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EMPIRICAL ANALYSIS ON ECONOMIC GROWTH AND ENERGY CONSUMPTION RELATIONSHIP IN CROATIA[1]

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ABSTRACT

This paper investigates the causal relationship between economic growth and energy consumption in Croatia for the period 1952-2010. Using Chow breakpoint test we identified a structural break in the year 1989. Therefore, we have conducted our analysis on two sub-samples. The first one refers to the period 1952-1989 while the second one refers to the period 1993-2010. The years between 1990 and 1992 have been omitted from the analysis due to massive damage to the Croatian economy caused by the war at that time. Our findings suggest that there is a bidirectional feedback in the short-run and that causality runs from energy consumption to economic growth in the long-run in the first sub-sample. At that time, especially in mid 1970s, Croatia became a medium developed industrial country with the industry sector as the biggest consumer of energy so energy consumption played an important role in the growth process. After the structural break, we found a unidirectional causality running from economic growth to energy consumption. In this case, energy conservation policies together with the establishment of a competitive energy market may be feasible with little or no detrimental side effects to economic growth and employment.

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I. INTRODUCTION

Since the 1970s there have been a number of empirical studies attempting to examine the causal relationship between economic growth and energy consumption. Even with fairly extensive empirical research undertaken within this topic, the results regarding causality direction have been largely inconclusive. Odhiambo (2009) quite clearly states that the empirical evidence from previous studies on this subject shows that the causal relationship between energy consumption and economic growth differs from country to country (and from one author to another) as well as over time. The reasons can be attributed to differences among countries, statistical techniques employed, time horizons and data sets. The mixed empirical evidence is by default matched with theoretical disagreement on the role of energy in economic growth (is energy just an intermediate input according to the traditional neo-classical growth model or is it an important input for production and all economic activities as stated by the ecological economists). This, in the end, makes the role of energy a rather controversial topic in economic literature. Nevertheless, knowing the direction of causality has significant implications on economic policy. For instance, should the state employ structural policies aimed at the reduction of energy consumption or should it employ additional resources in subsidizing energy prices and securing long-term and stable energy supply depends on the analysis of energy consumption-economic growth nexus.

Therefore, the purpose of this paper is to (re)examine the relationship between economic growth and energy consumption in Croatia. We are taking in consideration longer time period then, for instance, Vlahinić-Dizdarević and Žiković (2010) and recently Borozan (2013) did and the possibility of a structural break which was not recognized in the paper by Gelo (2009). The rest of the paper is organized as follows: Section 2 reviews the empirical literature on energy consumption-economic growth nexus. Section 3 presents the data and the econometric methodology. In section 4, empirical results are summarized and policy implications are discussed. Section 5 concludes.

II. LITERATURE REVIEW

In today's scientific literature the relationship between energy and economic growth is well established, but the empirical results regarding the direction of causality still remain without consensus. Scientific studies still have not conclusively determined whether economic growth results in energy consumption or is it the other way round. Nevertheless, it is important to know the direction of the above mentioned causality because knowing it has significant implications on economic policy. Ever since Kraft and Kraft (1978) initiated the empirical research regarding causal relationship between energy consumption and economic growth in the case of U.S. economy, numerous studies on this type of causality have been carried out on a wide range of developed as well as developing and emerging countries. The analysis regarding the link between energy consumption and economic growth provides an insight into the role of energy in economic growth. More importantly, it also provides a basis for discussion on appropriate and effective energy and environmental policy design and implementation as well as forming government policies regarding subsidies system (Vlahinić-Dizdarević and Žiković, 2010). In other words, the aforementioned causal relationship has important implications from the theoretical, empirical and policy standpoints (Ozturk et al., 2010; Odhiambo, 2009).

As already mentioned, the empirical literature on energy consumption – economic growth nexus (see Table 1) has yielded mixed results while the lack of a clear consensus on this relationship can be attributed to differences among countries in terms of structural and economic policy characteristics (different economic and political histories, political and institutional arrangements, different cultures), the heterogeneity in climate conditions, varying energy consumption patterns and different indigenous energy supplies, the alternative econometric methods employed as well as to the presence of omitted variable bias along with varying time horizons and the chosen lag structures (Ozturk, 2010; Apergis and Payne, 2009, p. 211; Chontanawat et al., 2008, p. 210; Sica, 2007).

TABLE 1. COMPARISON OF SELECTED EMPIRICAL STUDIES REGARDING CAUSALITY BETWEEN ENERGY CONSUMPTION AND ECONOMIC GROWTH IN THE LAST THIRTY YEARS

Authors[2]	***Analyzed country and period***	***Results***
Kraft and Kraft (1978)	USA (1947-1974)	GDP→Energy
Ackra and Long (1980)	USA (1950-1970)	no causality
Yu and Hwang (1984)	USA (1947-1979)	no causality
Yu and Choi (1985)	South Korea (1954-1976)	GDP→Energy GDP←Energy
	Philippines (1950-1976)	no causality
	USA (1947-1979), United Kingdom and Poland (both 1950-1976)	
Abosedra and Baghestani (1989)	USA (1947-1987)	GDP→Energy
Hwang and Gum (1991)	Taiwan (1961-1990)	GDP↔Energy
Yu and Jin (1992)	USA (1974-1990)	no causality
Masih and Masih (1996)	Malaysia (1955-1990), Philippines (1955-1991) and Singapore (1960-1990)	no causality
	India (1955-1990)	
	Indonesia (1960-1990)	GDP←Energy GDP→Energy
	Pakistan (1955-1990)	GDP↔Energy
Cheng (1997)	Brazil (1963-1993)	GDP←Energy
	Mexico (1949-1993) and Venezuela (1952-1993)	no causality
Cheng and Lai (1997)	Taiwan (1955-1993)	GDP→Energy
Glasure and Lee (1997)	South Korea and Singapore (1961-1990)	GDP↔Energy
Masih and Masih (1997)	Korea (1961-1990)	GDP→Energy GDP↔Energy
	Taiwan (1961-1990)	
Masih and Masih (1998)	Sri Lanka and Thailand (1955-1991)	GDP←Energy

[2] The numbers in the parentheses refer to the year when the articles were published.

continued table

Asafu-Adjaye (2000)	India, Indonesia and Turkey (1973-1995)	GDP←Energy
	Thailand and Philippines (1971-1995)	GDP↔Energy
Stern (2000)	USA (1948-1994)	GDP←Energy
Yang (2000)	Taiwan (1954-1997)	GDP↔Energy
Aqeel and Butt (2001)	Pakistan (1955-1996)	GDP→Energy
Glasure (2002)	Korea (1961-1990)	GDP↔Energy
Hondroyiannis et al. (2002)	Greece (1960-1999)	GDP↔Energy
Soytas and Sari (2003)	Argentina (1950-1990)	GDP↔Energy GDP→Energy
	Korea and Italy (both 1953-1991)	
	Turkey, France, Japan and Germany (all 1950-1992)	GDP←Energy
	Indonesia (1960-1992), Poland (1965-1994), Canada, UK and USA (all 1950-1992)	no causality
Fatai et al. (2004)	India and Indonesia (1960-1990)	GDP←Energy
	Australia and New Zealand (1960-1990)	GDP→Energy
	Thailand and Philippines (1960-1990)	GDP↔Energy
Oh and Lee (2004)	Korea (1970-1999)	GDP↔Energy
Paul and Bhattacharya (2004)	India (1950-1996)	GDP↔Energy
Wolde-Rufael (2004)	Shanghai (1952-1999)	GDP→Energy
Hatemi-J and Irandoust (2005)	Sweden (1965-2000)	GDP→Energy
Lee (2005)	18 developing countries (1975-2001)[3]	GDP←Energy
Lee (2006)	11 developed countries[4]	mixed results
Jobert and Karanfil (2007)	Turkey (1960-2003)	no causality
Akinlo (2008)	11 Sub-Sahara African countries (1980-2003)[5]	mixed results

[3] The list of selected developing countries: Korea, Singapore, Hungary, Argentina, Chile, Colombia, Mexico, Peru, Venezuela, Indonesia, Malaysia, Philippines, Thailand, India, Pakistan, Sri Lanka, Ghana i Kenya

[4] The results for selected developed countries:
Canada, Belgium, Netherlands and Switzerland (GDP Energy)
France, Italy and Japan (GDP Energy)
United States of America (GDP Energy)
United Kingdom, Germany and Sweden (no causality)
The analysed period spans from 1960 to 2001, except Canada (1965-2001) and Germany (1971-2001).

[5] The results for eleven countries in sub-Saharan Africa:
Congo, Sudan and Zimbabwe (GDP Energy)
Gambia, Ghana and Senegal (GDP Energy)
Cameroon, Cote D'Ivoire, Nigeria, Kenya and Togo (no causality)

continued table

Chiou-Wei et al. (2008)	Philippines and Singapore (1971-2003)	GDP⟶Energy
	USA (1960-2003), Thailand and Korea (both 1971-2003)	no causality
	Indonesia and Malaysia (1971-2003)	
	Taiwan (1954-2006) and Hong Kong (1971-2003)	GDP⟷Energy GDP⟵Energy
Erbaykal (2008)	Turkey (1970-2003)	GDP⟵Energy
Odhiambo (2009)	Tanzania (1971-2006)	GDP⟵Energy
Gelo (2009)	Croatia (1953-2005)	GDP⟶Energy
Odhiambo (2010)	South Africa and Kenya (1972-2006)	GDP⟵Energy
	Congo (1972-2006)	GDP⟶Energy
Tsani (2010)	Greece (1960-2006)	GDP⟵Energy
Imran and Siddiqui (2010)	Bangladesh, India and Pakistan (1971-2008)	GDP⟶Energy
Vlahinić-Dizdarević and Žiković (2010)	Croatia (1993-2006)	GDP⟶Energy
Žiković and Vlahinić-Dizdarević (2011)	Belgium, Denmark, Ireland, Norway, Sweden, Croatia, Latvia, Lithuania, Moldova, Slovenia	GDP⟶Energy
	Austria, Czech Republic, Slovakia, Malta, Bulgaria, Bosnia and Herzegovina[6]	GDP⟵Energy
Ying et al. (2011)	China (1954-1997)	GDP⟶Energy
Kakar and Khilji (2011)	Pakistan (1980-2009)	GDP⟵Energy
Borozan (2013)	Croatia (1992-2010)	GDP⟵Energy

Source: made by the author[7]

The review of empirical studies in Table 1 refers to approximately 40 selected researches on the causal relationship between energy consumption and economic growth within the last thirty three years. This type of research regarding the causality between energy and economic growth, as previously mentioned, has been extensively examined[8] within the energy economics

[6] Their paper examines the existence and the direction of causality between the oil consumption and the economic growth in small European countries over the period 1980-2007 for the developed countries and 1993-2007 for the transition countries. For more details see Žiković and Vlahinić-Dizdarević (2011).
[7] According to Borozan (2013), Žiković and Vlahinić-Dizdarević (2011), Ying et al. (2011), Kakar and Khilji (2011), Vlahinić-Dizdarević and Žiković (2010), Imran and Siddiqui (2010), Tsani (2010), Odhiambo (2010), Odhiambo (2009), Gelo (2009), Erbaykal (2008), Chiou-Wei et al. (2008), Erdal et al. (2008), Akinlo (2008), Jobert and Karanfil (2007), Lee (2006), Lee (2005), Hatemi-J and Irandoust (2005) and Aqeel and Butt (2001).
[8] For more detailed international evidence on energy consumption – economic growth nexus see Payne (2010) and Ozturk (2010). These two authors provide the most comprehensive international survey of the empirical literature on the causal relationship between energy consumption and economic growth. Their literature review covers more than 110 empirical studies in the period from 1978 till 2009. Also, a paper from Chontanawat et al. (2008) is worth mentioning since it investigates the causality between energy and GDP for over 100 countries (30 OECD and 78 non-OECD countries) in the period from 1960 to 2000 and from 1971 to 2000 respectively.

literature but with diverse results. At this point we would like to draw attention to the work of Gelo (2009), joint work of Vlahinić-Dizdarević and Žiković (2010) and recently published article by Borozan (2013). Although these papers analyze the causality between energy consumption and economic growth in Croatia, there are substantial differences among them. While Gelo (2009) analyzes the direction of causality for the period 1953 – 2005, Vlahinić-Dizdarević and Žiković (2010) analyzed the direction of causality in Croatia starting from its independence, i.e. for the period 1993 – 2006. Borozan (2013) performed her analysis using slightly longer time span (1992 – 2010) then Vlahinić-Dizdarević and Žiković (2010) did. Furthermore, Gelo (2009) used a VAR model in the presence of cointegration when an error correction model should have been used. Vlahinić-Dizdarević and Žiković (2010), however, overcame this methodological issue. Although the Johansen cointegration test was applied in the analysis done by Borozan (2013), the cointegration between the series was not established. Our paper, on the other hand, (re)examines the relationship between economic growth and energy consumption in Croatia for the period 1952 – 2010 but with the possibility of a structural break in the data.

According to the results of the empirical studies presented in Table 1, it can be concluded that the directions of causal relationship between energy consumption and economic growth could be categorized into four possible hypotheses (growth hypothesis, conservation hypothesis, neutrality hypothesis and feedback hypothesis).

Unidirectional causality from energy consumption to economic growth is commonly considered as the growth hypothesis which we marked in Table 1 as **"GDP Energy"**. According to Binh (2011, p. 2), policy makers should pay special attention on restrictions of energy use because this action may impede economic growth. In addition, Ozturk (2010, p. 341) states that growth hypothesis suggests that energy consumption plays an important role in economic growth both directly and indirectly in the production process as a complement to land, labour and capital. If this is the case, the economy is considered energy dependent and shocks to energy supply will have a negative impact on country's real GDP. Consequently, in this situation one may conclude that energy is a limiting factor to economic growth. On the other hand, according to Vlahinić-Dizdarević and Žiković (2010, p. 43), the state should employ additional resources in subsidizing energy prices and securing long-term and stable energy sources for its economy. If not, reducing energy consumption, for example, through bringing domestic energy prices in line with the market prices could lead to a fall in income and employment.

Evidence of unidirectional causality running from GDP to energy consumption (marked as **"GDP Energy"** in Table 1) could suggest full compatibility between energy conservation policies and economic growth policies (Sica, 2007) meaning that a country is not entirely dependent on energy for its economic growth (Zhang, 2011, p. 2266). This situation is known as the conservation hypothesis. It implies that energy conservation policies, such as the reduction in greenhouse gas emissions, efficiency improvement measures and demand management policies (Payne, 2010), designed to reduce energy consumption and waste will have little or no adverse effect on economic growth. Vlahinić-Dizdarević and Žiković (2010, p. 43) also add that policymakers may use these findings in decreasing the tax burden and attracting the investments or in increasing government spending.

The neutrality hypothesis (marked as **"no causality"** in Table 1) considers energy consumption to be a small component of overall output and thus have little or no impact on real GDP (Apergis and Payne, 2009.) According to Binh (2011), the neutrality hypothesis implies that energy is assumed to be neutral to growth (i.e. energy consumption not correlated with GDP) and that energy costs are negligible. In this instance, neither energy conservation nor expansion policies have any significant effect on economic growth. Likewise, any change in the economy may not affect the consumption of energy. Finally, a bidirectional causality between energy consumption and economic growth (which is also known as the feedback hypothesis and marked as **“GDP Energy”** in Table 1) suggests that energy consumption and economic growth cause each other. In other words, the variables are interdependent and may serve as complements to one another. Under this hypothesis, the two variables are jointly determined and affected at the same time meaning that increase (decrease) in energy consumption results in real GDP increase (decrease) and vice versa (Zhang, 2011; Ozturk, 2010; Payne, 2010).

III. DATA AND ECONOMETRIC METHODOLOGY

Data

All the data utilized in this paper consist of annual time series of real GDP and total energy consumption for the period 1952 – 2010 in Croatia. The real GDP data (in millions of US$) was originally obtained from the article by Družić and Tica (2002). Figures covering real GDP were subsequently expanded with the data from the Croatian Bureau of Statistics and its Statistical Yearbooks (Edition 2008; 2009; 2010) together with the estimates obtained from the Croatian Chamber of Commerce (2011). Data covering total energy consumption (in petajoules - PJ) was obtained from the Energy Institute Hrvoje Požar (2009a; 2009b; 2010; 2011). More precisely, from the annual energy reports/balances entitled “Energy in Croatia”. In order to graphically visualise the variables that will be used in this analysis, Figure 1 depicts Croatia’s total energy consumption and gross domestic product.

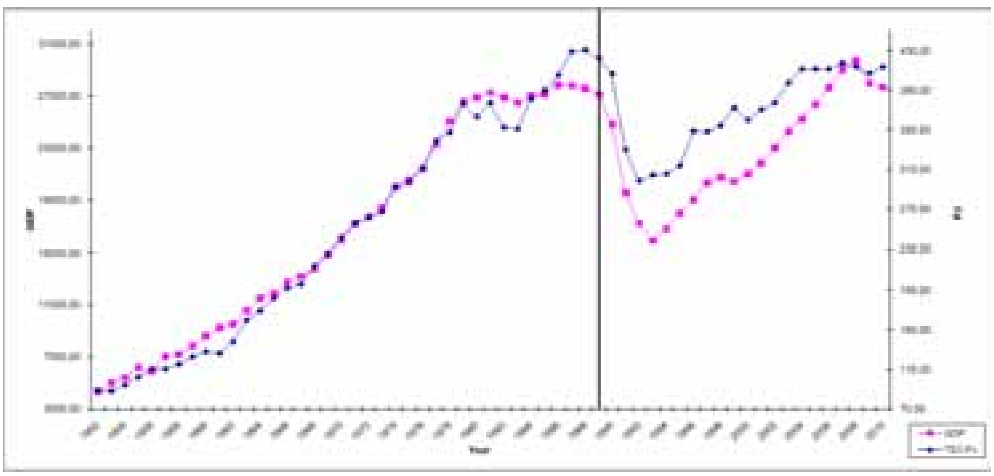

FIGURE 1. TOTAL ENERGY CONSUMPTION AND REAL GDP IN CROATIA FOR THE PERIOD 1952-2010

Source: Družić and Tica (2002); Croatian Bureau of Statistics (2008-2010); Croatian Chamber of Commerce (2011); Energy Institute Hrvoje Požar (2009a; 2009b; 2010)

The reasons for choosing 1952 as a starting period are purely historical and methodological in their nature. The explanation for the historical part lies in the following: it was not until 1950's when higher economic growth rates were recorded in Croatia (especially in the period 1950-1980). Regarding energy consumption, prior to 1952 (and 1953, respectively) there were no significant differences in the change of energy consumption. On the other hand, the enhancement of statistical documentation as well as development of macroeconomic analytical framework that initiated in the second half of the twentieth century (namely, after World War II) lays an explanation for the methodological part (Družić and Tica, 2003; Gelo, 2009).

Just by looking Figure 1 alone, one can comment that there might be a structural break in these series. By using the Chow breakpoint test (Chow, 1960) we recognize that our variables are "broken" at the year 1989 (the results are presented in tables A.1 – A.2 in the appendix). This breakpoint is depicted with a vertical line on Figure 1.

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. 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:

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

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.

Due to the structural break we divided the initial time series into two sub-series. Therefore, we analyze the causality between energy consumption and economic growth in Croatia for the period between 1952 and 1989 and for the period between 1993 and 2010. Also, for the purposes of our econometric analysis, both variables have been transformed into natural logarithms.

There are several reasons why the structural break occurred in the year 1989 (or at the end of it) and why we have omitted the years between 1990 and 1992 from this analysis. From an economic point of view, the reasons why the structural break happened in 1989 can be attributed to the following. Namely, the period from 1952 to 1980 (Družić and Tica, 2003, p. 107) was the most successful developmental period of the Croatian economy. Average annual GDP growth rate reached 6.7% during that time. The growth rate of per capita GDP amounted to 6.1% while the average growth rate of employment was approximately 4%. According to Družić and Tica (2003, p. 113), the extensive economic growth however resulted in the slow growth of production factors due to which Croatia, in the later stages of its industrialization, has failed to achieve rapid growth relying on the use of scarce resources and new technologies. This resulted in reduced competitiveness of Croatian companies on the foreign markets, accumulation of trade deficits and in an increased external debt. In the 1980's, the Croatian economy therefore started to lose the so-called development momentum and entered into stagnation. It was not until the very end of this decade (negative growth rate, hyper-inflation, the collapse of the administrative-planned economic system) when it came to an overall economic collapse.

In terms of energy consumption it can be stated (Gelo, 2010, p. 175) that the highest energy consumption was in 1987 and 1988 respectively. At that time, total energy consumption amounted up to 429.74 PJ. The decline in energy consumption began in 1989, two years before the war.

In political terms, the very end of 1980s and the beginning of 1990s can be identified with the making of the initial steps on the way to Croatia's independence by holding the first democratic parliamentary elections in April 1990 and by constituting a multiparty Croatian Parliament. This, in turn, marked the beginning of a recent Croatian history and the termination of all state and legal relations with the former Socialist Federal Republic of Yugoslavia. In other words, the separation from the former Yugoslavia initiated a process of creating an independent and sovereign Republic of Croatia. This political process was an overture to the exhaustive Croatian War of Independence. The war with its devastations, human casualties and vast destructions affected the performance of the Croatian economy (Družić and Tica, 2003; Stipetić, 2002). According to Pašalić (1999. p. 37), as a member of the former Yugoslav federation Croatia was experiencing deep transition crisis that continued in the 1990's (after its independence). War that started in 1991 only worsened the overall situation. More specifically, the war in Croatia caused direct and indirect material damage which were estimated at 27 billion USD. Half of this amount, 13.8 billion USD (or 51.34%) refers to damage caused to the economy alone. Damages to the economic infrastructure constitute around 34.3% (or 4.74 billion USD) of the total damage in the economy. Nearly half of that amount (47%) refers to the damage done on the energy infrastructure. Furthermore, the direct damage to the Croatian Electricity Company (Hrvatska elektroprivreda) was estimated at 519 million USD by the end of September 1992. Taking into account the value of lost property in the republics of the former Yugoslav federation, these estimates amounted up to 1.68 billion USD. For comparison, the direct damage on the ruined, damaged and confiscated property of INA (Croatian Oil Company), including the Adriatic oil pipeline, was estimated around 329.3 million USD by the middle of 1992 while the lost profits of INA were estimated at an additional 215.9 million USD by the end of 1993. Some estimates (Pašalić, 1999, p. 38) even indicate that in the period from 1990 to 1993 indirect damage to the Croatian economy was equivalent to the loss of one-year GDP (more than 109% of annual average GDP, to be more precise). In conclusion, these facts are the reason why the very first years of Croatian independence are excluded from the analysis in this paper.

Econometric methodology

This study uses Granger causality test (Granger, 1969) to investigate the causal relationship between economic growth and total energy consumption in Croatia. The result of causality is very sensitive to the lag length adopted in the causality models. In particular, this study uses the multivariate information criteria (namely, Akaike's information criterion – AIC and Schwarz's information criterion – SIC) to determine the optimal lag length (Gujarati and Porter, 2009, p. 494). Since causality test requires that the variables in question have the same order of integration, first we have to examine the stationarity of the variables. Since there is no uniformly powerful test of the unit root hypothesis (Gujarati and Porter, 2009) and in order to get more robust results (especially for the second sub-sample), we use three standard tests for the presence of a unit root, namely Augmented Dickey-Fuller (1979 – ADF) test, Phillips-Perron (1988 – PP) test and Elliott-Rothenberg-Stock (1996 – DF-GLS) test. Both trend and intercept are included in the test equation in the above mentioned unit root tests. For the purposes of ADF and DF-GLS tests, the Schwarz information criteria is used to determine the number of lags whereas Newey and West method is applied to choose the optimal lag length (or bandwidth) for the purposes of PP test.

If the variables are I(1) we must then evaluate if the variables in our analysis are cointegrated (Engle and Granger, 1987). For the purposes of our analysis we will employ the Johansen test as the most commonly used method (Johansen, 1991). This test provides two different likelihood ratio tests where one of them is based on the trace statistics and the other one on the maximum eigenvalue. When testing for cointegration using the Johansen procedure, under trend assumption we utilize the specification of no deterministic trend in the data with an intercept in the cointegrating equation. Accordingly, if the variables are indeed cointegrated, the causality relationship is determined by using the error correction model (ECM). The ECM is used to test for long and short-run causality among cointegrated variables (Gujarati and Porter, 2009). If one or both variables are not I(1) according to ADF, PP and DF-GLS unit root test, even after eventually being filtered (or if the Johansen procedure does not confirm the existence of cointegration among the variables), a vector autoregressive (VAR) model specified in differences comes as a valid causality testing solution (Vlahinić-Dizdarević and Žiković, 2010, p. 46).

IV. RESULTS AND POLICY IMPLICATIONS

Even though the correlation between our two variables is high (0.99 in the first sub-sample and 0.96 in the second), it does not directly imply that the variables are cointegrated. Table 2 reports the results of the standard unit root test (ADF, PP and DF-GLS). The results for the first sub-sample show that we can reject stationarity of levels for the tested variables and that the variables are integrated of order 1. Namely, differencing transformed them into stationary variables.

TABLE 2. UNIT ROOT TEST RESULTS USING ADF, PP AND DF-GLS

	Variables	ADF		PP		DF-GLS	
		Level	First difference	Level	First difference	Level	First difference
First sub-sample (1952-1989)	LGDP	-0.16458	-9.31490	0.29952	-9.17894	0.19792	-8.32835
	LTEC_PJ	-0.34188	-6.22517	-0.30257	-6.22872	-0.73198	-5.69718
	1% critical value	-4.22681	-4.23497	-4.22681	-4.23497	-3.77000	-3.77000
	5% critical value	-3.53660	-3.54032	-3.53660	-3.54032	-3.19000	-3.19000
	10% critical value	-3.20032	-3.20244	-3.20032	-3.20244	-2.89000	-2.89000

continued table

Second sub-sample (1993-2010)	LGDP	-2.69732	-2.53785	-1.07321	-2.37524	-3.30977*	-2.49614
	LTEC_PJ	-0.93389	-3.92604**	-0.77275	-4.20454**	-1.53812	-4.27815
	1% critical value	-4.66788	-4.72836	-4.61620	-4.66788	-3.77000	-3.77000
	5% critical value	-3.73320	-3.75974	-3.71048	-3.73320	-3.19000	-3.19000
	10% critical value	-3.31034	-3.32497	-3.29779	-3.31034	-2.89000	-2.89000

Source: author's calculation

*Note: *, **, *** indicates signification at 1%, 5% and 10%*

When it comes to second sub-sample (1993-2010), it must be stated that GDP remained nonstationary after differencing and had to be filtered (i.e. smoothed) to become stationary. After filtering and differencing the real GDP variable, the ADF test statistic was approximately (-3.49) or (-3.64) according to PP test and even (-3.89) when it comes to DF-GLS test. Moreover, energy consumption variable had also been smoothed[9] (prior to stationarity tests) due to changes in total energy consumption as well as sectoral (industry, households, transport, services) changes in energy consumption. These changes are marked by a sharp drop in energy consumption (1990-1992) followed by a gradual but slow growth. Moreover, the insufficient (and practically stagnant) growth of energy consumption in industry must be emphasized within this period. On the other hand, increase in energy consumption is recorded in household and transport sector. Since the variables are non-stationary and integrated of order 1, we then employ the Johansen approach to determine the long-term relationship between the variables.

TABLE 3. RESULTS OF JOHANSEN'S COINTEGRATION TESTS

	Variables	H_0	Trace statistics	Max-Eigen statistics
First sub-sample (1952-1989)	LGDP LTEC_PJ	None*	31.75502 (20.26)	25.62642 (15.89)
		At most 1	6.128602 (9.16)	6.128602 (9.16)
Trace test and Maximum Eigenvalue test indicate 1 cointegration equation at the 5% level				
Second sub-sample (1993-2010)	LGDP LTEC_PJ	None	13.13169 (20.26)	9.591088 (15.89)
		At most 1	3.540607 (9.16)	3.540607 (9.16)
Trace test and Maximum Eigenvalue test indicate no cointegration at the 5% level				

Source: author's calculation

*Note: * denotes rejection of the hypothesis at the 5% level; critical values are in ( ) and are taken from MacKinnon, Haug and Michelis (1999)*

[9] The real GDP and total energy consumption variables were smoothed using the Holt-Winters multiplicative smoothing method. This analysis together with unit root, cointegration and causality testing was done by using EViews 7.1 econometric software.

The Johansen cointegration results are presented in table 3. In the case of the first sub-sample (1952-1989) both Trace and Maximum Eigenvalue test indicate one cointegration vector at the 5% level of significance. Accordingly, economic growth and total energy consumption are said to be cointegrated and there must be a long-run relationship between them. In this case, we have to apply the error correction model (ECM) and test for long and short-run causality among cointegrated variables (see Table 4). In the case of the second sub-sample (1993-2010) however, both tests indicate that we cannot reject the hypothesis of no cointegration between GDP and total energy consumption at the 5% significance level. This, on the other hand, indicates that we have to apply a vector autoregressive model specified in differences in order to determine the causality between the variables (see Table 5). Since we found that real GDP is cointegrated with total energy consumption, there must be either unidirectional or bidirectional Granger causality. The estimation results of the error correction model are presented in Table 4.

TABLE 4. RESULTS OF THE ERROR CORRECTION MODEL FOR THE FIRST SUB-SAMPLE (1952-1989)

Dependent variable	***D(LGDP)***	***D(LTEC_PJ)***
CointEq1	0.018442	0.013664
	[5.38987]	[3.44326]
D(LGDP(-1))	-0.384805	0.000707
	[-2.55599]	[0.00405]
D(LTEC_PJ(-1))	0.328654	0.028273
	[2.39518]	[0.17766]
R-squared	0.443179	0.130178
Adj. R-squared	0.409433	0.077462
Sum sq. resids	0.039756	0.053475
S.E. equation	0.034709	0.040255
F-statistic	13.13252	2.469408
Log likelihood	71.47149	66.13519
Akaike AIC	-3.803972	-3.507511
Schwarz SC	-3.672012	-3.375551
Mean dependent	0.046718	0.043382
S.D. dependent	0.045166	0.041911

Source: author's calculation
Note: t-statistics are in [ ]

The results on short and long-term causality indicate a bidirectional Granger causality in the short-run as well as unidirectional Granger causality running from total energy consumption to economic growth in the long-run. The coefficients of the error correction terms are nonzero and significant at the 5% level. The error correction term estimates of 0.018 in the LGDP equation and 0.014 in the LTEC_PJ equation indicate that 1.8%, and 1.4% respectively, of the preceding period's disequilibrium is eliminated in the current period. In the long-run, total energy consumption positively influenced economic growth in the period from 1952 till 1989. A 1% increase in the total energy consumption raises real GDP by 0.33%. The coefficient of determination (adjusted R-squared) shows that the total energy consumption accounted for 40.9% of the changes in the economic growth.

The standard pairwise Granger causality test is used to determine the direction of relationship between the variables since the Johansen procedure did not confirm the existence of cointegration in the second sub-sample.

TABLE 5. RESULTS OF THE PAIRWISE GRANGER CAUSALITY TEST – SECOND SUB-SAMPLE (1993-2010)

Null Hypothesis:	*Obs*	*F-Statistic*	*Probability*
DLTEC_PJ does not Granger Cause DLGDP	16	2.22979	0.1592
DLGDP does not Granger Cause DLTEC_PJ		5.32165	0.0382

Source: author's calculation

Therefore, table 5 indicates that unidirectional causality exists between economic growth and total energy consumption in the second sub-sample and that direction of causality runs from GDP to total energy consumption. Moreover, VAR model specified in differences (see Table 6) has been evaluated and the results indicate that a 1% increase in the real GDP in the period *t-1* raises the total energy consumption by 0.575% in the period *t*.

TABLE 6. RESULTS OF THE VAR MODEL – SECOND SUB-SAMPLE (1993-2010)

Dependent variable	*D(LGDP)*	*D(LTEC_PJ)*
D(LGDP(-1))	-0.030966	0.575073
	[-0.09938]	[2.30687]
D(LTEC_PJ(-1))	0.491281	-0.059689
	[1.49325]	[-0.22677]
C	0.027080	-0.004806
	[1.59001]	[-0.35269]
R-squared	0.146921	0.292341
Adj. R-squared	0.015678	0.183471
Sum sq. resids	0.021804	0.013956
S.E. equation	0.040954	0.032764
F-statistic	1.119460	2.685216
Log likelihood	30.08302	33.65272
Akaike AIC	-3.385377	-3.831589
Schwarz SC	-3.240517	-3.686729
Mean dependent	0.035581	0.016126
S.D. dependent	0.041279	0.036259

Source: author's calculation

In addition, we assessed the robustness of the estimated VEC/VAR model. Residual test were conducted and the results are presented in tables A.3 – A.5 in the appendix. Namely, these tests indicate that there is no residual autocorrelation in real GDP – energy model even up to 8th lag (according to Portmanteau autocorrelation test), that residuals are multivariate normal (i.e. normally distributed) when using Jarque-Bera statistic. Also, the block exogeneity Wald test indicates whether an endogenous variable can be treated as exogenous. In conclusion, we can determine that all the diagnostic test statistics are satisfactory.

Our results are consistent with the ones of Gelo (2009) and especially with the results of Vlahinić-Dizdarević and Žiković (2010) when it comes to comparing causality results in the period of Croatia's independence.[10] In this sense, our paper enriches the recent literature on Croatia's

[10] Borozan (2013) however got an opposite result: there is a unidirectional causality running from energy consumption to real GDP. In other words, energy consumption is an important component determining economic growth. This study clearly indicates how the final outcome can change even with the same econometric approach but slightly different time period. According to Denona (1997, p. 206), economic trends in the period from 1991 even up to 1995 are not suitable for scientific analysis and examination of economic regularities because warfare dominantly influenced the overall political, social and economic progress. Due to data availability, methodologically justifiable compromise regarding the starting year of the analysis eventually has to be made.

energy-growth nexus. We can also add that our results are somewhat expected if we take a look at the historical development of the Croatian economy, namely if we describe the background of the two sub-samples analysed in this paper. As previously mentioned, after World War II and especially between 1952 and 1980 Croatia entered into its most successful development period characterized by an average annual GDP growth rate of 6.7% and GDP per capita growth rate of 6.1%. Also, average annual employment growth rate amounted up to approximately 4% whereas labour productivity experienced an annual growth rate of 2.6%. This is also a period of a relatively low inflation (average annual rate of 12.6%) and also a period when import coverage ratio tended to 80% (Družić and Tica, 2003, p. 107). Rapid industrialization has been a primary method of economic growth and development. Hence the bidirectional causality in the short-run in the first sub-sample. Moreover, in the initial stage of development priority was given to the construction of energy sector, especially electrification and utilization of natural resources. This further led to the development of (energy intensive) black and nonferrous metallurgy, metal processing industry followed by the chemical industry (Čavrak et al., 2011). In mid-1970s Croatia has become a medium developed industrial country with industry/GDP ratio around 35% and with the industry sector as the biggest consumer of energy (primarily liquid fuels, coal and coke, electricity and to some extent gaseous fuels).

Therefore, the ECM results (Table 4) indicate the presence of long-run causality from total energy consumption to economic growth. The positive impact that energy consumption had on economic growth at that time suggests that energy consumption spurred economic growth in Croatia and played an important role in the growth process as an indispensable production input as well as a complement to labor and capital. In this case, the so-called growth hypothesis (**GDP Energy**) indicates that economic growth is dependent on energy consumption and that a decrease in energy consumption could create a fall in income or employment. Nevertheless, in the second half of 1980s, due to low intensity of structural changes and the impact of global energy crisis Croatian economy entered into a period of stagnation burdened by inflation, indebtedness, collapse of socialism (and the so-called planned economy) and decrease in energy consumption followed by war losses and the economic and social deformations caused by the wrong model of privatization[11] and the wrong level of stabilization (Družić and Tica, 2002, Stipetić, 2002).

Transition depression during the 1990s and deindustrialization resulted in sharp industrial decline[12] (in absolute terms) and decreased industrial energy demand. The pairwise Granger causality test results suggest existence of a unidirectional causality running from economic growth to total energy consumption in the second sub-sample. Under the so-called conservation hypothesis (**GDP Energy**), which is common in developed economies, continuous economic growth simultaneously generates a continuous rise in energy consumption. In this case, energy consumption is fundamentally driven by GDP (Lee, 2006, p. 1091). In the matter of Croatia, this type of causality direction is no more than a mere consequence of the following reasons (Vlahinić-Dizdarević

[11] The applied privatization model in Croatia (combination of selling public property to privileged and unprivileged buyers together with nonlinear division of shares to targeted social groups) proved to be unacceptable and ineffective. Moreover, foreign direct investments (that were considered at that time as an important start-up factor for the outwornplanned economies) were conditioned by international financial institutions (especially the World Bank and IMF). The pressure was put on transition economiesto carry out the privatization (together with fiscal discipline, fixed exchange rate, trade and financial liberalization) as fast as possible. This is known as the so-called big bang strategy or radical system transformation therapy (i.e. shock therapy). For more details on transition process in Croatia see Družić (2004) and for critics of the Washington Consensus "as a trickle-down approach to poverty" see Rodrik (2007), Sundać and Nikolovska (2001).
[12] The industry/GDP ratio in the period between 1990 and 1995 was 22.5% (Čavrak et al., 2011, p. 189).

and Žiković, 2010, p. 50): dominant service sector that makes up to 60% of Croatia's GDP (due to brownfield investments in telecommunication and financial sector, orientation towards tourism and industries that are not energy intensive), industrial production decline (due to closure and restructuring of heavy industry), uncompetitive position of Croatian industry (due to trade liberalization, strong national currency, higher energy prices for industry). Also, in the last 15 years energy is mostly used for transportation and household purposes as opposed to production processes. Under the assumption of **GDP Energy**, energy conservation policies (such as curtailing energy use, phasing out energy subsidies or elimination of energy price distortions) may be feasible with little adverse or no detrimental side effects to economic growth and employment. Also, the conservation hypothesis implies that bringing domestic energy prices in line with market prices (Binh, 2011) can be a good opportunity to promote substitution and technological innovation. Not to mention the establishment of a competitive energy market in order to allocate energy resources into the most productive uses in the economy.

V. CONCLUSION

This paper examines the relationship between economic growth and total energy consumption in Croatia using the annual data covering the period 1952 – 2010. Since we determined the existence of a breakpoint in 1989, our initial time series was divided into two sub-samples. The first one covers the period between 1952 and 1989 while the second one refers to the period 1993 – 2010. The very first years of war that brought heavy human casualties, material damages and the overall destruction upon the Croatian economy were omitted from the analysis.

Our estimation results indicate that, in the first sub-sample, there is a bidirectional short-run causality and a unidirectional long-run causality running from total energy consumption to economic growth suggesting that energy consumption comes as a leading factor of the economy. After World War II and especially between 1952 and 1980, Croatia entered into its most successful development period. In the initial stage of development priority was given to the construction of energy sector, especially electrification and utilization of natural resources. This led to the development of (energy intensive) black and nonferrous metallurgy, metal processing industry followed by the chemical industry. In mid-1970s Croatia has become a medium developed industrial country with industry/GDP ratio around 35% and with the industry sector as the biggest consumer of energy. The positive impact that energy consumption had on economic growth at that time suggests that energy consumption spurred economic growth in Croatia and played an important role in the growth process as an indispensable production input as well as a complement to labor and capital.

The second sub-sample reflects different causality results. Namely, the direction of causality runs from economic growth to total energy consumption due to reasons such as: transition depression, sharp industrial production decline and decreased industrial energy demand. Moreover, uncompetitive position of Croatian industry, dominant service sector and orientation towards tourism and energy non-intensive industries also contribute to this type of causality. This, in turn, makes the implementation of energy conservation policies (namely, phasing out energy subsidies, elimination of energy price distortions, curtailing energy use) and the establishment of a competitive energy market feasible without compromising economic growth and employment. Also, bringing domestic energy prices in line with market prices can be a good opportunity to promote substitution, technological innovation and allocate energy resources into most productive uses in the economy.

The energy – growth nexus is a well studied topic in the energy economics literature nowadays. However, numerous empirical studies have yielded different and sometimes conflicting results. To avoid this shortcoming, new approaches are recommended. For instance, different sectors (i.e. industry) and different energy sources (i.e. electricity) have to be taken into consideration together with indicators such as energy prices, population, capital equipment, R&D on energy technologies, regulatory quality, government effectiveness etc. Future research should also address the area regarding the relationship between growth and greenhouse gas emissions. In future research, potential structural break(s) should be addressed by introducing a dummy variable in order to keep time series intact. In order for the results to be more robust, other econometric approaches should be utilized such as the leveraged bootstrap technique suggested by Hacker and Hatemi-J (2006, 2010) especially when dealing with small samples. Until present and future researchers get sound, robust, uniformed and non-conflicting empirical results, governments have to be careful in implementing the appropriate policies.

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APPENDIX

TABLE A.1 CHOW BREAKPOINT TEST FOR LBDP

Breakpoint year: 1989			
Statistic	Value		Probability
F-statistic	2.830059	F(4,49)	0.0344
Log likelihood ratio	11.84730	$X^2(4)$	0.0185
Wald Statistic	9.324856	$X^2(4)$	0.0535

Source: author's calculation

Null Hypothesis: No breaks at specified breakpoints

TABLE A.2 CHOW BREAKPOINT TEST FOR LTEC_PJ

Breakpoint year: 1989			
Statistic	Value		Probability
F-statistic	2.853957	F(3,52)	0.0460
Log likelihood ratio	8.840462	$X^2(3)$	0.0315
Wald Statistic	76.44257	$X^2(3)$	0.0000

Source: author's calculation

Null Hypothesis: No breaks at specified breakpoints

TABLE A.3 VEC/VAR GRANGER CAUSALITY – BLOCK EXOGENEITY WALD TEST

	Dependent variable D(LGDP)					***Dependent variable D(LGDP)***			
VEC	Excluded	Chi-sq	df	Probability	**VAR**	Excluded	Chi-sq	df	Probability
	D(TEC_PJ)	5.736908	1	0.0166		D(TEC_PJ)	2.229787	1	0.1354
	Dependent variable D(LTEC_PJ)					***Dependent variable D(LTEC_PJ)***			
	Excluded	Chi-sq	df	Probability		Excluded	Chi-sq	df	Probability
	D(LGDP)	1.64E-05	1	0.9968		D(LGDP)	5.321647	1	0.0211

Source: author's calculation

TABLE A.4 VEC/VAR RESIDUAL PORTMANTEAU TEST FOR AUTOCORRELATION

	Lag	***Q-stat***	***Prob.***	***Adj. Q-stat***	***Prob.***		***Lag***	***Q-stat***	***Prob.***	***Adj. Q-stat***	***Prob.***
VEC	1	0.25217	NA*	0.25938	NA*	**VAR**	1	2.22738	NA*	2.37587	NA*
	2	1.15528	0.9919	1.21561	0.9906		2	3.02113	0.8830	3.28301	0.8576
	3	4.78969	0.9409	5.18042	0.9221		3	6.99769	0.7993	8.17724	0.6973
	4	6.77112	0.9637	7.40953	0.9453		4	8.82199	0.8866	10.6096	0.7797
	5	9.65857	0.9609	10.7627	0.9316		5	12.6477	0.8561	16.1743	0.6456
	6	10.3948	0.9886	11.6461	0.9756		6	14.6698	0.9061	19.4098	0.6772
	7	12.0932	0.9939	13.7546	0.9835		7	15.6688	0.9590	21.1858	0.7775
	8	14.9555	0.9933	17.4346	0.9761		8	16.6558	0.9833	23.1596	0.8433

Source: author's calculation

Note: H_0 – no residual autocorrelation up to lag h

TABLE A.5 VEC/VAR RESIDUAL NORMALITY TEST

	Component	*Jarque-Bera*	*df*	*Prob.*		*Component*	*Jarque-Bera*	*df*	*Prob.*
VEC	1	20.5898	2	0.0000	***VAR***	1	0.68225	2	0.7110
	2	0.60462	2	0.7391		2	1.40445	2	0.4955
	Joint	15.7138	9	0.0731		Joint	6.87805	9	0.6498

Source: author's calculation

Note: orthogonalization – residual covariance (Urzua); H_0 – residuals are multivariate normal

EMPIRIJSKA ANALIZA ODNOSA IZMEĐU EKONOMSKOG RASTA I POTROŠNJE ENERGIJE U HRVATSKOJ[13]

SAŽETAK

U ovom radu istražuje se kauzalni odnos između ekonomskog rasta i potrošnje energije u Hrvatskoj za razdoblje od 1952. do 2010. godine. Upotrebom Chow testa za prisutnost strukturnog loma, isti je identificiran u godini 1989. Stoga je analiza provedena na temelju dva poduzorka. Prvi dio odnosi se na razdoblje od 1952. do 1989. godine dok se drugi odnosi na period od 1993. do 2010. Godine između 1990. i 1992. izostavljene su iz analize zbog velikih šteta uzrokovanih ratom koje su u tom periodu nanesene hrvatskom gospodarstvu. Naši empirijski rezultati sugeriraju da u slučaju prvog poduzorka postoji bidirekcionalnost u kratkom roku i jednosmjerna kauzalnost od potrošnje energije prema ekonomskom rastu u dugom roku. U to vrijeme, pogotovo sredinom 1970-ih, Hrvatska je postala srednje razvijena industrijska zemlja s industrijskim sektorom kao najvećim potrošačem energije čime je upravo potrošnja energije imala značajnu ulogu u ekonomskom rastu. Rezultati analize ukazuju da nakon strukturnog loma postoji unidirekcionalna kauzalnost od rasta BDP-a prema povećanoj potrošnji energije. U tom slučaju, smjernice za očuvanje energije zajedno s uspostavom konkurentnog energetskog tržišta mogu biti provedive sa malo ili pak bez ikakvih štetnih nuspojava za gospodarski rast i zapošljavanje.

Ključne riječi: ekonomski rast, potrošnja energije, Hrvatska, Chow test, Grangerova uzročnost

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