Revisiting the Electricity Consumption-Growth Nexus for Portugal: Evidence from a Multivariate Framework Analysis

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REVISITING THE ELECTRICITY CONSUMPTION-GROWTH NEXUS FOR PORTUGAL: EVIDENCE FROM A MULTIVARIATE FRAMEWORK ANALYSIS

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ABSTRACT

The aim of present paper is to re-investigate the long-run and causal relationship between electricity consumption, income, financial development, population and foreign trade in Portugal using the bounds testing approach to cointegration within the unrestricted error-correction model (UECM). The Granger causality test within the Vector Error-Correction Model (VECM) was conducted to examine the direction of causality. This study covered the annual sample of 1971 to 2009. Our empirical evidence supports the presence of a long-run relationship between the variables in Portugal. Moreover, the results indicate that increase in real income, financial development, population and foreign trade has positive impact on electricity consumption in Portugal. In addition, the overall Granger causality results exhibit bi-directional causal relationship between electricity consumption, real income, and population while uni-directional causality is running from financial development to electricity consumption. In this respect, Portugal is an energy dependent country, thus energy conservation policy (growth policy) may adversely affect the economic growth (environment or pollution) in Portugal. Ultimately, the Portuguese government should encourage research and development on technological innovation for energy savings without affecting economic development in Portugal.

Keywords: Causality; electricity consumption; financial development; Portugal
JEL classification: C32; O52; Q20; Q43

1. INTRODUCTION

The energy-income nexus is of great interest to economists as well as policymakers because of its significant policy implication. Kraft and Kraft (1978) was the first empirical work that dealing with the causal relationship between energy consumption and income. Their findings suggested strong uni-directional causality running from income to energy consumption in the United States. Motivated by interesting findings of the study, voluminous of empirical studies were conducted to replicate the causal relationship between energy (electricity) consumption and income (e.g., Li et al., 2008; Abosedra et al., 2009; Apergis and Payne, 2010) at different countries and/or regions. This is because understanding the interaction between energy (electricity) consumption and income is the key to a successful environmental and growth policy. For example, if the causality finding supports the *growth hypothesis* that is uni-directional causality running from energy (electricity) consumption to income, restriction of energy (electricity) consumption may adversely affect the process of economic growth and development. On the other hand, if there is evidence of uni-directional causality running from income to energy (electricity) consumption, environmental policy to conserve energy (electricity) consumption may have less or no impact on the economic growth. This is known as the *conservation hypothesis*. To the best of our knowledge on literature review, however the findings of the existing empirical studies do not show strong consensus evidence of the causal relationship between energy (electricity) consumption and income for country-specific, multi-countries as well as regional studies (Karanfil, 2009). Therefore, it is obstacle to provide a reliable policy recommendation for energy, environmental, and economics. Ozturk (2010) and Payne (2010) performed a comprehensive literature survey on the energy-growth nexus and also on the electricity consumption-growth nexus. Remarkably, both literatures survey consistently exhibited that the major factors for the ambiguous causality evidences are: (a) omission of relevant variables, (b) methodological flaws, and (c) different time span of study. Karanfil (2009) added that those research papers just changing the time period of analysis insufficient contribution neither to the literatures nor policymakers to formulate effective policy. They indicate that there should be other potential variables that could affect energy (electricity) consumption. For these reasons, empirical studies on the energy (electricity) consumption-income nexus began to include other variables such as carbon dioxide (CO_2) emissions (Ang, 2007), exports (Lean and Smyth, 2010), labour or employment (Chang et al., 2001; Warr and Ayres, 2010), population (Batliwala and Reddy, 1994; Tang, 2009), financial development (Yan and Zhang, 2009; Sadorsky, 2010), energy prices (Masih and Masih, 1997; Chandran et al., 2010), and foreign direct investment (Tang, 2009; Sadorsky, 2010).

The gap in the literature is that empirical study concerning the relationship between electricity consumption and income in Portugal is scarce. As far as we know, only Murry and Nan (1994) and Narayan and Prasad (2008) have investigated the electricity consumption-income nexus in Portugal, however they used a bi-variate framework which may suffer from the omission of variables bias (Lütkepohl, 1982). In addition, the direction of causality between electricity consumption and income for Portugal remains ambiguous. Murry and Nan (1994) suggested the *neutrality hypothesis*, while Narayan and Prasad (2008) exhibited uni-directional causality runs from electricity consumption to income. In light of this, it is utmost important to establish an empirical study fill the lacuna by re-investigating the electricity consumption-income nexus in the Portuguese economy with a multivariate framework. Unlike the earlier studies for Portugal on this topic, we take into account other potential variables such as financial development, population, and also foreign trade into the electricity consumption model. In addition to that, population growth has significant implication on electricity consumption. Some earlier studies included employment into the electricity consumption specification as the proxy for electricity user. Ironically, Tang (2008) argued that employment alone cannot represent the total population of electricity user because electricity is for all categories of population in an economy. Besides that, Lean and Smyth (2010) applied exports as a proxy for international trade to study the electricity consumption-income nexus. Against, exports alone may not be a good proxy to represent international transaction because both importing and exporting activities are consumes energy (electricity). In this respect, we suggest to use foreign trade measured by the ratio of total trade (export plus import) to gross domestic product (GDP).

Obviously, this paper not only looks into the electricity consumption-income nexus, but it is also examining the dynamic relationship between electricity consumption, income, financial development, population, and foreign trade in the Portuguese economy. By doing so, we have effectively married the literature on the electricity consumption-income nexus, finance-income nexus, trade-income nexus, and population-income nexus. Therefore, the results of this study are more robust, reliable, and relevant for policymaking. In terms of methodology, we follow Ozturk's (2010) recommendation to employ the bounds testing approach to cointegration developed by Pesaran et al. (2001) to examine the presence of a long-run equilibrium relationship between electricity consumption and its determinants. For the policymaking purposes, the Granger causality test within the vector error-correction model (VECM) will be employed to verify the direction of causality between the variables of interest.

The rest of this study is organised follows. Section 2 presents the literature review. Section 3 set out the data, model and estimation procedures used in this study. Section 4 discusses the empirical findings and finally the conclusion and policy recommendations will be reported in Section 5.

2. SURVEY OF EXISTING EMPIRICAL STUDIES

Review of empirical literatures, there are two strands of studies on the direction of causal relationship between electricity consumption and economic growth. The first strand of empirical literature reveals with multi-countries studies while the second strand of literature is linked with single-country studies. The energy (electricity)-growth nexus has been investigated extensively by using variety of methods such as Granger causality concept. Table 1 shows the finding of multi-countries studies, while Table 2 summarise the findings of single-country studies. The general conclusion from relevant literature reported in Table 1 and Table 2 is that that the causal relationship between electricity consumption and economic growth has been mixed.

For the case of multi-countries studies, Yoo (2006) conducted a study to examine the causal relationship between electricity consumption and economic growth for four ASEAN countries namely Indonesia, Malaysia, Singapore, and Thailand. Empirical evidence indicated bi-directional causality between electricity consumption and economic growth in Malaysia and Singapore. On the other hand, one-way causal relation was found from economic growth to electricity consumption in Indonesia and Thailand. Similarly, Wolde-Rufael (2006) investigated the relationship between electricity consumption and real GDP per capita (economic growth) for 17 African economies. Bounds testing approach to cointegration developed by Pesaran et al. (2001) was applied to examine the presence of long-run equilibrium relationship and the causality test suggested by Toda and Yamamoto (1995) was used to determine the direction of causality between the variables of interest. The results show that cointegration is only found in nine out of seventeen countries. However, causality analysis implies that electricity consumption Granger-causes economic growth in Benin, the Democratic Republic of Congo, and Tunisia, while economic growth Granger-causes electricity consumption in Cameroon, Ghana, Nigeria, Senegal, and Zimbabwe. Moreover, there exists bi-directional causal relationship between the variables in case of Egypt, Gabon, and Morocco.[1]

[1] Unfortunately, there exists no causal relationship between both variables for the case of Algeria, Congo Republic, Kenya, South Africa and Sudan over the period.

Table 1: The summary of multi-country studies on the electricity-growth nexus

No.	Authors	Period	Countries	Methodology	Direction of Granger causality
1.	Wolde-Rufael (2006)	1971–2001	17 African	ARDL Bounds testing;	$EC \rightarrow Y$ (Benin, Congo DR, Tunisia)
				Toda-Yamamoto's test for causality – Augmented VAR	$Y \rightarrow EC$ (Cameroon, Ghana, Nigeria, Senegal, Zambia, Zimbabwe)
					$EC \leftrightarrow Y$ (Egypt, Gabon, Morocco)
					$EC \not\leftrightarrow Y$ (Algeria, Congo Rep., Kenya, South Africa, Sudan)
2.	Yoo (2006)	1971–2002	4 ASEAN	Engle-Granger; Johansen-Juselius;	$Y \rightarrow EC$ (Indonesia, Thailand)
				Granger causality; Hsiao's causality – VAR	$EC \leftrightarrow Y$ (Malaysia, Singapore)
3.	Chen et al. (2007)	1971–2001	10 Asian	Johansen-Juselius;	$EC \rightarrow Y$ (Hong Kong)
				Granger causality – VECM	$Y \rightarrow EC$ (India, Malaysia, Philippines, Singapore)
					$EC \not\leftrightarrow Y$ (China, Indonesia, Korea, Taiwan, Thailand)
4.	Squalli (2007)	1980–2003	11 OPEC	ARDL Bounds testing;	$EC \rightarrow Y$ (Indonesia, Nigeria, UAE, Venezuela)
				Toda-Yamamoto's test for causality	$Y \rightarrow EC$ (Algeria, Iraq, Kuwait, Libya,)
				– Augmented VAR	$EC \leftrightarrow Y$ (Iran, Qatar, Saudi Arabia)
5.	Narayan and Prasad (2008)	1960–2002	30 OECD	Toda-Yamamoto's test for causality	$EC \rightarrow Y$ (Australia, Czech Rep., Italy, Slovak Rep., Portugal)
				with bootstrapping approach	$Y \rightarrow EC$ (Finland, Hungary, Netherlands)
					$EC \leftrightarrow Y$ (Iceland, Korea, UK)
					$EC \not\leftrightarrow Y$ (rest of the 19 countries)
6.	Yoo and Kwak (2010)	1975–2006	7 South	Johansen-Juselius; Granger causality;	$EC \rightarrow Y$ (Argentina, Brazil, Chile, Colombia, Ecuador)
			American	Hsiao's test for causality–	$EC \leftrightarrow Y$ (Venezuela)
				VAR and VECM	$EC \not\leftrightarrow Y$ (Peru)
7.	Ozturk and Acaravci (2010)	1980–2006	4 European	ARDL Bounds testing;	$EC \leftrightarrow Y$ (Hungary)
				Granger causality – VECM	$EC \not\leftrightarrow Y$ (Albania, Bulgaria, Romania)

Note: *EC* and *Y* represent electricity consumption and economic growth, respectively. $\rightarrow$, $\leftrightarrow$ and $\not\leftrightarrow$ represent unidirectional causality, bi-directional causality, and neutral causality, respectively.

For case of GCC countries, Squalli and Wilson (2006) investigated the electricity consumption-income growth hypothesis. Their empirical evidence indicated cointegration between the both variables. The causality analysis revealed bi-directional causality between electricity consumption and economic growth in Bahrain, Qatar and the Kingdom of Saudi Arabia (KSA), while unidirectional causality from economic growth to electricity consumption were observed in Kuwait and Oman.

Chen et al. (2007) re-investigated the relationship between electricity consumption and economic growth in China, Hong Kong, Indonesia, India, Korea, Malaysia, the Philippines, Singapore, Taiwan and Thailand. Their results confirm cointegration between electricity consumption and economic growth except in China and Malaysia. Panel Granger causality test reported bi-directional causality between electricity consumption and economic growth in long run and economic growth seems to Granger-causes electricity consumption short run.

Recently, Yoo and Kwak (2010) analyse the relationship between electricity consumption and economic growth in seven South American economies using cointegration and the Hsiao's (1981) version of Granger causality tests. Interestingly, they found that most of the selected countries support uni-directional causality running from electricity consumption to economic growth (i.e. Argentina, Brazil, Chile, Colombia, and Ecuador). While the rest of the two countries such as Venezuela supports conservation hypothesis and Peru supports the feedback hypothesis.

Narayan and Prasad (2008) examined causality between electricity consumption and economic growth over 38 OECD countries including Portugal. They used bootstrapping causality test and did not pay attention to explaining the presence of long-run relationship between the variables. Their findings showed that electricity consumption Granger-causes economic growth in case of Australia, Iceland, Italy, the Slovak Republic, the Czech Republic, Korea, Portugal, and the UK. The unidirectional causality was found running from economic growth to electricity consumption in Finland, Hungry, Korea, Netherlands and UK[2]. Similarly, Böhm (2008) conducted a study to investigate cointegration and causality between electricity consumption and economic growth[3] by employing VECM. The results showed one-way causal relation from electricity consumption in Belgium, Greece, Italy and the Netherlands while unidirectional found running from economic growth to electricity consumption in Ireland, Portugal and Spain. Moreover, electricity consumption and economic growth granger caused each other in case of Germany[4].

Narayan and Smyth (2009) assessed the causal link between income, electricity consumption and exports in Middle Eastern Countries namely, Iran, Israel, Kuwait, Oman, Saudi Arabia, and Syria. The results of panel granger causality reveal unidirectional causality found running from electricity consumption to economic growth while economic growth granger-caused to export only in short run. Besides that, Yoo and Kwak (2010) performed causality test to investigate relationship between electricity consumption and economic growth in seven South American countries i.e. Argentina, Brazil, Chile, Columbia, Ecuador, Peru, and Venezuela. Empirical evidence indicated unidirectional causality running from electricity consumption to economic growth in Argentina, Brazil, Columbia and Ecuador while economic growth granger caused electricity consumption in the case of Venezuela[5].

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[2] There was no causal link between electricity consumption and economic growth in Belgium, Canada, Denmark, France, Germany, Greece, Ireland, Japan, Luxembourg, New Zealand, Norway, Poland, Spain, Sweden, Switzerland, Turkey, Mexico, and the USA.

[3] Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, the Netherlands, Portugal, Spain and Sweden

[4] There is no causality was found in Austria, Denmark, Finland, France, Luxemburg and Sweden

[5] There was no causal relation was between both variables in case of Peru.

Table 2: The summary of major findings of single-country studies on the electricity-growth nexus

No.	Growth hypothesis	Conservation hypothesis	Feedback hypothesis	Neutrality hypothesis
1.	Aqeel and Butt (2001)	Ghosh (2002)	Yang (2000)	–
2.	Altinay and Karagol (2005)	Narayan and Smyth (2005)	Jumbe (2004)	
3.	Lee and Chang (2005)	Yoo and Kim (2006)	Zachariadis and Pashouortidou (2007)	
4.	Shiu and Lam (2005)	Ho and Siu (2007)	Tang (2008)	
5.	Yoo (2005)	Mozumder and Marathe (2007)	Aktas and Yilmaz (2008)	
6.	Narayan and Singh (2007)	Jamil and Ahmad (2010)	Odhiambo (2009b)	
7.	Yuan et al. (2007)	Ciarreta and Zarraga (2010)	Tang (2009)	
8.	Abosedra et al. (2009)		Lean and Smyth (2010)	
9.	Gupta and Chandra (2009)		Ouédraogo (2010)	
10.	Chandran et al. (2010)		Lorde et al. (2010)	
11.	Odhiambo (2009a)		Acaravci (2010)	

Note: Growth hypothesis represents uni-directional causality running from electricity consumption to economic growth; Conservation hypothesis represents uni-directional causality running from economic growth to electricity consumption; Feedback hypothesis represents bi-directional causality; Neutrality hypothesis represents no causality.

Apart from that, Ciarreta and Zarraga (2010) performed panel cointegration and causality tests to investigate the long-run and causal relationship between electricity consumption and real GDP European[6]. Empirical evidence indicated long-run equilibrium relationship between electricity consumption, electricity prices and real GDP. Unidirectional causality from electricity consumption to GDP and bivariate between energy prices and GDP was found[7].

Next, there are voluminous of studies on single-country, hence it is impossible for us to comprehensively discuss all the empirical studies in the precise manner. Therefore, we divided the studies based the four types of hypothesis suggested by Payne (2009) to make the discussion concise but clear. The hypotheses are (a) *Growth hypothesis*, (b) *Conservation hypothesis*, (c) *Feedback hypothesis*, and (d) *Neutrality hypothesis*.

As shown in Table 2, growth and feedback hypotheses are usually found by the studies compared to the rests of the two hypotheses. However, there is very limited evident for neutrality hypothesis. From our literature survey, no country-specific study on electricity-growth nexus supports the neutrality hypothesis. There are quite a numbers of studies support the growth hypothesis where there is uni-directional Granger causality running from electricity consumption to economic growth. For example, Aqeel and Butt (2001) for Pakistan, Altinay and Karagol (2005) for Turkey, Lee and Chang (2005) for Taiwan, Shiu and Lam (2004) for China, Yoo (2005) for Korea, Narayan and Singh (2007) for Fiji Islands, Yuan et al. (2007) for China, Abosedra et al. (2009) for Lebanon, Gupta and Chandra (2009) for India, Chandran et al. (2009) for Malaysia, and Odhiambo (2009a) for Tanzania. On the other hand, Ghosh (2002), Narayan and Smyth (2005), Yoo and Kim (2006), Ho amd Siu (2007), Mozumder and Marathe (2007), Jamil and Ahmad (2010), and Ciarreta and Zarraga (2010) found uni-directional causality running from economic growth to electricity consumption in India, Australia, Indonesia, Hong Kong, Bangladesh, Pakistan, and Spain, respectively. Evidently, the findings of these studies support the conservation hypothesis. Eventually, there are also studies that found bi-directional Granger causality between electricity consumption and economic growth using the cointegration and Granger causality tests. This is also known as the feedback hypothesis. From summary of literature survey of single-country reported in Table 1, Yang (2000) for Taiwan, Jumbe (2004) for Malawi, Zachariadis and Pashouortidou (2007) for Cyprus, Tang (2008) for Malaysia, Aktas and Yilmaz (2008) for Turkey, Odhiambo (2009b) for the South Africa, Tang (2009) for Malaysia, Lean and Smyth (2010) for Malaysia, Ouédraogo (2010) for Burkina Faso, Lorde et al. (2010) for Barbados, and Acaravci (2010) for Turkey are supporting this hypothesis.

3. METHODOLOGY

3.1 Data

This study uses the secondary annual data of electricity consumption (EC) per capita (in million KWh), real gross domestic product (GDP) per capita (2000 = 100), financial development (FD) is measured by the ratio domestic credit to private sector to GDP,[8] total

[6] Austria, Belgium, Denmark, Finland, France, Germany, Italy, Luxembourg, Netherlands and Sweden, and two non-EU countries: Norway and Switzerland.

[7] Acaravci and Ozturk (2010) examined the long-run relationship and causality between electricity consumption and economic growth in Transition countries namely Austria, Belgium, Denmark, Finland, France, Germany, Italy, Luxembourg, Netherlands and Sweden, and two non-EU countries: Norway and Switzerland. Their results found no cointegration between electricity consumption and real GDP. This could not lead them to pursuance in investigating causality between both variables.

[8] For variable justification see (Shahbaz et al. 2008; Shahbaz, 2009; Shahbaz et al. 2010)

population (POP), and foreign trade (TR) is measured by the ratio of total trade (export plus import) to GDP. This study covers the sample period of 1971 to 2009. All data are collected from the World Bank, *World Development Indicators* (WDI) database. Ultimately, all series are transformed into natural logarithm form to obtain stationarity in the variance-covariance matrix (Chang et al., 2001; Fatai et al., 2004).

3.2 Empirical model

Based on the compelling argument presented in the earlier sections, electricity consumption of a country could be affected by income (GDP), financial development (FD), population (POP), and foreign trade (TR). Therefore, the empirical model of this study can be specified as follow.

$$\ln EC_t = \eta_0 + \eta_1 \ln GDP_t + \eta_2 \ln FD_t + \eta_3 \ln POP_t + \eta_4 \ln TR_t + \mu_t \quad (1)$$

Here, $\ln$ denotes the natural logarithm, $\ln EC_t$ is the electricity consumption per capita, $\ln GDP_t$ is the real GDP per capita, $\ln POP_t$ is the population, and $\ln TR_t$ is the foreign trade. The residuals μ_t are assumed to be normally distributed and white noise. The parameters $(\eta_1, \eta_2, \eta_3, \eta_4)$ are expected to be positive in sign. The positive sign of income need no further explanation because it was well noted in the earlier energy literatures (e.g., Tang, 2009). It is more interest to focus on how financial development, population, and foreign trade induce electricity consumption to change. Sadorsky (2010) pointed out that several way that financial development can affect electricity consumption. The development of financial system will provide more facilities for consumers to purchase electronic and electrical appliances (i.e., televisions, computers, refrigerators, washing machines, and air conditioners). In addition, financial development also benefited the producers by borrowing money to purchase machinery and equipments for production. Therefore, the demand for electricity is expected to be positively related to financial development (see also Yan and Zhang, 2009). Apart from that, more people will consume more energy (electricity). Therefore, whenever population is high, the demand for electricity tends to be high (Tang, 2009). Finally, more international trade activities will consume more electricity to support daily imports and exports transactions (see Halicioglu, 2009; Narayan and Smyth, 2009). Therefore, it is very important to include foreign trade into the model and it is positively related with electricity consumption.

3.2 Estimation procedures

Confirming the order of integration is a pre-requisite for almost all time series analysis. In this study, we applied the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and Kwaitkowski-Phillips-Schmidt-Shin (KPSS) unit root tests to determine the order of integration for each series. Since the ADF test is low power in small sample (Cheung and Lai, 1995), we also applied the PP and KPSS unit root tests to check the robustness of the estimation results.[9]

After determining the order of integration, we employ the bounds testing approach to cointegration (Pesaran et al., 2001) within the autoregressive distributed lag (ARDL) framework to investigate the existence of a long-run equilibrium relationship between the variables of interest. The bounds testing approach has certain advantages over the conventional cointegration techniques. Unlike the conventional cointegration techniques, the

[9] Amano and van Norden (1992), Kwaikowski et al. (1992), and Cheung and Chinn (1997) pointed out that a joint-testing unit root procedure can substantially increase the robustness of the results.

bounds testing approach can be applied to the model irrespective of whether the variables are purely $I(0)$ or purely $I(1)$. In addition to that, the Monte Carlo analysis exhibits that the ARDL cointegration approach has superior properties in small sample (e.g., Pesaran and Shin, 1999). The ARDL model for bounds testing to cointegration can be formulated as follows:

$$\Delta \ln EC_t = a_0 + \sum_{j=1}^{k} b_j \mathrm{DET}_{j,t-1} + \sum_{i=1}^{p} c_{0i} \Delta \ln EC_{t-i} + \sum_{i=0}^{p} \sum_{j=1}^{k} c_{ji} \Delta \mathrm{DET}_{j,t-i} + \varepsilon_t \qquad (2)$$

Here $\ln EC_t$ is the electricity consumption per capita and DET_t is a vector of k determinant of $\ln EC_t$ which includes $\ln GDP_t$, $\ln FD_t$, $\ln POP_t$, and $\ln TR_t$. p is the lag order selected by Akaike's Information Criterion (AIC). The residuals ε_t are assumed to be normally distributed and white noise. According to Pesaran et al. (2001), we can use the F-test to determine the presence of a long-run relationship by restricting the coefficients of the lagged level variables $\left(H_0 : b_0 = b_1 = \ldots = b_k = 0\right)$ in Equation (2). Pesaran et al. (2001) computed two set of asymptotic critical values for ARDL cointegration test that is lower bounds critical values $I(0)$ and upper bounds critical values $I(1)$. Strictly speaking, the critical values tabulated in Pesaran et al. (2001) are not suitable for small sample study. In order to circumvent this problem, Narayan (2005) provided a new set of critical values for small sample.[10] Given the sample size of our study is only 40 observations; we employ the critical values suggested by Narayan (2005) instead of Pesaran et al. (2001).

If the calculated F-statistics exceeds the upper critical value, we conclude in favour of a long-run relationship regardless of the order of integration. If the calculated F-statistics falls below the lower critical values, we cannot reject the null hypothesis of no cointegration. However, if the calculated F-statistic falls between the critical bounds, inference would be inconclusive.

3.4 Granger causality

According to the concept of Granger causality, 'X causes Y' if and only if the past values of X help to predict the changes of Y. While, 'Y causes X' if and only if the past values of Y help to predict the changes of X. The vector autoregression (VAR) model is likely to be used for this purpose. However, Granger (1988) noted that a set of variables are cointegrated, meaning that there contained short- and also long-run Granger causality information. Therefore, if electricity consumption and its determinants are cointegrated, we implement the Granger causality test with the VECM framework as follows:

$$\Delta \ln EC_t = \alpha_1 + \sum_{i=1}^{p} \beta_i \Delta \ln EC_{t-i} + \sum_{i=1}^{p} \vartheta_i \Delta \ln GDP_{t-i} + \sum_{i=1}^{p} \kappa_i \Delta \ln FD_{t-i} + \sum_{i=1}^{p} \theta_i \Delta \ln POP_{t-i} + \sum_{i=1}^{p} \phi_i \Delta \ln TR_{t-i} + \psi_1 ECT_{t-1} + \upsilon_{1t} \qquad (3)$$

[10] Apart from that, Turner (2006) also suggested a surface response procedure to compute the small sample critical values. Unfortunately, this procedure is limited to four variables cases only.

$$\Delta \ln GDP_t = \alpha_2 + \sum_{i=1}^{p} \vartheta_i \Delta \ln GDP_{t-i} + \sum_{i=1}^{p} \beta_i \Delta \ln EC_{t-i} + \sum_{i=1}^{p} \kappa_i \Delta \ln FD_{t-i} + \sum_{i=1}^{p} \theta_i \Delta \ln POP_{t-i} + \sum_{i=1}^{p} \phi_i \Delta \ln TR_{t-i} + \psi_2 ECT_{t-1} + \upsilon_{2t} \quad (4)$$

$$\Delta \ln FD_t = \alpha_3 + \sum_{i=1}^{p} \kappa_i \Delta \ln FD_{t-i} + \sum_{i=1}^{p} \beta_i \Delta \ln EC_{t-i} + \sum_{i=1}^{p} \vartheta_i \Delta \ln GDP_{t-i} + \sum_{i=1}^{p} \theta_i \Delta \ln POP_{t-i} + \sum_{i=1}^{p} \phi_i \Delta \ln TR_{t-i} + \psi_3 ECT_{t-1} + \upsilon_{3t} \quad (5)$$

$$\Delta \ln POP_t = \alpha_4 + \sum_{i=1}^{p} \theta_i \Delta \ln POP_{t-i} + \sum_{i=1}^{p} \beta_i \Delta \ln EC_{t-i} + \sum_{i=1}^{p} \vartheta_i \Delta \ln GDP_{t-i} + \sum_{i=1}^{p} \kappa_i \Delta \ln FD_{t-i} + \sum_{i=1}^{p} \phi_i \Delta \ln TR_{t-i} + \psi_4 ECT_{t-1} + \upsilon_{4t} \quad (6)$$

$$\Delta \ln TR_t = \alpha_5 + \sum_{i=1}^{p} \phi_i \Delta \ln TR_{t-i} + \sum_{i=1}^{p} \beta_i \Delta \ln EC_{t-i} + \sum_{i=1}^{p} \vartheta_i \Delta \ln GDP_{t-i} + \sum_{i=1}^{p} \kappa_i \Delta \ln FD_{t-i} + \sum_{i=1}^{p} \theta_i \Delta \ln POP_{t-i} + \psi_5 ECT_{t-1} + \upsilon_{5t} \quad (7)$$

where Δ is the first difference operator and $\ln$ is the natural logarithm. The residuals υ_{it} are assumed to be normally distributed and white noise. ECT_{t-1} is the one period lagged error-correction term derived from the cointegration equation. The ECT_{t-1} variable will be excluded from that model if the variables are not cointegrated. The optimal lag length p is determined by the Akaike's Information Criterion (AIC) because of its superior performance in small sample (Lütkepohl, 2005). Next, we apply the Likelihood Ratio (LR) statistics to ascertain the direction of Granger causality between the variables of interest. In this study, we test the following hypotheses:

$H_{01}: \vartheta_1 = \vartheta_2 = \cdots = \vartheta_p = 0$, implying that GDP does not Granger-cause EC,
$H_{02}: \beta_1 = \beta_2 = \cdots = \beta_p = 0$, implying that EC does not Granger-cause GDP,
$H_{03}: \kappa_1 = \kappa_2 = \cdots = \kappa_p = 0$, implying that FD does not Granger-cause EC,
$H_{04}: \theta_1 = \theta_2 = \cdots = \theta_p = 0$, implying that POP does not Granger-cause EC,

and so on for the other variables.

4. EMPIRICAL RESULTS AND DISCUSSION

In this section, we begin by testing the order of integration using the ADF, PP and KPSS unit root tests. The results of the three unit root tests are reported in Table 3. At the 1 per cent significant level, the results of ADF unit root test suggest that all variables are integrated of order one, $I(1)$ process, except for population is found to $I(0)$ process. However, the PP and KPSS unit root tests exhibit that all variables included population are stationary at the first difference. As noted in the earlier section, the ADF test often has weak power when the sample size of a study is small, so we preferred to use the results provided by PP and KPSS unit root tests. For this reason, we surmised that the variables can be well characterised as $I(1)$ process.

Table 3: Unit root estimation

Variables	ADF	PP	KPSS
$\ln EC_t$	–3.173 (0)	–3.063 (3)	0.243 (3)***
$\Delta \ln EC_t$	–5.106 (3)***	–9.330 (3)***	0.052 (3)
$\ln GDP_t$	–2.036 (2)	–2.576 (3)	0.170 (3)**
$\Delta \ln GDP_t$	–4.901 (3)***	–3.997 (3)**	0.060 (3)
$\ln FD_t$	– 1.833 (2)	–0.999 (3)	0.232 (3)***
$\Delta \ln FD_t$	–4.410 (0)***	–4.455 (3)***	0.099 (3)
$\ln POP_t$	–7.200 (3)***	–1.837 (3)	0.162 (3)**
$\Delta \ln POP_t$	–4.361 (3)***	–6.263 (3)***	0.067 (3)
$\ln TR_t$	–3.001 (1)	–2.698 (3)	0.120 (3)*
$\Delta \ln TR_t$	–4.625 (3)***	–5.422 (3)***	0.052 (3)

Note: ***, ** and * denote the significant at the 1, 5 and 10 per cent level, respectively.

Given that all variables are found to be stationary after first differencing, we proceed to examine whether electricity consumption per capita, real income per capita, financial development, population, and foreign trade to form a cointegrating relationship using the bounds test for cointegration approach. An important issue in applying bounds testing approach to cointegration is the selection of the optimal lag length. We set the maximum lag length at 3 years which is sufficiently long for annual data study to capture the dynamic relationship, then the AIC statistic is use to choose a best ARDL model. AIC statistics is preferred in this study because it has superior properties, particularly in small sample (Lütkepohl, 2005). According to AIC statistics, ARDL(1,2,1,1,0) is the best model and the model also passes a number of diagnostic tests.[11] The results of the cointegration test are reported in Table 4.

[11] The Jarque-Bera (JB) normality indicates that the residuals are normally distributed, 0.504 (0.777). The Breusch-Godfrey (BG) Lagrange Multiplier (LM) statistics cannot reject the null hypothesis of no serial correlation, [1]: 1.623 (0.203) and [2]: 3.027 (0.220). The Autoregressive Conditional Heteroskedasticity (ARCH) LM test statistics shows absence of heteroskedasticity problem in the residuals, [1]: 0.082 (0.775) and [2]: 0.515 (0.733). The Ramsey RESET test exhibit no general specification error, [1]: 0.336 (0.562). Finally, the plots of CUSUM and CUSUM of Squares statistics do not break the 5 per cent critical bounds, thus reveal

Table 4: The results of ARDL cointegration test

Panel I: Bounds testing to cointegration		
	$F_{EC}\left(EC\middle|GDP,FD,POP,TR\right)$	
Optimal lag structure	(1, 2, 1, 1, 0)	
F-statistics	7.419***	
Significant level	Critical values (T = 40)[#]	
	Lower bounds, $I(0)$	Upper bounds, $I(1)$
1 per cent	4.045	5.898
5 per cent	2.962	4.268
10 per cent	2.483	3.647
Panel II: Diagnostic tests	Tests statistic	
R^2	0.895	
Adjusted- R^2	0.828	
F-statistics	13.358 (0.000)***	
JB Normality test	0.504 (0.777)	
Breusch-Godfrey LM test	[1]: 1.623 (0.203), [2]: 3.027 (0.220)	
ARCH LM test	[1]: 0.082 (0.775), [2]: 0.515 (0.773)	
Ramsey RESET	[1]: 0.336 (0.562)	

Note: The asterisks ***, ** and * denote the significant at 1, 5 and 10 per cent levels, respectively. The optimal lag structure is determined by AIC. [ ] is the order of diagnostic tests, while ( ) is the p-values. # Critical values are collected from Narayan (2005).

To ascertain the presence of cointegrating relationship among electricity consumption and its determinants, a joint significance F-test for the null hypothesis of no cointegrating relations $\left(H_0: b_0 = b_1 = \ldots = b_k = 0\right)$ was conducted. Interestingly, the calculated F-statistics for cointegration test $F_{EC}\left(EC\middle|GDP,FD,POP,TR\right) = 7.419$ is higher than the 1 per cent upper bounds critical values (5.898) provided by Narayan (2005). This implied that we do find evidence of a cointegrating relationship between electricity consumption and its determinants in the Portuguese economy. Therefore, computation of long-run relationship is needed to assess the effect of real income per capita, financial development, population, foreign trade on electricity consumption per capita in Portugal. The results of long-run elasticities and the t-statistics are presented in Table 5. Given the small sample, we employed the simple Ordinary Least Squares (OLS) estimator proposed by Engle and Granger (1987). If the variables are cointegrated, OLS estimator is valid and super-consistent. Moreover, Abeysinghe and Tan (1999) suggests that in the case of small sample, the performance of the simple OLS estimator is superior to other long-run estimators (i.e., ARDL, Fully Modified OLS, three-step OLS, Dynamic OLS, and Johansen's Maximum Likelihood).

Foremost, we find that all variables are positive sign where consistent with the earlier literature on this topic. Among our key results, we find that real income and population are statistically significance at the 1 per cent level, while financial development and foreign trade are statistically significance at the 10 per cent level. Among four explanatory variables, real

that the estimated parameters are stable over the sample period. [ ] and ( ) are the order of diagnostics tests and the p-values, respectively.

income and population are the dominant factors for electricity consumption in Portugal. Tellingly, a 1 per cent increase in real income per capita and population, on average electricity consumption per capita in Portugal will increases by 1.4 and 2.4 per cent, respectively. On the other hand, the effects of financial development and foreign trade on electricity consumption per capita are inelastic. A 1 per cent increase in financial development and foreign trade, the demand for electricity in Portugal will increase less than 1 per cent (i.e., 0.04 and 0.16 per cent). Based on the magnitude and also the significance level of the selected variables, we can confidently claim that the earlier studies on Portugal (i.e., Murry and Nan, 1994; Narayan and Prasad, 2008) which focused on bi-variate framework are bias owing to the omission of variables.

Table 5: The results of cointegrating relationship

Dependent variable: $\ln EC_t$		
Variables	Coefficients	t-statistics
Constant	–11.365	–34.450***
$\ln GDP_t$	1.399	23.438***
$\ln FD_t$	0.044	1.716*
$\ln POP_t$	2.440	9.035***
$\ln TR_t$	0.161	1.965*

Note: The asterisks ***, ** and * denote the significant at 1, 5 and 10 per cent level, respectively.

After determining the presence of cointegrating relationship, it is also interesting to perform the Granger causality test to provide a clearer picture for policymakers to formulate energy, environment, and economic policies by understanding the direction of causality. As the variables are cointegrated, we employed the VECM framework as presented in the previous section to achieve the objective. The results of Granger causality are presented in Table 6. Since the variables are cointegrated, the direction of causality can be divided into short- and long-run causation. The t-significance of the one period lagged error-correction term ECT_{t-1} in Equations (3) to (7), represent the long-run causality, while the joint significance LR test of the lagged explanatory variables represent the short-run causality. Begin with the long-run causality, our empirical results suggest that the ECT_{t-1} is negative sign and statistically significant in all VECM, implying that there is bi-directional causality between the variables of interest in the long-run. In addition to that, the significant of ECT_{t-1} also exhibiting that if the system expose to shock it will convergence to the long-run equilibrium at a relatively slow speed for financial development (–0.116) and population (–0.258) VECMs compare to the convergence speed of electricity consumption (–0.750), real income (–0.777), and foreign trade (–0.772) VECMs.

Contrary with the finding of long-run causality, we find that the short-run causality vary among VECMs. In summary, our empirical evidence shows that at the 1 per cent level there is Granger causality runs from real income, financial development, and population to electricity consumption. However, at the same level of significance, the results shows Granger causality runs from electricity consumption to real income, population and foreign trade. With respect to these findings, we affirmed that electricity consumption, real income, and population are bilateral causality, and these results are significantly contradicted with the findings provided by the earlier studies for Portugal. Apart from that, at the 5 per cent level, we also find evidence of Granger causality runs from electricity consumption, financial development, and population to real income. As a result, the Portuguese dataset support the energy-led growth, finance-led growth, and population-led growth hypotheses.[12]

Table 6: The results of Granger causality test

Dependent Variable	Type of causality					
	Short-run					Long-run
	$\sum \Delta \ln EC_{t-i}$	$\sum \Delta \ln GDP_{t-i}$	$\sum \Delta \ln FD_{t-i}$	$\sum \Delta \ln POP_{t-i}$	$\sum \Delta \ln TR_{t-i}$	ECT_{t-1}
	Likelihood Ratio (LR) statistics [p-values]					[t-statistic]
$\Delta \ln EC_t$	–	31.937*** [0.0000]	13.573*** [0.0011]	9.469*** [0.0088]	0.650 [0.4199]	–0.750*** [–4.446]
$\Delta \ln GDP_t$	24.801*** [0.0000]	–	9.639** [0.0219]	30.807*** [0.0000]	1.656 [0.1981]	–0.777*** [–5.360]
$\Delta \ln FD_t$	0.407 [0.5237]	0.108 [0.7425]	–	6.309** [0.0427]	5.259* [0.0721]	–0.116** [–2.472]
$\Delta \ln POP_t$	16.012*** [0.0003]	48.882*** [0.0000]	0.375 [0.5432]	–	16.942*** [0.0002]	–0.258*** [–4.642]
$\Delta \ln TR_t$	16.860*** [0.0021]	8.444** [0.0147]	12.004*** [0.0025]	4.492** [0.0340]	–	–0.772*** [–4.469]

Note: The asterisks ***, ** and * denote the significance at the 1, 5 and 10 per cent level, respectively.

5. CONCLUSION AND POLICY IMPLICATIONS

To fill the lacuna of the previous studies, this study attempts to re-investigate the relationship between electricity consumption, real income, financial development, population, and foreign trade in Portugal using a multivariate framework analysis. In order to achieve the objective of this study, we employed the bounds testing approach to cointegration to examine the presence of cointegrating relationship. For policymaking, we applied the Granger causality test within the VECM framework to verify the direction of causality between electricity consumption, real income, financial development, population, and foreign trade in Portugal.

As a values added to the existing literature for Portugal in this topic, we find that the variables are cointegrated, meaning that there is a stable long-run relationship between electricity consumption and its determinants although there might be deviation in the short-run. Overall, the estimated long-run elasticities reveals that real income, financial development, population, and foreign trade are the importance sources for electricity consumption in Portugal even though the magnitude may deviate among variables.

[12] The Granger causality test results indicate uni-directional causality running from real income to foreign trade. This implied that export-led growth or trade-led growth may not valid in Portugal. However, we find uni-directional causality running from real income to foreign trade, meaning that the domestic market size of the Portuguese economy attracted the foreign trade.

Furthermore, the long-run elasticities results show that real income, financial development, population, and foreign trade have a positively impact on electricity consumption in Portugal.

Differ from those studies for Portugal, this study find that electricity consumption and real income is bi-directional causality, implying that energy conservation policy (growth policy) may adversely affect the economic growth (environment or pollution) in Portugal. Therefore, the Portuguese government should encourage research and development on technological innovation for energy savings. In doing so, we could simultaneously reduce environmental degrading and also enhance economic development in the Portuguese economy. In addition to that, alternative energies such as solar power, hydro power, and wind power should be considered because these alternative energies are more environmental friendly compare to fossil fuel.

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