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GDP, Electricity Consumption and Financial Development in Croatia: an Empirical Analysis*

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ABSTRACT

The development of modern society cannot be imagined without electricity as a ubiquitous and almost irreplaceable energy source. Energy is a key factor in human development, it provides a standard of living and enables the economy to grow, with electricity being one of its most important forms. In the modern world, efficient energy supply, particularly electricity as its most flexible, commercial and cleanest form represents an important basis for economic growth and development. Although research of the causal link between electricity consumption, financial development and economic growth has been represented in the scientific literature for the last 20-30 years, the results are still contradictory. However, this particular topic has not been systematically investigated and addressed in Croatia. Therefore, studying the causal relationship and economic effects of the mentioned variables represents an important and challenging research task. The purpose of this paper is to determine the interconnectedness of electricity consumption, financial development and economic activity in Croatia. This will be achieved by analysing the available data for the last two and a half decades using the so-called bootstrap approach. According to the empirical results, causality runs from real GDP to total electricity consumption and from financial development to real GDP. In addition to empirical results, policy implications and recommendations for future research will also be presented in the paper.

INTRODUCTION

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. A survey conducted on a sample of more than a hundred countries (Ferguson et al.,

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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 does not imply that there is a causal relationship between the observed variables.

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 consumption and economic growth. In addition, financial development has also become a part of the equation.

Financial development is one of the main determinants of energy / electricity demand. Financial development can affect the demand for electricity by making it easier and cheaper for individuals to borrow money to buy durable goods such as new houses, refrigerators and other appliances. These goods usually use a lot of electricity in daily life, which can affect a country's aggregate electricity consumption (Chang, 2015). In addition, financial development also allows businesses to benefit from well-organized financial infrastructure in terms of easier and less expensive financial funds that can be used to start or improve businesses like buying or building more plants, hiring more workers, and buying more machinery and equipment (Magazzino, 2017). All these factors in their turn will increase the demand for electricity.

Although the international literature is (to some extent) abundant with empirical analysis regarding the relationship between electricity consumption, economic growth and financial development, not a single study concerns Croatia. This fact was the basic motive for conducting the analysis in this paper (for the justification of this statement and literature review see, for example, Jakovac, 2018). Therefore, the purpose of this paper is to examine the relationship between economic growth, electricity consumption and financial development in Croatia using the econometric methodology suitable for relatively small sample and taking into consideration the possibility of structural break(s) in the data. The paper is divided into four sections. Following the introduction, the relevant data and the applied econometric methodology is presented in Section 1. The results of the test and policy implications are summarized in Section 2. Concluding remarks and recommendations for further research are given in the last section.

1. DATA AND METHODOLOGY

All of the data used in this paper consist of annual time series of Croatian real GDP, total electricity consumption and domestic credit to private sector for the period 1995-2019. The choice of the starting period was constrained by domestic credit to private sector data availability. The domestic credit to private sector (in % of GDP) have been obtained from World Development Indicators of World Bank (2021) and it is used as a proxy for financial development. According to Sadorsky (2010), this variable indicates the actual amount of money used in investment projects which is extremely important for financing projects in the electricity sector, which are generally capital intensive. Thus, the (proper) functioning of financial institutions and markets represents an important condition for the development of the electricity sector. 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 - CBS (2012; 2015; 2021). Data covering total electricity consumption (in GWh) were obtained from the Energy Institute Hrvoje Pozar - EIHP (2017; 2020) and exclude transmission and distribution losses. Table 1 shows the trends of GDP, total electricity consumption (TEC) and financial development (FD) in Croatia for the period 1995-2019.

Just by looking at Table 1, one can comment that there might be a structural break in these series. First, for estimation purposes, the variables (GDP, TEC, and FD) were transformed into natural logarithms in order to reduce heteroscedasticity. Second, we used the Chow breakpoint test (Chow, 1960) to detect structural break(s) in the series. The basic idea of Chow breakpoint test is to fit the equation separately for each subsample and to see whether there are significant differences in the estimated equations. A significant difference indicates a structural change in the relationship. To carry out the test, we partition the data into two subsamples. Each subsample must contain more observations than the number of coefficients in the equation so that the equation can be estimated.

Table 1. The trends of GDP, total electricity consumption (TEC) and financial development (FD) in Croatia for the period 1995-2019

Year	*GDP (in millions of US$ at constant prices)*	*Total electricity consumption-TEC (in GWh)*	*Domestic credit to private sector-FD (in % of GDP)*
1995	18184.45	10698.40	26.02
1996	19265.07	10969.90	24.39
1997	20567.37	11809.10	31.37
1998	21072.00	11926.10	34.83
1999	20882.35	12540.20	31.76
2000	21655.00	12639.90	31.87
2001	22542.86	12869.10	36.30
2002	23827.80	13730.60	43.12
2003	25043.13	14018.80	45.05
2004	25773.69	14762.60	47.80
2005	26778.77	15440.90	51.93
2006	28063.79	16143.00	58.51
2007	29495.26	16579.40	61.52
2008	30055.41	17196.20	64.11
2009	27860.99	16440.40	66.75
2010	27498.81	16848.10	68.15
2011	27444.00	16696.60	69.94
2012	26785.34	16299.60	70.75
2013	26677.86	15977.50	69.48
2014	26597.97	15743.20	68.10
2015	27236.35	16388.90	64.42
2016	28189.26	16543.00	60.20
2017	29147.43	17171.90	57.08
2018	29963.12	17195.30	55.41
2019	30831.93	17234.30	54.42

Source: Druzic and Tica (2002), CBS (2012; 2015; 2021), EIHP (2017; 2020)

The Chow breakpoint test then compares the sum of squared residuals obtained by fitting a single equation to the entire sample with the sum of squared residuals obtained when separate equations are fit to each subsample of the data (Chow, 1960). The null hypothesis of the Chow test asserts that there are no breaks at specified breakpoints while the Chow test statistic is computed as:

$$F = \frac{(\bar{u}'\bar{u} - (u_1'u_1 + u_2'u_2))/k}{(u_1'u_1 + u_2'u_2)/(T-2k)} \quad (1)$$

where $\bar{u}'\bar{u}$ is the restricted sum of squared residuals, $u_i'u_i$ is the sum of squared residuals from subsample *i*, *T* is the total number of observations and *k* is the number of parameters in the equation.

By using the Chow test, we recognize that our variables are "broken" at the year 2009 (see Tables A1-A3 in the Appendix). The variables lnGDP (F-statistic = 4.471151) and lnTEC (F-statistic = 4.528689) are "broken" at the 5% significance level while the variable lnFD (F-statistic = 5.653276) was borderline "broken" at the 1% significance level. This structural break was expected and the reasons are self-explanatory in their nature. The period 2009-2014 reflects the time of a severe recession Croatia was going through. At the end of 2008, the global economic crisis manifested itself in Croatia, first by stopping economic growth, then by reducing production and consumption. GDP growth rate was 1.9% (in 2008) compared to 5.1% (in 2007). According to CBS (2021), in the following six years (2009-2014) GDP growth rates were negative (2009 = -7.3%; 2010 = -1.3%; 2011 = -0.2%; 2012 = -2.4%; 2013 = -0.4% and 2014 = -0.3%). In 1999, Croatia faced a mild recession that was caused by the banking crisis in Croatia (internal factor) but also by NATO's war operations in Kosovo (external factor), which had an extremely negative impact on Croatian tourism. In addition, two major crises took place in the region: the Asian crisis of 1997 and the Russian crisis of 1998. Nevertheless, the Chow test recognized no significant breaks at the specified breakpoint year for the variables lnGDP and lnTEC. However, the variable lnFD was "broken" in the year 1999 (F-statistic = 3.129764) at the 10% significance level.

To account for the mentioned structural breaks and to make the causality results more robust, dummy variables DV1999 (equal to 1 for the year 1999 and 0 otherwise) and DV2009 (equal to 1 for the period 2009-2014 and 0 otherwise) were introduced in the analysis. To test for the causal effects between electricity consumption, financial development and economic growth (and dummy variables) we utilize the following vector autoregressive model of order *p*, VAR(*p*):

$$\gamma_t = \nu + \mathrm{A}_1\gamma_{t-1} + \ldots + \mathrm{A}_p\gamma_{t-p} + \varepsilon_t \qquad (2)$$

where y_t is 5x1 vector of our variables, v is a 5x1 vector of intercepts and ε_t is a 5x1 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)[1]. The bootstrap simulation technique is used to generate more reliable critical values in order to test Granger causality between integrated variables. This method is based on the empirical distribution of the underlying data, it is not sensitive to the assumption of normality, it works well even for nonstationary and non-cointegrated data and it has better small sample properties compared to standard tests for causality.

2. RESULTS AND POLICY IMPLICATION(S)

Because many macroeconomic variables are nonstationary, 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, and to determine the order of the series in more robust manner, we conducted three standard tests for the presence of a unit root. We used the Augmented Dickey-Fuller (ADF) test (Dickey & Fuller, 1979), Phillips-Perron (PP) test (Phillips & Perron, 1988) and Elliot-Rothenberg-Stock Dickey-Fuller GLS de-trended (DF-GLS) test (Elliot et al., 1996).

[1] We thank J.A. Hatemi for providing the GAUSS code that was used for the estimation purposes.

Both “intercept and trend” regressors were included in the test equation in all three previously mentioned unit root tests (see Table 2). For the purposes of the ADF and the DF-GLS 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 unit root tests. The critical values for the ADF and PP tests are taken from MacKinnon (1996) while the critical values for DF-GLS are taken from Elliott et al. (1996). 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.

Table 2. Unit root tests

Variables	*ADF*	*PP*	*DF-GLS*
Panel A: Log levels (intercept and trend)			
lnGDP	-1.970069 (1)	-1.856452 (2)	-1.859309 (1)
lnTEC	-1.230191 (0)	-1.270854 (2)	-1.361559 (3)
lnFD	-0.239989 (3)	1.082359 (14)	-1.832660 (3)
1% critical value	-4.416345	-4.394309	-3.770000
5% critical value	-3.622033	-3.612199	-3.190000
10% critical value	-3.248592	-3.243079	-2.890000
Panel B: Log first differences (intercept and trend)			
lnGDP	-2.631914 (0)	-2.603714 (2)	-2.767206 (0)
lnTEC	-4.927369 (0)	-4.940006 (2)	-5.104004 (0)
lnFD	-3.886411 (3)	-5.976908 (6)	-1.125912 (3)
1% critical value	-4.416345	-4.416345	-3.770000
5% critical value	-3.622033	-3.622033	-3.190000
10% critical value	-3.248592	-3.248592	-2.890000

Optimal lag lengths are shown in parenthesis. The maximum lag length considered is 3

Source: authors’ calculation using EViews 7.1

The results for the three unit root tests summarized in Table 2 reveal that all variables are nonstationary at level but become stationary after first difference except the real GDP variable. The lnGDP variable remained nonstationary after differencing and had to be filtered (i.e. smoothed) to become stationary. After filtering and differencing the lnGDP variable, the ADF test statistic was approximately (-3.89) or (-3.90) according to PP test and even the DF-GLS test. Moreover, lnFD variable had also been smoothed since it remained nonstationary (only) according to the DF-GLS test. After filtering and differencing the lnFD variable, the DF-GLS test statistic was approximately (-4.80).[2]

Prior to tests for causality, and given the fact that our time series is relatively short (only 25 observations due to data availability) in the GAUSS code we set the maximum lag length at one year. In samples that are relatively long, the maximum lag length should be set at three years, which is sufficiently long for the annual data to capture the dynamic relationship. 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. In addition, according to Hatemi-J (2003), we use the Hatemi-J Criteria (HJC) 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. In our case, as expected, according to the HJC (and other criteria such as AIS, SBC and HQC), the optimal lag length is 1. The causality test results for the null hypothesis that lnTEC does not Granger cause lnGDP (and vice versa) are presented in Table 3. The same logic is applied when testing lnFD against lnTEC / lnGDP (and vice versa). If the computed MWALD test statistic is greater than the critical values, we reject the null hypothesis.

[2] The lnGDP and lnFD variables were smoothed using the Holt-Winters multiplicative smoothing method. This analysis was done by using EViews 7.1 econometric software.

Table 3. 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*
lnTEC ≠> lnGDP	2.558	9.459	4.761	3.274
lnGDP ≠> lnTEC	13.812	9.308	5.005**	3.412
lnFD ≠> lnGDP	8.344	9.772	4.870**	3.248
lnGDP ≠> lnFD	0.575	9.625	4.884	3.179
lnFD ≠> lnTEC	2.884	9.367	4.753	3.153
lnTEC ≠> lnFD	2.037	9.407	4.865	3.221

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 21.0

The bootstrap causality test results presented in Table 3 suggest the existence of a unidirectional causality running from financial development to real GDP. This implies that financial development affects economic growth in Croatia. These results are somewhat expected since in Croatia the service sector is dominant (up to 60% of its GDP) with the financial sector being a part of it. This is due to the privatization process in Croatia that has resulted with brown-field investments in service sector, especially telecommunications and financial sector because of the high profits in these oligopolistic markets. When it comes to the financial sector / system alone, according to the Croatian National Bank-CNB (2021) and based on the share of financial sector assets held, the most important financial intermediaries in Croatia are credit institutions, most notably the banks. In addition to banks, also present in the market are housing savings banks (promoting special-purpose savings and providing household lending), the Croatian Bank for Reconstruction and Development (HBOR) and credit institutions from other EU countries (CNB, 2021). Therefore, it is possible to conclude that Croatia is characterized by dependence on its banking system. Namely, the obtained causality results imply (or better yet confirm) that the bank-centricity in Croatia influenced the banks to stand out as the most important part of the financial system. These results reveal (in theory) that Croatian financial system allows firms and households to find easier and less expensive financial fund to start or improve their businesses and to buy durable goods. Nevertheless, one could expect the causality to run from financial development to total electricity but the results reveal that this not the case in Croatia. It turns out that the flow of credit to the private sector (in this case electricity sector) in not (statistically) significant. In addition, the data in Table 1 shows that in the last couple of years (from 2013 onwards) the share of domestic credit to private sector in decreasing.

Furthermore, the test results (see Table 3) indicate the existence of a unidirectional causality running from real GDP to total electricity consumption. These results are in line with the findings of Borozan (2013). This, in turn, implies that there is a scope for electricity conservation measures (for example, curtailing electricity use, phasing out energy / electricity subsidies or elimination of electricity price distortions) and that these measures may be feasible with little adverse or no detrimental side effects on Croatian economic growth and employment. In addition, the conservation hypothesis implies that bringing domestic electricity prices in line with market prices can be a good opportunity to promote technological innovation. Not to mention the establishment of a truly and finally competitive electricity market (in line with EU electricity directives and the postulates of Energy Union) in order to allocate energy / electricity resources into the most productive uses in the economy and to boost economy's competitiveness.

CONCLUSION

This paper examines the relationship between economic growth, total electricity consumption and financial development in Croatia using the annual data covering the period 1995 – 2019. Since we determined the existence of breakpoints (i.e., in 1999 and 2009), our initial time series was expanded with two additional dummy variables. Our estimation results indicate the existence of unidirectional causality running from economic growth to total electricity consumption and from financial development to economic growth. The analysed nexus between financial development and total electricity consumption indicate the existence of the so-called neutrality hypothesis. The results show that financial development (i.e., financial sector) affects economic growth in Croatia since it allows businesses (and households) access to additional sources of funding. Therefore, Croatia has to deepen its financial sector and strengthen the relationship between the financial and real sectors. Under the assumption of causality running from economic growth to total electricity consumption, electricity conservation policies can be implemented with little or no effects / risks for Croatian economy.

The electricity–financial development–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, financial development 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 other sophisticated econometric methods.

In the future, it may be interesting to investigate (wider) multivariate causality between electricity consumption, financial development and GDP and, depending on the data availability and reliability, to use other control variables such as capital stock (as a proxy for capital) and employment (as a proxy for labour) as standard (neoclassical) inputs. In addition to these variables, future research should include technological progress as independent variable. Through its impact on energy efficiency and savings in energy consumption, technological progress plays an important role in both electricity consumption and generation. In addition, technological changes affect both prices and energy availability. It may also be interesting to use an additional dummy variable as a reflection of the recent COVID-19 pandemic. According to the CBS (2021), throughout 2020 the Croatian economy dropped at a record rate of 8.4% due to the corona crisis.

Also, principal component analysis (PCA) should be used in the future research in order to construct a “better” FD variable since PCA can be applied to reduce the dimensionality of the variables by addressing the variance in form of principal components. For example, Rashid (2015) states that using the PCA method helps to find / create the (most) suitable indicator when measuring a country's financial development. This recommendation is due to the fact that the concept of financial development cannot be measured through any single variable. Indeed, most of the studies employ the indicator on domestic credit to private sector. However, financial development can be measured with a number of (other similar) variables such as financial system deposits, broad money (or M2 monetary aggregate), liquid liabilities (or M3 monetary aggregate) and domestic credit provided by banking sector. If we include some of them (or all) in a single equation, a problem of multicollinearity will appear since all these variables are closely related to each other. That is why the PCA method could be used since it reduces the number of variables without hurting the data

Ultimately, this remains a challenge for present and future research on this topic. In general, authors should keep in mind that policy makers are not interested about the examined time frame 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.

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APPENDIX

Table A1. Chow breakpoint test for lnGDP

Breakpoint year: 2009				
Statistic	Value			Probability
F-statistic	4.471151		F(3,18)	0.0163
Log likelihood ratio	13.36475		$\chi^2(3)$	0.0039
Wald Statistic	19.89889		$\chi^2(3)$	0.0002

Null Hypothesis: No breaks at specified breakpoints

Source: authors' calculation using EViews 7.1

Table A2. Chow breakpoint test for lnTEC

Breakpoint year: 2009				
Statistic	Value			Probability
F-statistic	4.528689		F(3,18)	0.0156
Log likelihood ratio	13.49626		$\chi^2(3)$	0.0037
Wald Statistic	20.06082		$\chi^2(3)$	0.0002

Null Hypothesis: No breaks at specified breakpoints

Source: authors' calculation using EViews 7.1

Table A3. Chow breakpoint test for lnFD

Breakpoint year: 2009				
Statistic	Value			Probability
F-statistic	5.653276		F(3,18)	0.0066
Log likelihood ratio	15.93187		$\chi^2(3)$	0.0012
Wald Statistic	18.09265		$\chi^2(3)$	0.0004

Null Hypothesis: No breaks at specified breakpoints

Source: authors' calculation using EViews 7.1