LEM_t &= \alpha_4 + \alpha_T T + \alpha_{GDP} LGDP_{t-1} + \alpha_{RE} LRE_{t-1} \\ &+ \alpha_{TR} LTR_{t-1} + \alpha_{EM} LEM_{T-1} + \alpha_K LK_{t-1} \\ &+ \sum_{i=1}^{p} \alpha_i \Delta LGDP_{t-i} + \sum_{j=0}^{q} \alpha_j \Delta LRE_{t-j} + \sum_{k=0}^{r} \alpha_k \Delta LTR_{t-k} \\ &+ \sum_{l=0}^{s} \alpha_L \Delta LEM_{t-l} + \sum_{m=0}^{t} \alpha_m \Delta LK_{t-m} + \varepsilon_{4t} \quad (3.8)\end{aligned}$$

$$\begin{aligned}\Delta LK_t &= \alpha_5 + \alpha_T T + \alpha_{GDP} LGDP_{t-1} + \alpha_{RE} LRE_{t-1} \\ &+ \alpha_{TR} LTR_{t-1} + \alpha_{EM} LEM_{T-1} + \alpha_K LK_{t-1} \\ &+ \sum_{i=1}^{p} \alpha_i \Delta LGDP_{t-i} + \sum_{j=0}^{q} \alpha_j \Delta LRE_{t-j} + \sum_{k=0}^{r} \alpha_k \Delta LTR_{t-k} \\ &+ \sum_{l=0}^{s} \alpha_L \Delta LEM_{t-l} + \sum_{m=0}^{t} \alpha_m \Delta LK_{t-m} + \varepsilon_{5t} \quad (3.9)\end{aligned}$$

Where: $LGDP_t$ is the natural logarithm of Gross Domestic Product. LRE_t is the natural logarithm of Renewable energy consumption. LTR_t is the natural logarithm of trade openness. LEM_t is the natural logarithm of employment. LK_t denotes the natural logarithm of capital formation. T and Δ represent the time period and the first difference operator, respectively. It is assumed that the residuals ($\varepsilon_{1t,}$ $\varepsilon_{2t,}$ $\varepsilon_{3t,}$ $\varepsilon_{4t,}$ ε_{5t}) are normally distributed and white noise.

The existence of a long run relationship between the variables is determined based on an F-test (Wald test) by setting the coefficients of one period lagged level of the independent variables equal to zero. The null hypothesis of no co-integration among the variables is H_0: $\alpha_{GDP} = \alpha_{RE} = \alpha_{TR} = \alpha_{EM =}\ \alpha_K = 0$ tested against the alternative hypothesis H_1: $\alpha_{GDP} \neq \alpha_{RE} \neq \alpha_{TR} \neq \alpha_{EM} \neq \alpha_K \neq 0$. In order to reject or accept the null hypothesis, the value of the F-test is compared with critical value bounds. The lower bound values are computed based on the assumption that all of the variables in the regression equation are I(0), while upper critical bound values are computed based on the assumption that all of the variables in the regression equation are I(1). Therefore, the two sets of critical values provide critical value bounds for all classification of the repressors into purely I(0), purely, I(1) or mutually co-integrated.

As a result, if the calculated F-statistics exceeds the upper critical bound value, then the H_0 is rejected and the results conclude in favour of co-integration. On the contrary, H_0 cannot be rejected if the F-statistics falls below the lower critical bound value. Finally, if the F-statistics falls within the two bounds, then the co-integration test becomes inconclusive.

If a long run relationship between the variables is established, the next step is to investigate the long run and short run relationship among variables of interest. To estimate the long run relationship among the variables based on the ARDL approach, the following equation is built up.

$$\begin{aligned}LGDP_t &= \alpha_1 + \sum_{i-1}^{p} \varphi_i LGDP_{t-1} + \sum_{i=0}^{q} \lambda_i LRE_{t-i} \\ &+ \sum_{i=0}^{r} \eta_i LTR_{t-i} + \sum_{i=0}^{s} \vartheta_i LEM_{t-i} + \sum_{i=0}^{v} \theta_i LK_{t-i} + \mu_t \quad (3.10)\end{aligned}$$

Furthermore, in order to investigate the short run dynamics from the ARDL model and recheck the presence of co-integration established in the ARDL model, the study estimates the error correction model, which is developed as follows:

$$\Delta LGDP_t = \alpha_2 + \sum_{i-1}^{p} \varphi_i \Delta LGDP_{t-1} + \sum_{i=0}^{q} \lambda_i \Delta LRE_{t-i} + \sum_{i=0}^{r} \eta_i \Delta LTR_{t-i} + \sum_{i=0}^{s} \vartheta_i \Delta LEM_{t-i} + \sum_{i=0}^{v} \theta_i \Delta LK_{t-i} + \Psi ECM_{t-1} + \mu_t \quad (3.11)$$

If the coefficient of the ECM in the equation is negative and significant, there is an existence of a long run relationship among the variables. This also denotes the speed of adjustment to the equilibrium.

Finally, to determine the reliability of the ARDL result, the study checks for serial correlation, functional form, normality and heterosckedasticity of the ARDL model. In addition, the stability of the parameters will be tested using the Cumulative Sum of Recursive Residual (CUSUM).

3.5. Granger-causality

After examining the long run relationship between the variables, the Granger-causality is applied to find the direction of causality among the variables. If the results detect existence of a long run relationship, the Vector Error Correction Model is used to estimate the direction of causality. The VECM is used to determine the long run and short run relationship between the variables and can detect sources of causation. The VECM is moulded by (Eq. 3.10-Eq. 3.14). In each equation, the dependent variable is explained by itself, the independent variables and the error correction term:

$$\Delta LGDP_t = \alpha_{10} + \sum_{i=1}^{q} \alpha_{11} \Delta LGDP_{t-i} + \sum_{i=1}^{r} \alpha_{12} \Delta LRE_{t-i} + \sum_{i=1}^{s} \alpha_{13} \Delta LTR_{t-i} + \sum_{i-1}^{t} \alpha_{14} \Delta LK_{t-i} + \sum_{i-1}^{u} \alpha_{15} \Delta LEM_{t-i} + \psi_1 ECT_{t-1} + \varepsilon_{1t} \quad (3.12)$$

$$\Delta LRE_t = \alpha_{20} + \sum_{i=1}^{q} \alpha_{21} \Delta LRE_{t-i} + \sum_{i=1}^{r} \alpha_{22} \Delta LTR_{t-i} + \sum_{i=1}^{s} \alpha_{23} \Delta LGDP_{t-i} + \sum_{i-1}^{t} \alpha_{24} \Delta LK_{t-i} + \sum_{i-1}^{u} \alpha_{25} \Delta LEM_{t-i} + \psi_2 ECT_{t-1} + \varepsilon_{2t} \quad (3.13)$$

$$\Delta LTR_t = \alpha_{30} + \sum_{i=1}^{q} \alpha_{31} \Delta LTR_{t-i} + \sum_{i=1}^{r} \alpha_{32} \Delta LRE_{t-i} + \sum_{i=1}^{s} \alpha_{33} \Delta LGDP_{t-i} + \sum_{i-1}^{t} \alpha_{34} \Delta LK_{t-i} + \sum_{i-1}^{u} \alpha_{35} \Delta LEM_{t-i} + \psi_3 ECT_{t-1} + \varepsilon_{3t} \quad (3.14)$$

$$\Delta LK_t = \alpha_{40} + \sum_{i=1}^{q} \alpha_{41} \Delta LK_{t-i} + \sum_{i=1}^{r} \alpha_{42} \Delta LRE_{t-i} + \sum_{i=1}^{s} \alpha_{43} \Delta LTR_{t-i} + \sum_{i-1}^{t} \alpha_{44} \Delta LGDP_{t-i} + \sum_{i-1}^{u} \alpha_{45} \Delta LEM_{t-i} + \psi_5 ECT_{t-1} + \varepsilon_{5t} \quad (3.15)$$

$$\Delta LEM_t = \alpha_{50} + \sum_{i=1}^{q} \alpha_{51} \Delta LEM_{t-i} + \sum_{i=1}^{r} \alpha_{52} \Delta LRE_{t-i} + \sum_{i=1}^{s} \alpha_{53} \Delta LTR_{t-i} + \sum_{i-1}^{t} \alpha_{54} \Delta LGDP_{t-i} + \sum_{i-1}^{u} \alpha_{55} \Delta LK_{t-i} + \psi_5 ECT_{t-1} + \varepsilon_{5t} \quad (3.16)$$

Δ represent the difference operator, α_{it} is the constant term and ECT refers to the error correction term derived from the long run cointegrating linkages. The short run causal relationships are captured through the coefficients of the independent variables. This is determined using a standard Wald test. The long run causal relationships are based on the error correction terms. The t-statistics is employed to test the significance of the speed of adjustment in ECT terms. If the coefficients of the error correction term are negative and significant, then there is evidence of a long run causal relationship.

4. FINDINGS OF THE STUDY

4.1. Unit Root Tests

The first step taken in the study was to determine whether the variables are stationary or not. This was examined using the Augmented Dickey Fuller, Phillips and Perron and Dickey Fuller Generalised Least Squares unit root tests for the five variables. The results are presented in Table 1. Table 1 shows that we fail to reject the null hypothesis of non-stationary at levels for all the variables but at first difference the null hypothesis is rejected. This means that all the variables are non-stationary at levels but are found to be stationary when differenced once. Hence they are integrated of first order, I(1).

4.2. Co-Integration

Having established that the variables are stationary, the next step is to determine whether there is a long run relationship among the variables. But before investigating the existence of a long run relationship between economic growth, renewable energy consumption, trade openness, employment and capital, it is necessary to determine the optimal lag length. The Akaike information criteria and Schwartz Criteria are employed to find the optimal lag length and the results are illustrated in Table 2. The optimal lag length p*=2 is chosen (Table 2).

The long run relationship was examined using the ARDL bounds tests and the results are presented in Table 3. There results suggest there is an existence of a long run relationship among the variables when economic growth is used as the dependent variable. This

Table 1: Unit root tests

Variable	Levels			First difference		
	ADF	PP	DF-GLS	ADF	PP	DF-GLS
LGDP	−1.0771	−2.0401	0.0954	−2.6574***	−4.2783*	−1.8992***
LRE	−1.9792	−2245	−1.5642	−2.6358***	−5.0837*	−1.6515***
LTR	1.8189	−2.5393	−0.4092	−2.8060***	−4.4777*	−1.6286***
LEM	−0.9443	−0.8239	0.5456	−3.2311**	−5.1484*	−3.0822*
LK	−1.7131	−2.4042	−0.3520	−2.6912***	−4.8175*	−1.7410***

Source: Own calculation. *,**,***represent 1%, 5% & 10% significance levels, respectively

Table 2: Selection order criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	856.056	NA	1.14e-14	−17.9178	−17.7843	−17.8639
1	1862.27	1869.79	182e-23	−38.1745	−37.3711	−37.8486
2	1991.51	222.849*	2.08e-24*	−40.3440*	−38.8748*	−39.7501*
3	2001.42	16.5223	288e-24	−40.0297	−37.8927	−39.1659
4	2005.62	6.5520	4.54e-24	39.5962	−36.7914	−38.4625

Source: Own calculation

Table 3: ARDL Co-integration test

Critical value bound of the F-statistic						
K	90% level		95% level		99% level	
	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
3	2.022	3.112	2.459	3.625	3.372	4.797
4	1.919	3.016	2.282	3.340	3.061	4.486

Calculated F-statistics. F_{GDP} (GDP/RE, TR, K, EM) = 28.80, F_{RE} (RE/GDP, TR, K, EM) = 3.73, F_{TR} (TR/GDP, RE, K, EM) = 8.86, F_{K} (K/GDP, RE, TR, EM) = 23.63, F_{EM} (EM/GDP, RE, TR, K) = 22.77, The critical bound values were taken from Narayan and Smyth (2005.p. 470)

Table 4: Long run results

Dependent variable=LGDP			
Long term results			
Variable	Coefficients	Standard error	T-statistics
Constant	1.78***	0.8495	2.0947
LRE	0.17**	0.0701	2.4476
LTR	−0.01	0.0735	−0.1948
LEM	0.95*	0.1785	5.3374
LK	0.30*	0.0465	6.4789

Source: Own calculations. R-squared 0.99. Durbin Watson Stat 2.02. Where *,**,***represent 1%, 5% and 10% significance levels, respectively

is on account that the F-statistics of economic growth (28.8) is greater than the upper critical bound value of 4.797 at 1% level of significance. This means that when economic growth is used as an independent variable, there is evidence of a long run relationship between the variables.

Similar results were obtained when renewable energy consumption, trade openness, capital and employment are each used as dependent variables. This is because the F-statistics of trade openness (8.86), capital (23.63) and employment (22.77) are greater than the upper critical bound value of 4.797 at 1% percent level of significance, while the F-statistics of renewable energy consumption (3.73) is greater than the upper critical bound value of 3.72 at 5% level of significance. Therefore, we conclude that there is a long run relationship between economic growth, renewable energy consumption, trade openness, employment and capital in Argentina.

Table 4 presents the estimated coefficients of the long run relationship. Based on the findings in Table 4, the long run economic growth model can be moulded as follows:

$$LGDP_t = 1.78 + 0.17LRE – 0.01LTR + 0.95LEM + 0.30LK$$

The estimated coefficients suggest that renewable energy consumption, employment and capital have a statistically significant positive impact on economic growth, which is in line with theoretical argument that renewable energy consumption, employment and capital boost economic growth. More specifically, the long run elasticity of renewable energy consumption is 0.17, which implies that a 1% increase in renewable energy consumption leads to about 0.17% rise in economic growth, when all else is the same. These results are in line with the findings of Khobai and Le Roux (2017), Apergis and Payne (2011) and Sadorsky (2009).

Similarly, the elasticity of employment suggests that a 1% increase in employment results in 0.95% increase in economic growth on average, all else held constant. The long run elasticity of capital is 0.30, which implies that a 1% rise in capital leads to approximately 0.30% increase in economic growth. The results coincides with the findings Adebola (2011). However, trade openness has an insignificant impact on economic growth.

Table 5 presents the short run results. The results suggest that renewable energy consumption has a positive and significant impact on economic growth. Specifically, a 1% increase in renewable energy consumption leads to a 0.09% increase in economic growth in the short run. These results confirm Sebri and Ben-Salha' (2014) findings. Moreover, the findings posits that employment and capital have a positive and significant effect on economic growth.

Based on the results illustrated in Table 5, the estimated coefficient of the ECM_{t-1} is −0.64. Since the error correction term is negative and significant, this means that the results support the existence of a long run relationship among the variables. The results indicate that departure from long-term growth path due to a certain shock is adjusted by 64% each quarter.

Table 5: Short run analysis

Variable	Coefficient	Standard error	T-statistics
LRE	0.09*	0.0250	3.4956
LEM	0.41*	0.0699	5.8419
LK	0.23*	0.0139	16.5862
ECM_{t-1}	-0.6400	0.0047	-13.5065
R^2	0.97		
D.W test	2.02		

Source: Own calculation. *,**,***represent 1%, 5% & 10% significance levels, respectively

The diagnostic tests results are illustrated in Table 6. It was validated that the error terms of the short run models are free of heteroscedasticity, have no serial correlation and are normally distributed. It was also discovered that the Durbin Watson statistics is greater than the R^2, which implies that the short run models are not spurious.

The stability of the long run parameters were tested using the cumulative sum of recursive residuals (CUSUM). The results are illustrated in Figure 1. The results fail to reject the null hypothesis at 5% level of significance because the plot of the tests fall within the critical limits. Therefore, it can be realised that our selected ARDL model is stable.

4.3. Granger Causality

After confirming the presence of a long run relationship between the variables, the VECM Granger-causality approach is used to examine the direction of causality between economic growth, renewable energy consumption, trade openness, capital and employment. The system of the vector error correction model uses all the series endogenously. This system allows the predicted variables to explain itself both by its own lags and lags of forcing variables as well as the error correction term and by residual term.

The short run and long run Granger causality results are reported in Table 7. The reported values in parentheses are the p-values of the test. The findings indicate that there is a long run causality flowing from economic growth, trade openness, capital and employment to renewable energy consumption. This is because the error correction term (−0.36) is negative and significant when renewable energy consumption was used as the dependent variable. The results suggest that there is an existence of a conservation hypothesis which indicates that renewable energy consumption has less or no impact on economic growth in the long run. As a result, a fall in renewable energy consumption will lead to a minor or no impact on economic growth. These results are consistent to Ziramba (2013) and Ocal and Aslan (2013).

Furthermore, it was observed that there is a long run causality flowing from economic growth, renewable energy consumption, trade openness and employment to capital. The short run results validated a causality flowing from capital to economic growth. Another short run causality was established flowing from economic growth to trade openness. Lastly, it was discovered that economic growth Granger-causes capital in the short run.

Table 6: Short-run diagnostics

Short run diagnostics		
Test	F-statistics	P-value
Normality	0.2381	0.1251
Heteroskedasticity	0.9406	0.5202
Serial correlation	0.1492	0.8616

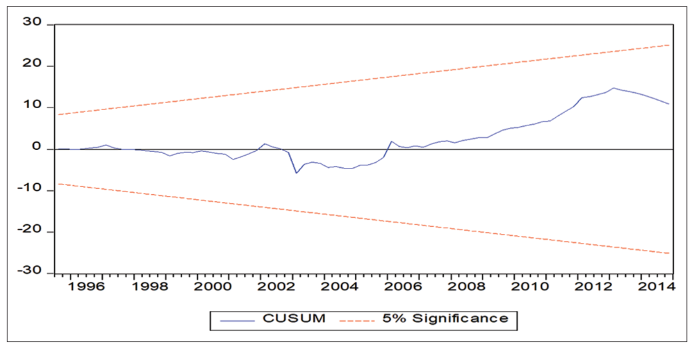
Source: Own calculation

Table 7: VECM

Dependent variable	Types of causality					
	Short run					Long run
	$\sum\Delta$Lgdp	$\sum$ Δlre	$\sum$ Δltr	$\sum\Delta$lk	$\sum$ Δlem	ECT_{t-1}
ΔLgdp		0.33	0.04	2.71***	1.19	0.0869
Δlre	0.40		0.08	0.32	0.12	−0.3628*
Δltr	2.52**	0.22		2.12	0.99	0.1630
Δlk	3.49**	0.48	0.05		1.00	0.44**
Δlem	0.53	0.01	0.004	1.01		0.0179

Source: Own calculation. VECM: Vector error correction model

Figure 1: CUSUM



5. CONCLUSION

This paper investigated the causal relationship between renewable energy consumption and economic growth in Argentina for the period 1990-2014. Despite numerous studies which were conducted on this notion, there is still no consensus as to whether renewable energy consumption drives economic growth or whether it is economic growth that stimulates renewable energy consumption. Unlike some of the previous studies done on this subject, the current study employed the recently developed ARDL bounds testing approach to co-integration and the Vector Error Correction Model Granger-causality to determine this relationship. To the best of the author's knowledge, this might be the first study of its kind to investigate the causal relationship between renewable energy consumption and economic growth in Argentina using this modern time-series techniques.

The empirical results established that there is a long run relationship between economic growth, renewable energy consumption, trade openness, capital and employment in Argentina. The VECM test technique confirmed a unidirectional causality flowing from economic growth, trade openness, capital and employment to renewable energy consumption. More specifically, economic growth Granger-causes renewable energy consumption. This implies that economic growth drives renewable energy consumption but not the other way around. In this case, implementation of the energy conservation policies will have a minor or no effect at all on economic growth. Therefore, the study recommends that the energy conservation policies should be applied to curb unnecessary waste of energy in Argentina.

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