OVERVIEW OF ELECTRICITY CONSUMPTION-ECONOMIC GROWTH CAUSALITY LITERATURE: WHERE HAS THE EMPIRICAL RESEARCH LED US FO FAR?

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Abstract

Given the undisputed theoretical and practical importance of energy, including electricity, it can be stated that this factor represents an important foundation for economic growth and development. Not only because it improves the productivity of labour, capital, technology and other production factors, but also due to the fact that increased consumption of energy, primarily electricity (as its most flexible, commercial and purest form and a key infrastructural input in the socio-economic development), affects economic growth. The lack of consensus on whether economic growth results in electricity consumption and generation or is electricity the stimulant of economic growth has aroused the curiosity and interest among economists and analysts to investigate the direction of causality between these variables. Although economic growth models explicitly do not contain energy variable(s), during the last 20 years a number of empirical research papers have addressed the causality between electricity variables (consumption and/or generation) and economic growth. Over time, various empirical studies have focused on different countries or groups of countries (both developed and developing countries as well as the so-called emerging economies), time periods, main (and proxy) variables and quantitative methods. The results of such studies are often contradictory. This can be explained by different econometric methodologies, different data set and different countries' characteristics. Furthermore, in most of the studies the causality analysis between electricity variables and the gross domestic product was carried out in the so-called bivariate framework. With the exception of a few studies, most of them do not establish whether the effect of independent variable on the dependent variable is positive or negative, nor do they examine the intensity of the causal relation. Although new and more sophisticated econometric methods for (better) identification and understanding of causality were developed over the years, an increasing number of published empirical studies regarding interconnectedness of electricity and GDP still has inconsistent results. A lack of compliance on what kind of causal relationship actually exists can result in inadequate implementation of appropriate economic and energy policy. Therefore, the aim of this paper is to give an overview of the existing literature with subsequent conclusions and guidelines for future research.

Keywords: electricity consumption, economic growth, causality literature, empirical results.

1. INTRODUCTION

After the financial sector, energy sector is probably the largest global industry with the broadest impact on other sectors of the economy since all economic activity depends on energy either in urban or rural areas. Electricity and fossil fuels are an integral part of economic growth, development and trade and form the basis for supporting the development of agriculture, industry, transport and entrepreneurship in all countries. Although energy itself is not sufficient, it is certainly a prerequisite for achieving economic growth, especially in developing countries. Given the undisputed theoretical and practical importance of energy, including electricity, it can be stated that this factor represents an important foundation for economic growth and development. A survey conducted on a sample of more than a hundred countries (Ferguson et al., 2000), confirms the existence of a strong correlation between electricity usage and the level of economic growth. However, the presence of a (theoretical and practical) correlation between electricity consumption and economic growth does not imply that there exists a causal relationship at the same time. This thematic area has been the subject of empirical research for the last several decades, although with no consensus on whether economic growth causes electricity consumption or whether electricity consumption acts as a stimulus of economic growth. The reasons for inconclusive results can be attributed to differences among countries, statistical techniques employed, time horizons and data sets. In the context of electricity sector reform, knowing the direction and intensity of causal relationship represents an important foundation for design and implementation of the appropriate economic and energy policy. Although new and more sophisticated econometric methods for (better) identification and understanding of causality were developed over the years, an increasing number of published empirical studies regarding interconnectedness of electricity and GDP still has inconsistent results. Therefore, the aim of this paper is to give an overview of the available existing literature with subsequent conclusions and guidelines for future research.

The rest of the paper is organized as follows: Section 2 presents an overview of electricity consumption-economic growth causality literature worldwide and for selected European countries while Section 3 gives remarks on the studied causality literature. Final section gives the conclusion and recommendations for further research in the field of interconnectedness between electricity consumption and economic growth.

2. OVERVIEW OF ELECTRICITY CONSUMPTION-ECONOMIC GROWTH CAUSALITY LITERATURE (WORLDWIDE AND SELECTED EUROPEAN COUNTRIES)

The existence of a causal link between electricity consumption and economic growth nowadays is mainly an accepted thesis, and at the same time, an interesting topic of many empirical studies worldwide. Research studies dealing with the interconnections between electricity consumption and economic growth, as opposed to the causality between total energy consumption and economic growth, are relatively new to the causality literature.

The causal link between electricity consumption and economic growth can be synthesized into four possible hypothesis: 1) the growth hypothesis that asserts unidirectional causality from electricity consumption to economic growth; 2) the conservation hypothesis which postulates unidirectional causality from economic growth to electricity consumption; 3) the neutrality hypothesis that suggests the absence of a causal relationship between electricity consumption and economic growth; 4) the feedback hypothesis that emphasizes the interdependent relationship between electricity consumption and economic growth in which causation runs in both directions.

A paper by Ramcharran (1990) was the first one that dealt with the topic of interconnectedness between electricity consumption and economic growth. The causality relation was studied using Jamaica as an example over the period from 1970-1986. Using Granger causality test, a unidirectional causality running from electricity consumption to economic growth was determined. Several years later, Murray and Nun (1996) using vector autoregression model (VAR) carried out the first big causality analysis using a sample of 23 countries and the period from 1970-1990.[1]

A detailed chronological review of available empirical research regarding the interconnectedness between electricity consumption and economic growth is available in Tables 1 (worldwide) and 2 (selected European countries). In addition, all analysed countries are classified according to the OECD membership criteria.

[1] Colombia, Indonesia, Kenya, Mexico and El Salvador (GDP→EC); Philippines, Hong Kong, Canada, Pakistan and Singapore (GDP←EC); South Korea and Malaysia (BDP↔EC); India, Israel, the US and Zambia (no causality). The remaining 7 European countries are listed in Table 2.

Table 1. Summary of literature review for electricity consumption (EC) and economic growth (GDP) - worldwide

Study	Country	Period	Methodology	Results
OECD member countries				
Fatai et al. (2004)	Australia	1960-1999	Johansen-Juselius and ARDL approach; cointegration; VEC, Granger and Toda-Yamamoto causality test	GDP→EC
Narayan and Smyth (2005)	Australia	1966-1999	ARDL approach; cointegration; VEC	GDP→EC
Yoo (2005)	South Korea	1970-2002	Johansen-Juselius; cointegration; VEC	GDP↔EC
Chen et al. (2007)	South Korea	1971-2001	Johansen-Juselius; Pedroni; cointegration; VEC	GDP→EC
Narayan and Prasad (2008)	7 OECD Member countries[2]	1960-2002	Bootstrapped Granger causality test	mixed results
Narayan et al. (2010)	G-6 countries[3]	1980-2006	Pedroni; cointegration; Canning-Pedroni causality test	GDP↔EC **(-)**
Bildirici et al. (2012)	Japan Canada and USA	1970-2010	ARDL approach; cointegration; VEC	GDP→EC GDP←EC
Non OECD countries				
Yang (2000)	Taiwan	1954-1997	Engle-Granger; no cointegration; Granger causality test (Hsiao version)	GDP↔EC
Aqeel and Butt (2001)	Pakistan	1955-1996	Engle-Granger; no cointegration; Granger causality test (Hsiao version)	GDP←EC
Ghosh (2002)	India	1950-1997	Johansen-Juselius; no cointegration; VAR	GDP→EC
Jumbe (2004)	Malawi	1970-1999	Engle-Granger; cointegration; VEC	GDP→EC[4]
Shiu and Lam (2004)	China	1971-2000	Johansen-Juselius; cointegration; VEC	GDP←EC
Lee and Chang (2005)	Taiwan	1954-2003	Johansen-Juselius; cointegration; weak exogenity test	GDP←EC
Squalli and Wilson (2006)	6 countries[5]	1980-2003	ARDL approach; cointegration; Toda-Yamamoto causality test	mixed results
Wolde-Rufael (2006)	17 countries[6]	1971-2001	Toda-Yamamoto causality test	mixed results
Yoo (2006)	Indonesia and Thailand Malaysia and Singapore	1971-2002	Engle Granger and Johansen-Juselius; no cointegration; Granger causality test (Hsiao version)	GDP→EC GDP↔EC

[2] Australia (GDP←EC), Japan (no causality), South Korea (1971-2002; GDP↔EC), Canada, Mexico (1971-2002), New Zealand and USA (1970-2002; no causality).

[3] The authors state that the panel includes six major industrialized countries.

[4] Jumbe (2004) also analysed the intensity of the causal link between electricity consumption and gross domestic product and found that 1% increase in GDP causes an increase in electricity consumption by 0.25%.

[5] Bahrain and Qatar (GDP↔EC), Kuwait and Oman (GDP→EC), Saudi Arabia (GDP↔EC), United Arab Emirates (no causality).

[6] Algeria (no causality), Benin (GDP←EC, **(+)**),Democratic Republic of the Congo (GDP←EC, **(+)**), Egypt (GDP↔EC, **(+)**), Gabon (GDP→EC, **(+)**; GDP←EC, **(–)**), Ghana (GDP→EC, **(+)**), South Africa (no causality), Cameroon (GDP→EC, **(+)**), Kenya (no causality), Congo (no causality), Morocco (GDP↔EC, **(+)**), Nigeria (GDP→EC, **(+)**), Senegal (GDP→EC, **(+)**), Sudan (no causality), Tunisia (GDP←EC, **(–)**), Zambia (GDP→EC, **(+)**) and Zimbabwe (GDP→EC, **(+)**).

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Chen et al. (2007)	9 countries[7]	1971-2001	Johansen-Juselius; Pedroni; cointegration (6 countries plus entire panel); VEC; VAR (3 countries)	mixed results – country by country entire panel: GDP↔EC
Ho and Siu (2007)	Hong Kong	1966-2002	Johansen-Juselius; cointegration; VEC	GDP←EC
Mozumder and Marathe (2007)	Bangladesh	1971-1999	Johansen-Juselius; cointegration; VEC	GDP→EC
Narayan and Singh (2007)	Fiji	1971-2002	ARDL approach; cointegration; VEC	GDP←EC
Squalli (2007)	11 OPEC member countries[8]	1980-2003	ARDL approach; cointegration; VEC and Toda-Yamamoto causality test	mixed results
Yuan et al. (2007)	China	1978-2004	Johansen-Juselius; cointegration; VEC	GDP←EC
Tang (2008)	Malaysia	1972-2003[9]	ARDL approach; no cointegration; Toda-Yamamoto causality test	GDP↔EC
Yuan et al. (2008)	China	1963-2005	Johansen-Juselius; cointegration; VEC; IR	GDP↔EC
Abosedra et al. (2009)	Lebanon	1995-2005[10]	VAR	GDP←EC[11]
Akinlo (2009)	Nigeria	1980-2006	Johansen-Juselius; cointegration; VEC	GDP←EC
Narayan and Smyth (2009)	6 countries[12]	1974-2002	Westerlund; cointegration; panel VEC	GDP↔EC[13]
Odhiambo (2009a)	Tanzania	1971-2006	ARDL approach; cointegration; VEC	GDP←EC
Odhiambo (2009b)	South Africa	1971-2006	Johansen-Juselius; cointegration; VEC	GDP↔EC
Pao (2009)	Taiwan	1980-2007	Johansen-Juselius; cointegration; VEC	GDP→EC
Chandran et al. (2010)	Malaysia	1971-2003	Engle-Granger; Johansen-Juselius and ARDL approach; cointegration; VEC	GDP←EC[14]
Lorde et al. (2010)	Barbados	1960-2004	Johansen-Juselius; cointegration; VEC; IR; VD	GDP↔EC
Ouédraogo (2010)	Burkina Faso	1968-2003	ARDL approach; cointegration; VEC	GDP↔EC
Yoo and	7 countries[15]	1975-	Johansen-Juselius; cointegration (2 countries);	mixed results

[7] **VEC**: Hong Kong (GDP↔EC), India and Singapore (GDP→EC), Indonesia (GDP←EC), Thailand and Taiwan (no causality); **VAR**: Philippines and Malaysia (GDP→EC), China (no causality). The entire panel also includes South Korea (OECD member country since 1996).

[8] Algeria and Iraq (GDP→EC), Iran and Qatar (GDP↔EC), Libya (GDP→EC), Saudi Arabia (GDP↔EC) and Venezuela (GDP←EC). When VEC and Toda-Yamamoto (YT) causality tests were employed, the results were quite the opposite in the case of Indonesia (GDP→EC, **(ARDL)**; GDP←EC, **(TY)**), Kuwait (GDP←EC, **(ARDL)**; GDP→EC, **(TY)**), Nigeria and the United Arab Emirates (GDP↔EC, **(ARDL)**; GDP←EC, **(TY)**).

[9] The analysed period includes the first quarter of 1972 until the last quarter of 2003.

[10] The authors used data on a monthly basis (January 1995 – December 2005).

[11] Abosedra et al. (2009) used data on imports as an alternative to the real GDP. The reasons for such selection are high import dependence, tourism as an important sector of employment of the local population due to the lack of agricultural and industrial production and the unavailability of monthly data on the movement of GDP. They also use the data on the change of temperature and relative humidity as exogenous variables.

[12] Iran, Israel (OECD member country since 2010), Kuwait, Oman, Saudi Arabia and Syria.

[13] Narayan and Smyth (2009) also determined the intensity of the causal connection. Therefore, a 1% increase in electricity consumption results in GDP increase of 0.04%, while at the same time an increase of GDP by 1% increases electricity consumption by 0.95%.

[14] Chandran et al. (2010) also determined the intensity of the causal connection. They found that 1% increase in electricity consumption leads to an increase in GDP by 0.68 – 0.79%.

Kwak (2010)		2006	VEC; Granger causality test – Hsiao version (5 countries)	
Adebola (2011)	Botswana	1980-2008	ARDL approach; cointegration; VEC	GDP←EC[16]
Kouakou (2011)	Ivory Coast	1971-2008	ARDL approach; cointegration; VEC	GDP↔EC
Ozturk and Acaravci (2011)	11 countries[17]	1971-2006	ARDL approach; cointegration; VEC	mixed results
Bildirici et al. (2012)	4 countries[18]	1970-2010	ARDL approach; cointegration; VEC	mixed results
Shahbaz and Lean (2012)	Pakistan	1972-2009	Johansen-Juselius and ARDL approach; cointegration; VEC	GDP↔EC
Shaari et al. (2013)	Malaysia	1980-2010	Johansen-Juselius; cointegration; Granger causality test	GDP→EC
Solarin and Shahbaz (2013)	Angola	1971-2009	ARDL approach; cointegration; VEC	GDP↔EC[19]
Tang and Tan (2013)	Malaysia	1970-2009	ARDL approach; cointegration; VEC	GDP↔EC
Countries classified by major world regions				
Narayan et al. (2010)	93 countries[20]	1980-2006	Pedroni; cointegration; Canning-Pedroni causality test	mixed results
Other causality studies				
Wolde-Rufael (2004)	Shanghai[21]	1952-1999	Toda-Yamamoto causality test	GDP←EC

Note that causal directions reported in Table 1 incorporate both short-run and long-run causality. VAR = vector autoregression model; ARDL approach = autoregressive distributed lag approach; VEC = vector error correction model; VD = variance decomposition; IR = impulse response

Source: Jakovac and Vlahinic Lenz (2016, pp. 81-83)

Over time, various empirical studies have focused on different countries or groups of countries (sometimes only one country was analysed by many different authors), time periods, main variables (or their substitutes) and quantitative methods. The results of such studies are often contradictory, and the lack of consensus on this matter could result in inadequate selection and implementation of economic and energy/electricity policies.

[15] VEC: Colombia (GDP←EC), Venezuela (GDP↔EC); Granger causality test (Hsiao version): Argentina, Brazil, Chile (OECD member state since 2010) and Ecuador (GDP←EC), Peru (no causality).

[16] This paper also determined the intensity of the causal connection. Therefore, a 1% increase in electricity consumption causes a 1.06% increase in GDP.

[17] Algeria, Jordan, Tunisia and United Arab Emirates were subsequently excluded from further analysis since unit root tests did not meet the basic assumption concerning ARDL approach. The GDP variable (in the case of Algeria and Jordan) and electricity consumption variable (in the case of Tunisia and United Arab Emirates) were not integrated of order 1, that is I(1). In the case of Iran, Morocco and Syria no cointegration was determined between the variables so the authors concluded that causal connection using VEC could not be estimated. The causality results for the remaining 4 countries are: Egypt and Saudi Arabia (GDP←EC), Israel (GDP→EC; OECD member state since 2010), Oman (GDP↔EC).

[18] Brazil (GDP←EC), India and South Africa (GDP→EC), China (GDP←EC).

[19] Solarin and Shahbaz (2013) use the level of urbanization as a control variable because urbanization has significant implications regarding energy/electricity consumption. Urbanization is at the same time determined and it self intensively determines the process and context of economic growth and development. Urbanization leads to a large concentration of population, which generates economic activity, higher per capita income and ultimately results in increased demand for energy/electricity. In this study, the level of urbanization is defined as the ratio of population in urban areas in relation to total population.

[20] Analysed countries are classified into 6 panels: Western Europe (20 countries), Asia (17 countries), Latin America (17 countries), Africa (25 countries), Middle East (12 countries) and a global panel that includes all countries. The results indicate the existence of positive mutual causality. In the case of panel covering the Middle East, a one-way causality was determined running from real GDP to electricity consumption.

[21] Shanghai is administratively equal to a province and is divided into 16 county-level districts.

The studies listed in Table 1 include most countries of the world (both developed and developing ones). The situation is similar when it comes to the countries of the European continent. To the best of our knowledge, more than 40 European countries have so far been a subject of econometric analysis (see Table 2).

Table 2. Summary of literature review for electricity consumption (EC) and economic growth (GDP) for selected European countries

Study	Country	Period	Methodology	Results
OECD member countries				
Murray and Nan (1996)	7 countries[22]	1970-1990	VAR	mixed results
Altinay and Karagol (2005)	Turkey	1950-2000	Dolado-Lütkepohl and Granger-causality test	GDP←EC
Ciarreta and Zarraga (2007)	Spain	1971-2005	Johansen-Juselius and ARDL approach; no cointegration; VAR; Toda-Yamamoto and Dolado-Lütkepohl causality test	GDP→EC
Erbaykal (2008)	Turkey	1970-2003	ARDL approach; cointegration; VEC	GDP←EC
Narayan and Prasad (2008)	23 OECD Member countries[23]	1960-2002	Bootstrapped Granger-causality test	mixed results
Acaravci (2010)	Turkey	1977-2006	ARDL approach; cointegration; VEC	GDP←EC
Acaravci and Ozturk (2010)	3 countries[24]	1990-2006	Pedroni; no cointegration	no causality
Ciarreta and Zarraga (2010)	12 countries[25]	1970-2007	Pedroni; cointegration panel VEC	GDP←EC
Shahbaz et al. (2011)	Portugal	1971-2009	ARDL approach; cointegration; VEC	GDP↔EC
Acaravci and Ozturk (2012)	Turkey	1968-2006	ARDL approach; cointegration; VEC	GDP←EC
Bildirici et al. (2012)	4 countries[26]	1970-2010	ARDL approach; cointegration; VEC	GDP→EC
Georgantopoulos (2012)	Greece	1980-2010	Johansen-Juselius; cointegration; VEC	GDP←EC
Gurgul and Lach (2012)	Poland	2000 - 2009	Johansen-Juselius; cointegration; VEC and Toda-Yamamoto causality test	GDP↔EC
Baranzini et al. (2013)	Switzerland	1950-2010	ARDL approach; cointegration; VEC	GDP→EC
Non-OECD countries				
Acaravci and Ozturk (2010)	12 countries[27]	1990-2006	Pedroni; no cointegration	no causality
Kayhan et al. (2010)	Romania	2001-2010	Dolado-Lütkepohl, Toda-Yamamoto and Granger-causality test	GDP←EC
Bildirici and Kayikçi (2012)	11 countries[28]	1990-2009	Pedroni and ARDL approach; cointegration; panel VEC	mixed results[29]

[22] France, Luxembourg, Norway, Germany, Portugal and United Kingdom (no causality); Turkey (GDP←EC).

[23] Austria and Belgium (no causality), Czech (GDP←EC), Denmark (no causality), Finland (GDP→EC), France, Greece and Ireland (no causality), Island (GDP↔EC), Italy (GDP←EC), Luxembourg (no causality), Hungary (1965-2002; GDP→EC), Netherlands (GDP→EC), Norway, Germany and Poland (no causality), Portugal (GDP←EC), Slovakia (1971-2002; GDP←EC), Spain, Sweden and Turkey (no causality), United Kingdom (GDP↔EC).

[24] Czech, Poland and Slovakia.

[25] Austria, Belgium, Denmark, Finland, France, Italy, Luxembourg, Netherlands, Norway, Germany, Sweden and Switzerland.

[26] Italy, France, Turkey and United Kingdom.

[27] Albania, Belarus, Bulgaria, Estonia (member of OECD since 2010), Latvia, Lithuania, FYR Macedonia Moldova, Romania, Russia, Serbia and Ukraine.

[28] The sample consists of 11 former soviet republics classified in three panels: Panel A) Azerbaijan, Belarus, Kazakhstan and Russia – GDP p/c 1900-2500$); Panel B) Kyrgyzstan, Moldova, Tajikistan and Uzbekistan – GDP p/c 300-800$; Panel C) Armenia, Georgia and Ukraine – GDP p/c 1000-1500$.

Shahbaz et al. (2012)	Romania	1980-2011	ARDL approach; cointegration; Toda-Yamamoto causality test; VD	GDP↔EC
Borozan (2013)	Croatia	1992-2010	VAR; Granger-causality test; VD; IR	GDP→EC
Jakovac and Vlahinic Lenz (2016)	Croatia	1966-2010	ARDL approach; cointegration; VEC	GDP←EC

Note that causal directions reported in Table 2 incorporate both short-run and long-run causality. VAR = vector autoregression model; ARDL approach = autoregressive distributed lag approach; VEC = vector error correction model; VD = variance decomposition; IR = impulse response

Source: Jakovac and Vlahinic Lenz (2016, pp. 81-83), Borozan (2013)

When the analysed countries (worldwide and European) were divided into OECD Member countries and non-OECD countries it was found that in both groups prevails the direction of causality (with or without feedback nexus) running from electricity consumption to GDP. Specifically, in the case of OECD countries, the results of the causality analysis show that in 35.48% of cases electricity consumption affects economic growth compared to 33.87% of cases where causality runs from GDP to electricity consumption. In the case of non-OECD countries, it has been found that electricity consumption affects GDP in 58.92% of cases compared to 54.26% of cases where it is found that causality runs from economic growth to electricity consumption.

Under the so-called growth hypothesis (i.e. unidirectional causality running from electricity consumption to economic growth), an economy will grow if policy makers increase the amount of electricity in a country. This also means that a shortage of electricity may adversely affect economic growth. In that case, electricity can be a limiting factor of economic growth (Narayan and Prasad, 2008). Energy represents a key factor in human development and standard of living. One of its most important form is electricity whose usage worldwide continues to grow due to the degree and speed of socio-economic growth and development (Kalea, 2007, pp. 95.). Globally, demand for electricity is set to continue to grow faster than for any other final form of energy. More specifically, demand for electricity will expand by over 70% between 2010 and 2035, or 2.2% per year on average. Geographically, over 80% of the growth arises in non-OECD countries, over half in China (38%) and India (13%) alone (IEA, 2012, pp. 180.).

3. REMARKS ON THE STUDIED CAUSALITY LITERATURE

The reason why it is important to investigate the relationship between electricity consumption and economic growth is straightforward: the implementation of economically efficient energy (electricity) policies and the prediction of the impacts of various energy (electricity) and economic policies require an understanding of which of these variables causes the other. The increasing interest of researches on the electricity consumption-growth nexus is obviously reflected by the increasing number of studies concerned with this subject. Consequently, such studies have gained impetus especially within the last 10 years resulting in voluminous but divided literature. Thereby, at the present it is quite difficult to summarize the status of our knowledge regarding this causal relationship (Karanfil, 2009).

Although new and more sophisticated econometric methods for (better) identification and understanding of causality were developed over the years, an increasing number of published empirical studies regarding interconnectedness of electricity and GDP still has inconsistent results. These diverse results arise due to the different data set (i.e. variable selection and time periods of the studies), model specification, alternative econometric methodologies and different countries' characteristics such as different indigenous energy (electricity) supplies, different political and economic histories, different political arrangements, different institutional arrangements, different cultures and different energy policies (Ozturk, 2010, pp. 340; Payne, 2010, pp. 729). As pointed out by Karanfil (2008), in developing countries the investigation on the linkage between electricity consumption and official GDP may not give reliable results mainly due to the unrecorded economic activities that hinder the correct measurement of the official GDP.

Looking at the empirical studies on electricity consumption-economic growth nexus presented in Tables 1 and 2, it can be concluded that a large number of these studies is focused on developed and developing countries as well as on the so-called emerging economies. Studies related to transition countries of Europe

[29] Panel A (GDP↔EC), Panel B (GDP↔EC), Panel C (GDP↔EC).

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and Central Asian countries (especially the so-called commonwealth of independent states which includes the former Soviet republics) are numerically inferior in relation to the rest of the world. The reason is found primarily in the fact that these countries in the early 1990s began an economic transformation from a centrally-planned to a market-oriented economy, thus limiting the availability of data needed to implement robust and high-quality analysis.[30]

Most of the studies that have conducted the research on causality analysis between electricity consumption and economic growth used the so-called bivariate framework. To be more precise, 65.08% of examined studies use bivariate framework while the remaining 34.92% of studies use multivariate framework. A common problem associated with bivariate analysis is the possibility of omitted variable bias, drawing into question the validity of the inferences of a causal relationship (Payne, 2010, pp. 729). Bivariate models, despite their usefulness because they can be applied in countries where only limited data are available, represent only a rough approximation of reality. On the other hand, the use of a multivariate model may be better founded in economic theory, it can help avoid econometric problems caused by afore-mentioned potential omitted variable bias and offers multiple causality channels that may remain hidden under a bivariate approach (Zachariadis, 2007).

Most of the studies that we have observed[31] do not examine the sign (positive or negative) nor the intensity of the causal link between electricity consumption and gross domestic product (the magnitude of the coefficients associated with the causality tests). It was also found that the growth hypothesis appears 55 times, the conservation hypothesis 47 times, the neutrality hypothesis 40 times and the feedback hypothesis 35 times.[32]

4. CONCLUSION AND RECOMMENDATIONS FOR FURTHER RESEARCH

The electricity–growth nexus is a well-studied topic in the energy economics literature nowadays. However and as already stated, numerous empirical studies have yielded different and sometimes conflicting results. In order to avoid this shortcoming and to make future empirical results as robust and as representative as possible (and more interesting to potential interested parties), and to determine as precisely as possible the causal relationship between electricity consumption and GDP, further research is needed. This calls for new approaches in terms of newer data sets (i.e. longer time series and other potential control variables) and sophisticated econometric methods.

In the future, according to Apergis and Payne (2009), it may be interesting to investigate multivariate causality between electricity consumption and GDP and, depending on the data availability and reliability, to use other control variables such as labour and capital. It may also be interesting to use data on:

1) total population (to reflect the overall demographic corpus of one country and the needs of every individual for electricity);

2) government expenditures (since public investments in public utilities such as electricity have an influence on electricity generation/consumption and economic growth);

3) financial development (since well-functioned financial institutions and financial markets represent an important condition for the development of electricity sector);

4) carbon dioxide emissions (since the integration of data on CO_2 emissions in the causality analysis would help to better identify the interactions between electricity generation and economic growth);

5) a dummy variable (as a reflection of the recent economic crisis).

Future research on this topic can potentially gain importance if one (or a combination) of the following several econometric methods is applied:

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[30] In all examined studies, except panel data analysis, the number of observations ranges (in average) from 35 to 45 units of time (mostly years), which ultimately results in a relatively small sample when it comes to time series analysis.

[31] Except those of Jumbe (2004), Wolde-Rufael (2006), Erbaykal (2008), Narayan and Smyth (2009), Chandran et al. (2010), Ciarreta and Zarraga (2010), Sharma (2010), Adebola (2011), Baranzini et al. (2013) as well as Jakovac and Vlahinic Lenz (2016).

[32] In the study by Payne (2010, pp. 729), 35 studies were surveyed (covering the period from 1996-2009) and the conclusions were the following: a) 26 of the 35 studies rely on bivariate causality tests; b) across the 74 countries reported, the results for the specific countries surveyed show that 31.15% supported the neutrality hypothesis, 27.87% the conservation hypothesis, 22.95% the growth hypothesis and 18.03% the feedback hypothesis.

1) nonlinear threshold regression model by which one can determine to which particular levels (limits) electricity consumption actually affects GDP and by doing so one can "prescribe" economic and energy policies to those before and after the critical limits;

2) the leveraged bootstrap technique which is highly applicable when dealing with relatively small samples;

3) panel approach (combination of time series and cross sectional data) since panels provide more informative data, more variability, less collinearity among the variables, more degrees of freedom and greater efficiency in econometric estimates.

Ultimately, this remains a challenge for present and future research on this topic. According to Karanfil (2009) and Ozturk (2010), research papers using the same methods with the same variables but with a different time period examined have no more potential to make a contribution to the existing causality literature. These studies just increase the number of conflicting results and nothing more. Thus, authors should focus on new approaches and perspectives rather than employing usual methods based on a common set of variables. As indicated by Karanfil (2009), authors should keep in mind that policy makers are not interested about the examined time period nor the methodology used by a researcher. Policy makers are only interested in the robustness and the consistency of the final causality results.

Therefore, until researchers get sound, robust, uniformed and non-conflicting empirical results using some of the above-mentioned recommendations, governments have to be careful in implementing the appropriate policies.

5. ACKNOWLEDGEMENT

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