ANOTHER LOOK AT THE ELECTRICITY CONSUMPTION-GROWTH NEXUS IN CROATIA: HAS THE CONSENSUS FINALLY BEEN REACHED?

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Abstract

During the last two decades, a number of papers have addressed the causality between economic growth and electricity consumption. Although a strong interdependence and causality between economic growth and electricity consumption represent a stylized economic fact, the existence and direction of the causality is still not clearly defined. Most studies have been based on a bivariate approach that explores the causal relationship between electricity consumption and output (GDP). This approach has limitations and is not able to capture the multivariate framework within which the changes in electricity use are frequently countered by the substitution of other factors of production, resulting in an insignificant overall impact on output. The lack of consensus on whether economic growth results in electricity consumption 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. 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. The aim of this paper is to analyse the available data on GDP and electricity consumption in Croatia for the last six decades using the so-called bootstrap approach within a multivariate framework that includes capital stock and labour (and dummy variables to reflect structural breaks in the data). The time period used in this analysis is 1952-2015, which covers a long-term period during which substitution among production inputs could occur. Therefore, the main aim of the paper is to empirically determine whether a causal link exists among capital stock (as a proxy for capital), employment (as a proxy for labour), total electricity consumption (without transmission and distribution losses) and economic growth in Croatia. In addition to empirical results, policy implications and recommendations for future research will also be presented in the paper.

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

1. INTRODUCTION

Economic growth requires (more) energy and it becomes quite clear that economic growth is inextricably linked to energy. Since energy sources undoubtedly represent the fundamental resources and content of the national wealth of each country, it can be concluded that reliable supply and meeting the increasing demand for energy are therefore the biggest challenges of the 21st century. 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. 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 (Udovicic, 2004). A survey conducted on a sample of more than a hundred countries (Ferguson et al., 2000), in which Croatia was not included, confirms the existence of a strong correlation between electricity usage and the level of economic growth. However, the presence of a correlation between electricity consumption and economic growth does not imply that there exists a causal relationship at the same time. The lack of consensus on whether economic growth results in electricity consumption 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 consumption and economic growth.

Therefore, the purpose of this paper is to examine the relationship between economic growth and electricity consumption in Croatia using the so-called multivariate framework and the econometric methodology suitable for relatively small sample as well as taking into consideration the possibility of structural break(s) in the data. 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. Section 3 presents data, methodology and empirical results while final section gives the conclusion.

2. LITERATURE REVIEW

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.

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.	Australia	1960-	Johansen-Juselius and ARDL approach;	GDP→EC

[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.

(2004)		1999	cointegration; VEC, Granger and Toda-Yamamoto causality test	
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

[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).

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
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]

[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, **(+)**).

[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.

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 Kwak (2010)	7 countries[15]	1975-2006	Johansen-Juselius; cointegration (2 countries); VEC; Granger causality test – Hsiao version (5 countries)	mixed results
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

[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%.
[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).

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.

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

[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.

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

[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
Jakovac and Majstrovic (2017)	Croatia	1952-2014	Bootstrapped Granger-causality test	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), Jakovac and Majstrovic (2017)

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. DATA, METHODOLOGY AND RESULTS

All of the data used in this paper consist of annual time series of Croatian real GDP and total electricity consumption for the period 1952-2015 in order to cover long-term period during which the substitution among production factors occurred. The real GDP data (in millions of US$ at 2000 constant prices) were originally obtained from Druzic and Tica (2002). These figures were subsequently expanded with data on real GDP growth rates from the Croatian Bureau of Statistics (2012; 2016). Data covering total electricity consumption (in GWh) were obtained from the Energy Institute Hrvoje Požar (2009a; 2009b; 2016) and exclude transmission and distribution losses. Capital stock variable (K) was generated using the GDP data and the data on gross fixed capital formation in fixed assets from Croatian Statistical Yearbooks and World Bank (2017) since there is no readily available data for Croatia's capital stock. For the initial capital stock, we divided real fixed investment in the first period (1952 – the first year of our analysis) with the sum of depreciation rate (5%) and average growth rate of investment (Hall & Jones, 1999; Kyriacou 1991). The capital stock data for the rest of the observed period was generated using linear perpetual inventory method and the following equation:

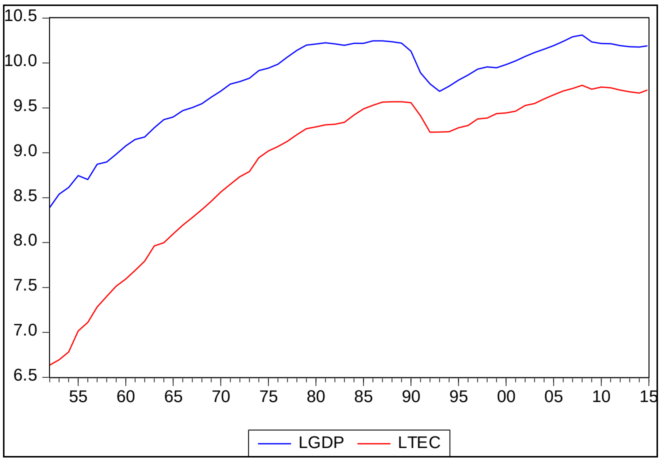
$$K_t = \sum_{i=0}^{n-1}\left(1-\frac{i\delta}{2}\right)I_{t-i} + (1-n\delta)K_{t-n}$$

where *K* represents physical capital, *I* investments and *δ* rate of depreciation. In order to increase the realism of the estimates, this equation differs from the standard linear PIM equation when it comes to depreciation of

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

new investment (namely, δ is divided by 2) since new investment is assumed to be placed in service at midyear instead of at the end of the year. According to Kamps (2004), investment typically occurs throughout the year, not only at the end of the year. Employment (L) data, due to methodological issues in the pre- and post-transition periods, present the number of employed people (in thousands) without those employed in public administration, police and defense. These figures were retrieved from Croatian Bureau of Statistics (2016) together with Raguz, Druzic and Tica (2011). In order to graphically visualize the variables, Figure 1 only depicts Croatia's total electricity consumption (TEC) and real GDP.

Figure 1. Plots of variables



Source: made by the author using EViews 7.1

For estimation purposes, the four variables were transformed into natural logarithms in order to reduce heteroscedasticity. Figure 1 indicates a presence of a structural break in these series. By using the Chow breakpoint test (Chow, 1960) we recognize that our (main) variables, the real GDP (F-statistic=9.814043) and TEC (F-statistic=10.34607) are "broken" in the year 1990 at the 5% significance level. There are several reasons why the structural break occurred. In the year 1990, the Croatian economy was faced with a negative growth rate, hyperinflation and the collapse of the so-called self-managing (market) socialism (or workers' self-management) as the dominant economic system in ex-Yugoslavia. The GDP decreased because of the transition depression and the Croatian Homeland War, which began in 1991 after Croatia terminated all state and legal relations with the former Socialist Federal Republic of Yugoslavia (Vlahinic and Jakovac, 2014, 439).

Because of the transition depression and structural changes (industrial production dropped sharply as the result of the closure and restructuring of heavy industry, strong national currency and extensive trade liberalization led to further declines in industrial production, orientation of economy towards services and energy non-intensive industries), the total electricity consumption declined sharply after 1990. To account for the mentioned structural break, a dummy variable DV1990 (equal to 1 for the period 1990-2015 and 0 otherwise) is introduced in the analysis. We have additionally introduced two more dummy variables to make the causality results more robust: the variable DV1999 (equal to 1 for 1999 and 0 otherwise) to account for the mild recession Croatia faced in 1999 and the variable DV2009 (equal to 1 for the period 2009-2015 and 0 otherwise) to account for the (current) severe recession.

To test for the causal effects between electricity consumption and economic growth (capital, employment and dummy variables) we utilize the following vector autoregressive model of order p, VAR(p):

$$\gamma_t = \nu + \mathrm{A}_1\gamma_{t-1} + \ldots + \mathrm{A}_p\gamma_{t-p} + \varepsilon_t$$

where y_t is *7x1* vector of our variables, v is a *7x1* vector of intercepts and ε_t is a 7x1 vector of error terms while A denotes the matrix of parameters.

According to Sims et al. (1990), standard distributions usually do not apply for testing Granger causality if the variables are integrated. To overcome this issue, Toda and Yamamoto (1995) suggested an augmented VAR(p+d) model where the basic model is augmented by extra lags, d, which is equal to the integration order of the variables. They introduced the modified Wald (MWALD) test statistic which is asymptotic chi-square (χ^2) distributed. However, Hacker and Hatemi-J (2006) demonstrated that the inference based on the MWALD test statistic becomes more precise if bootstrap distributions are utilized instead of asymptotic χ^2

distributions. In other words, bootstrap distribution reduces size distortions compared with an asymptotic distribution. Furthermore, Hacker and Hatemi-J (2006) showed that asymptotic distribution can be a poor approximation especially when dealing with small samples that are common in empirical studies.

Therefore, in this paper we use a bootstrap test for causality with endogenous lag length choice (meaning that the data-driven preselection of lag length is taken into account) created by Hacker and Hatemi-J (2012).[30] The bootstrap simulation technique is used to generate more reliable critical values for test of Granger causality between integrated variables.[31] This method is based on the empirical distribution of the underlying data, it is not sensitive to the assumption of normality, it works well for nonstationary data and it has better small sample properties compared to standard tests for causality.

Because many macroeconomic variables are nonstationary (Nelson and Plosser, 1982), unit root test are important and useful in examining whether the variables are stationary (or not). In other words, unit root tests are required to investigate the integration order of the variables in question. This is also important in obtaining an unbiased estimation from the causality test and the GAUSS code for implementing the bootstrap test for causality with endogenous lag length also requires the input on whether the variables are stationary or if they have a one unit root.

Since there is no uniformly powerful test of the unit root hypothesis (Gujarati and Porter, 2009), and to determine the order of the series in more robust manner, we conducted five different unit root tests. We used the Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1979), Phillips-Perron (PP) test (Phillips and Perron, 1988), Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test (Kwiatkowski et al. 1992), Elliot-Rothenberg-Stock Dickey-Fuller GLS de-trended (DF-GLS) test (Elliot et al. 1996) and Ng-Perron MZ_t (NG-P (MZ_t)) test (Ng and Perron, 2001).[32]

Both "intercept and trend" regressors were included in the test equation in all five previously mentioned unit root tests (see Table 3). For the purposes of the ADF, DF-GLS and NG-P unit root tests, the Schwarz information criterion (SIC) is used to determine the number of lags, whereas the Newey-West method is applied to choose the optimal lag length (or bandwidth) for the purposes of the PP and KPSS unit root tests. The critical values for the ADF and PP tests are taken from MacKinnon (1996). For KPSS, the critical values are taken from Kwiatkowski et al. (1992). The critical values for DF-GLS are taken from Elliott et al. (1996), while and the NG-P (MZt) critical values are taken from Ng and Perron (2001). All unit root tests have a null hypothesis (H_0) stating that the series in question has a unit root against the alternative that it does not. The null hypothesis (H_0) of KPSS, on the other hand however, states that the variable is stationary. The results for all five unit root tests summarized in Table 3 reveal that our (main) variables[33] are non-stationary at level but become stationary after first difference.

Table 3. Unit root test results

Variables	ADF	PP	KPSS	DF-GLS	NG-P (MZ_t)
Panel A: Log levels (intercept and trend)					
lnGDP	-1.850986 (1)	-2.160700 (4)	0.217408 (6)	-0.935147 (1)	-0.96856 (1)
lnTEC	-2.520738 (1)	-1.971098 (4)	0.249047 (6)	-0.907015 (1)	-0.77996 (1)
Panel B: Log first differences (intercept and trend)					
lnGDP	-5.005256 (0)	-5.068362 (2)	0.114287 (4)	-4.613653 (0)	-3.41556 (0)
lnTEC	-5.234096 (0)	-5.285827 (2)	0.125098 (4)	-4.875772 (0)	-3.51663 (0)

Optimal lag lengths are shown in parenthesis. The maximum lag length considered is 10.

[30] We thank J.A. Hatemi for providing the GAUSS code that was used for the estimation purposes.
[31] When using the bootstrap method, the information in the data set is recycled by simulations and the basic idea is, as already mentioned, to reduce bias and provide reliable critical values. We do not describe the bootstrap technique in details to conserve space. For more information about this simulation method, see Efron (1979), Hatemi-J (2002), Hatemi-J and Irandoust (2005), Hacker and Hatemi-J (2006) and Hacker and Hatemi-J (2012).
[32] See Maddala and Kim (1998) for a review of ADF, PP, KPSS, and DF-GLS and Ng-Perron (2001) for additional information on NG-P.
[33] The calculations for other variables are available upon request from the author.

Source: Authors calculation using EViews 7.1

Prior to tests for causality, in the GAUSS code we set the maximum lag length at three years, which is sufficiently long for the annual data to capture the dynamic relationship (Tang and Shahbaz, 2011). The integration order is set to 1 meaning there is one unit root (as instructed by the unit root test results) and the maximum number of simulations for computing bootstrapped critical values is set to 10000.

Also, according to Hatemi-J (2003), we use the Hatemi-J Criteria to determine the optimal/true lag length due to its ability to better choose the optimal lag length in both stable and unstable VAR models.[34] The causality test results for the null hypothesis that TEC does not Granger cause real GDP (and vice versa) are presented in Table 4. If the computed MWALD test statistic is greater than the critical values we reject the null hypothesis.

Table 4. Results of the causality test based on bootstrap simulation technique

The null hypothesis	The estimated MWALD test value	1% bootstrap critical value	5% bootstrap critical value	10% bootstrap critical value
TEC ≠> GDP	8.968	8.687	4.804**	3.283
GDP ≠> TEC	0.014	7.337	4.389	3.030

The notation ≠> implies non-Granger causality. The notation ***, ** and * means that the null hypothesis on non-Granger causality is rejected at the 1%, 5% and 10% significance level, respectively.

Source: Authors' calculation using GAUSS 10.0

The estimation results presented in Table 4 suggest the existence of a unidirectional causality running from total electricity consumption to real GDP in Croatia. These results contradict the bivariate analysis of Borozan (2013) and Jakovac and Majstrović (2017), which found bivariate causality running from GDP to (total) electricity consumption. However, Jakovac and Vlahinic Lenz (2016) found the same causality that runs from (total) electricity consumption to GDP, but using shorter time span (1966-2010). This study differs from those three by including capital and labor variables and by using the longest time period from 1952 to 2015.

The obtained results imply that high electricity consumption tends to lead high economic growth. These empirical results have important implications for Croatian economic and energy policy. The direction of causality implies that Croatia should find ways not to adversely affect economic growth by reducing electricity consumption. In that context, Croatian economic policy has to give incentives for reforming economic structure towards re-industrialization and more energy-efficient industries. Since small Croatian economy is import dependent and strongly vulnerable to exogenous energy shocks, it is important to implement energy strategy that will increase new investments in installed energy capacities and diversify energy mix in order to decrease import dependence. Since Croatia has significant potentials for using renewable energy sources, its energy mix should rely more on renewables including hydro power.

4. CONCLUSION

One of the main assumptions for future electricity market development is to remove current obstacles, such as the existence of large subsidies to RES and absence of common EU electricity market. Namely, in 2008 in Germany average wholesale electricity market price was 66 €/MWh, while retail price was 217 €/MWh. Six years later, wholesale market price dropped to 37 €/MWh, while retail price increased to 292 €/MWh. In short, in the same period of time wholesale market price dropped for 44%, while retail price increased for 34%, meaning that large portion of additional taxes and (RES) fees are added to the product (electricity) price. This is the consequence of large RES integration. The market cannot be fairly developed if growing portion of players are constantly subsidized. At the same time the idea of common EU market is obviously struggling with its realization. Almost 20 years after introduction the idea of common EU electricity market and huge efforts and investments, comparable countries like Germany and Italy are having very different results: wholesale electricity price in Germany is 37€/MWh, while wholesale electricity price in Italy is 63 €/MWh (or 1,85 times higher), clearly proving absence of common integral EU market. In order to keep the electricity system and market sustainable, it is necessary to resolve these issues as soon as possible.

[34] According to the Hatemi-J Criteria, and all other information criterions (AIC, SBC, HQC), the optimal lag length is 1.

The estimation results of the causality test based on bootstrap simulation technique indicate the existence of a unidirectional causality running from total electricity consumption to real GDP in Croatia. These results contradict the other papers that were dealing with the causal relationship between (total) electricity consumption and economic growth in Croatia. Different empirical results could be explained by different methodology and time frame since this study is the only one that includes capital and labor variables and the longest time period. The results presented in this paper are important for policy makers because they show that energy can be a limiting factor in economic growth and that Croatia should find ways not to adversely affect economic growth by reducing electricity consumption.

The electricity–growth nexus is a well-studied topic in the energy economics literature nowadays. However, 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:

1) newer data sets (i.e. even longer time series and other potential control variables);

2) more sophisticated econometric methods.

In the future it may be interesting, depending on the data availability and reliability, to use other control variables such as:

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);

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

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) autoregressive distributed lag (ARDL) approach which is also 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.

Continuous empirical research, in line with the above mentioned future research recommendations, is a necessity together with the Croatian Energy Strategy update. Right now, these are the two crucial steps in order to get robust empirical results: implement the appropriate policies and fulfil commitments on pan-European common electricity market.

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