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Revisiting the Energy Consumption-Growth Nexus for Croatia: New Evidence from a Multivariate Framework Analysis[1]

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Abstract

This paper applies the most recently developed autoregressive distributed lag (ARDL) cointegration procedure to re-investigate cointegration and the causal relationship between energy consumption and real GDP within a multivariate framework that includes capital stock and labor input for Croatia during the 1952–2011 period. The empirical results fully support a positive long-run cointegrated relationship between production inputs and real GDP and important role of energy in economic growth. It is found that there is a unidirectional causality running from total final energy consumption to real GDP in the long run and bidirectional causality in the short run. This means that energy is a necessary requirement for economic growth, as well as the reduction in energy consumption could adversely affect GDP in the short and long run. Therefore Croatia should adopt a more vigorous economic policy that should aim to increase investments in installed energy capacities and to reform economic structure towards re-industrialization and more energy-efficient industries.

Keywords: economic growth; energy consumption; ARDL;and Croatia

JEL Classification: Q43

1. Introduction

During the last two decades there have been a number of papers dealing with the causality between economic growth and energy consumption.

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Although a strong interdependence and causality between economic growth and energy consumption represents a stylized economic fact, the existence and direction of causality is still not clearly defined. Most of the studies have been based on bivariate approach by exploring the causal relationship between energy consumption and output (GDP). This approach is based on the standard neo-classical economic theory that explains output (GDP) as a function of two independent variables: capital (K) and labor (L). Therefore, the economic growth is the result of the increased inputs or their quality. Energy inputs have indirect importance and they have been seen as intermediate inputs. The bivariate approach has limitations and it could not capture the multivariate framework within which the changes in energy use are frequently countered by the substitution of other factors of production, resulting in an insignificant overall impact on output.

However, after the first oil crisis in 1973-74 certain economists started to formulate energy-dependent production functions that have included energy and materials besides conventional labor and capital inputs (for example, Berndt & Wood, 1979; Hannon & Joyce, 1981; Tintner et al., 1977). They retained the condition of constant returns to scale and the equality assumption i.e. that factor elasticities should be equal to factor payments' share in the national accounts. According to Ayres and Warr (2009), this three-factor model is implicitly two-sector model because, in practice, the cost of energy (E) is not defined in terms of payments to "nature", but rather to extractive industries that own energy resources. During the time, the alternative views on economic growth have also appeared. There are much of the relevant literature outside the mainstream known as ecological economics that emphasize the importance of energy in production and growth. Even more, some of them see the energy as the only primary factor of production, while capital and labor are treated as flows of capital consumption and labor services, rather than stocks (Gever et al., 1986). Not just that energy is a crucial production factor according to ecological economists, but some (Cleveland et al., 1984) even conclude that energy availability drives economic growth, in the contrast to economic growth that result from increased energy use.

In the theoretical framework of energy-dependent Cobb-Douglas function that involves energy as the third input, the paper tests cointegration of three inputs (capital, labor and energy) and GDP in Croatia. Time period used in this analysis is 1952–2011 in order to cover long-term period during which the substitution among production inputs could occur.

The main aim of the paper is to determine empirically whether there is a causal link between capital stock (as a proxy for capital), employment (as a proxy for labor), total final energy consumption (as a proxy for energy) and economic growth in Croatia and the direction of causality between energy consumption and GDP in the short and long run.

Although there have been a few papers focusing the relationship between energy consumption and GDP in Croatia, to the best of our knowledge, there has been no paper testing this causality within multivariate framework. In 2013 Croatia became the new 28th EU Member State and its national energy policy is strongly influenced by the EU Energy Policy. The EU's energy policy aims to achieve three underlying goals till 2020 known as the "20-20-20" targets: the 20% reduction in primary energy use to be achieved by improving energy efficiency, the reduction in EU greenhouse gas emissions of at least 20% below 1990 levels and 20% of EU energy consumption to come from renewable energy sources. Since energy production and consumption are one of the main sources of CO_2 emissions, the dilemma whether the reduction of energy production and use would lower economic growth has become a crucial policy issue, especially in a small and energy dependent economy like Croatia that is vulnerable to exogenous energy shocks. Therefore it is very important for policy makers to know the direction of the causality between energy consumption and economic growth. If causality runs from energy to GDP, it would imply that the reduction in energy consumption would harm economic activities and economic and energy policy should take these results into the consideration.

The paper is organized in the following fashion. Section 2 gives the literature review on empirical testing, while Section 3 describes data and econometric methodology and presents the obtained empirical results. Final section contains the conclusions.

2. Literature Review on Causal Relationship between Energy and Economic Growth

Although strong interdependence and causality between economic growth and energy consumption is a stylized economic fact, the direction of causality between economic growth and energy consumption is not clearly defined.

During the last two decades a number of academic papers explored the relationship between economic growth and energy consumption. On one hand, it is argued that energy is a vital and necessary input along with other factors of production (such as labor and capital). Consequently, energy is a necessary requirement for economic and social development so that energy is potentially a "limiting factor to economic growth" (Ghali & El-Sakka, 2004). On the other hand, it is argued that since the cost of energy is a very small proportion of GDP, it is unlikely to have a significant impact; hence there is a "neutral impact of energy on growth". The overall findings vary significantly with some studies concluding that causality runs from economic growth to energy consumption, other conclude the complete opposite, while a number of studies find bidirectional causality

Most of the earlier work, starting with the pioneering paper by Kraft and Kraft (1978), conducted Granger causality tests between energy and output (Akarca & Long, 1980; Erol & Yu, 1987; Yu & Hwang, 1984; Yu & Choi, 1985). The earlier studies reported different results for different countries and even different results for the same country for different time periods. More recent studies (Asafu-Adjaye, 2000; Ghali & El-Sakka, 2004; Glasure, 2002; Lee, 2005; Masih & Masih, 1997, 1996; Soytas & Sari, 2007, 2006; Yang, 2000) have incorporated relatively new time series techniques, such as cointegration and vector error correction modeling to overcome the stationarity problem related to the traditional tests. However, there is still no consensus on whether causality exists between energy consumption and output or not, and on the direction of causality if it exists.

Although the production theory suggests the multivariate cointegration of output and all production factors, the most of the literature focuses the bivariate cointegration between energy consumption and GDP in order to examine the role of energy in economic growth. Some papers examined the causality between energy and output in a framework of production function with three inputs (KLE). Ghali and El-Sakka (2004), assumed a neo-classical one sector production function with three inputs for Canada and find bidirectional causality between energy use and output.

Their results do not seem to confirm the neo-classical assumption of neutrality of energy to growth. Soytas and Sari (2006) examined the relationship between energy consumption and output in a three factor (KLE) production function framework in G-7 countries. They found long run causality between energy use and income in all G-7 countries.

In four countries (Canada, Italy, Japan and UK) causality seems to run both ways, in two of them (US and France) from energy use to income, and only in one (Germany) from income to energy consumption.

Some economists applied the multivariate methodology, which is important step because changes in energy use are frequently countered by the substitution of other factors of production. Stern (2000) applied multivariate cointegration tests of output, capital, labor and energy in the USA and found that cointegration does occur and that energy input cannot be excluded from the cointegration space. On the other hand, when the model is restricted to a Cobb-Douglas production function without a time trend and under the condition that the output elasticities of capital and labor (but not energy) have to sum up to unity, Stern (2000) did not find cointegration anymore. Oh and Lee (2004) investigated causal relationship between energy consumption and economic growth in Korea by applying a multivariate model of capital, labor, energy and GDP. Empirical results for Korea over the period 1970–1999 suggested a long-run bidirectional causal relationship between energy and GDP, and short-run unidirectional causality running from energy to GDP.

The source of causation in the long-run is found to be the error correction terms in both directions. Stresing et al. (2008) applied cointegration analysis to output, capital, labor and energy for Germany, Japan and the USA since 1960 and confirmed the existence of cointegration. They also found that output elasticities for energy are much larger than the cost shares of this factor. On the other hand, output elasticities for labor are much smaller than the cost share of the labor. In the already mentioned study, Ayres and Warr (2009) also found that capital, labor, energy (exergy) and output are cointegrated. The calculated output elasticity of energy is up to ten times higher than its cost share, while "pure" (unskilled) labor, in the absence of machines and sources of power, is nearly unproductive at the margin.

Regarding studies on Croatia, the new 28th EU Member State, there have been no papers dealing with the multivariate framework, though several papers analyzed bivariate cointegration between energy consumption and GDP (Borozan, 2013; Gelo, 2009; Vlahinic-Dizdarevic &Zikovic, 2010).

Their findings differ due to different methodology and time frame. Gelo (2009) used VAR and Granger causality test to analyze the causal relationship between annual GDP and total energy consumption from 1953 to 2005 in Croatia and concluded that GDP Granger causes total energy consumption, and that total energy consumption and the constant are not significant in the VAR model, whereas GDP is significant. Similar results were obtained by Vlahinic-Dizdarevic and Zikovic (2010) who examined the causal relationship between several energy variables (energy consumption in industry and households, oil consumption, primary energy production and net energy imports) and real GDP in the period 1993–2006. They found cointegration for all of the tested relationships and causality that again runs from real GDP growth to all energy variables. The same authors (Zikovic & Vlahinic-Dizdarevic, 2011) examined the causal relationship between oil consumption and economic growth for 22 small European countries including Croatia over the period 1980–2007 and employed ECM. Their results show that small European states could be divided into two groups regarding the direction of causality. Croatia belongs to the group of countries, mostly developed ones, where the causality is running from real GDP to oil consumption. On the contrary, Borozan (2013) found that total energy consumption Granger causes real GDP. She used bivariate vector autoregression (VAR) and Granger causality tests and covered the period from 1992 to 2010. Confronting results of these studies require further analysis within longer time period and more complex and superior methodology framework which is based on multivariate cointegration analysis.

3. Data and Methodology

3.1. Data

All the data used in this paper consist of annual time series for the period 1952–2011 in order to cover long-term period during which the substitution among production factors occurred. The variables for energy consumption-economic growth hypothesis are real gross domestic product (GDP), capital stock (K), employment (L) and total final energy consumption (TFEC). The real GDP data (in millions of US$) at 2000 constant prices was originally obtained from Druzic and Tica (2002).

Figures covering real GDP were subsequently expanded with the data from the Croatian Bureau of Statistics–CBS (2012).

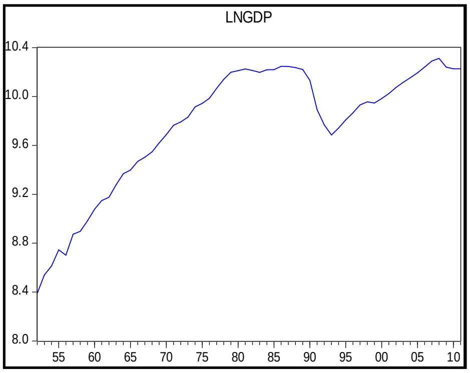
Capital stock variable (K) was generated using the GDP data and the data on gross fixed capital formation in fixed assets from Croatian Statistical Yearbooks and World Bank (2012) since there is no readily available data for Croatia's capital stock. For the initial capital stock, we divided real fixed 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:

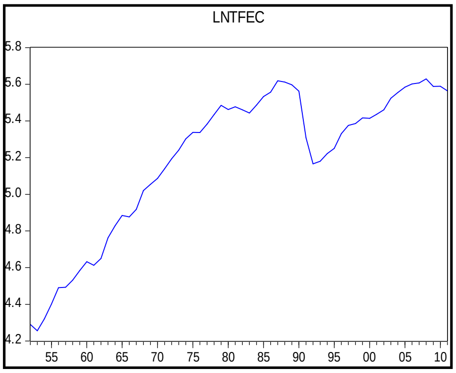
$$K_t = \sum_{i=0}^{n-1}\left(1-\frac{i\delta}{2}\right)I_{t-i} + (1-n\delta)K_{t-n} \quad (1)$$

where$K$ represents physical capital, I investments and δ rate of depreciation. In order to increase the realism of the estimates, equation (1) differs from the standard linear PIM equation when it comes to depreciation of 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 (Kamps, 2004). 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 CBS (2012) together with Raguz et al. (2011). Total final energy consumption data (TFEC, in petajoules) was obtained from the Energy Institute Hrvoje Pozar–EIHP (2012). It excludes conversion losses, energy sector own use, transmission losses and non-energy use.

For estimation purposes all variables were transformed into natural logarithms to reduce heteroscedasticity and to obtain the growth rate of the relevant variables by their differenced logarithms (Chang et al., 2001; Fatai et al., 2004; Ozturk & Acaravci, 2010). In order to graphically visualize the variables, Figure 1 only depicts Croatia's total final energy consumption and gross domestic product.

Figure 1: Plots of Variables





Source: CBS (2012), EIHP (2012), Druzic and Tica (2002)

Figure 1 indicates that there might be a structural break in these series. By using the Chow breakpoint test (Chow 1960) we recognize that lnGDP (F-statistic=5.258663) and lnTFEC (F-statistic=1.767822) are "broken" in the year 1990 at the 1% and exactly 10% significance level, respectively.

Several reasons can be attributed to this break in data. In 1990, Croatian economy was faced with negative growth rate, hyper-inflation and the collapse of the administrative-planned economic system. GDP decreased as the result of the transition depression and Croatian Homeland War which started in 1991 after Croatia terminated all state and legal relations with the former Socialist Federal Republic of Yugoslavia. Some estimates (Pasalic, 1999) indicate that in the period from 1990 to 1993 indirect damage to the Croatian economy due to the war was equivalent to the loss of 109% of annual average GDP. Industrial production dropped sharply as the result of the closure and restructuring of heavy industry, the biggest energy consumer, and thus the energy consumption in industry decreased considerably. Uncompetitive position of Croatian industry has been additionally enforced by strong national currency and extensive trade liberalization which led to further decline in industrial production and industrial energy consumption. Since then Croatian economy has been oriented mainly towards services, especially tourism, and light industries (e.g. food processing, pharmaceuticals, textile industry) which are not energy-intensive. As the result of transition depression and structural changes, total final energy consumption declined sharply after 1990.

In order to account for the mentioned structural break, variable D1990 is introduced in the analysis (dummy variable equal to 1 for the period 1990-1993 and 0 otherwise). We have additionally introduced a second dummy variable D2009 (equal to 1 for the period 2009-2011 and 0 otherwise) to reflect the ongoing economic downturn in Croatia and to make the results more robust.

3.2. Methodology

3.2.1. Unit Root Tests

Due to the fact that there is no uniformly powerful test of the unit root hypothesis (Gujarati & Porter, 2009) and in order to determine the order of the series in more robust manner, we conducted five different unit root test as suggested by Soytas and Sari (2007) and Sari et al. (2008). We used the Augmented Dickey-Fuller (ADF) test (Dickey & Fuller, 1979), Phillips-Perron (PP) test (Phillips & Perron, 1988), Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test (Kwiatkowski et al., 1992), Elliot-Rothenberg-Stock Dickey-Fuller GLS detrended (DF-GLS) test (Elliot et al., 1996) and Ng-Perron MZ_t (NG-P (MZ_t)) test (Ng & Perron, 2001). The reason why five different tests are used is to establish, without any arbitrary decisions, the order of integration bearing in mind the size (the level of significance) and power (the probability of rejecting the null hypothesis when it is false) of these tests. We do not discuss the details of the unit root tests here (see Maddala & Kim (1998) for a review of ADF, PP, KPSS, DF-GLS and Ng-Perron (2001) for more on NG-P).

3.2.2. ARDL Bounds Testing Approach to Cointegration

Most widely used methods to empirically analyze the long-run relationship and dynamic interactions between two or more variables include Engle and Granger's (1987) two-step procedure and multivariate maximum likelihood based approach of Johansen (1988) and Johansen and Juselius (1990). However, these approaches require that the variables in question must be integrated of order one. In addition, Engle-Granger is only appropriate for two variables even though there is a possible cointegration relationship among several variables. Johansen's multivariate approach, on the other hand, has a problem with the degree of freedom when applied to a small sample (Toda, 1994).

To avoid restrictions mentioned above, this study employed recently developed autoregressive distributed lag (ARDL) cointegration procedure introduced by Pesaran et al. (2001). The ARDL cointegration approach has several advantages over other techniques of cointegration. First, it can be applied irrespective of whether underlying regressors are I(0), I(1) or a combination of both with no need for unit root pre-testing.[4] Second, the model takes a sufficient number of lags to capture the data generating process in general to specific modeling frameworks and allows the variables to have different optimal lags. Third, the error correction model can be derived from ARDL through a simple linear transformation which integrates short-run adjustments with long-run equilibrium without losing long-run information. Fourth, the small sample properties are superior to those of the Johansen cointegration technique. Fifth, endogeneity is less of a problem in the ARDL technique because it is free of residual correlation. Finally, the ARDL procedure employs a single reduced form equation while the conventional cointegration procedures estimate the long-run relationship within a context of system equations (Acaravci, 2010; Dantama et al., 2012; Ozturk & Acaravci, 2010).

The bounds testing procedure consists of estimating an unrestricted error correction model with the following generic form (Eq. 2) in which each variable comes in turn as a dependent variable:

$$\Delta \ln GDP_t = \alpha_{10} + \alpha_{11} D1990_t + \alpha_{12} D2009_t + \sum_{i=1}^{n} \alpha_{13} \Delta \ln GDP_{t-i} + \sum_{i=1}^{n} \alpha_{14} \Delta \ln KSM_{t-i} + \sum_{i=1}^{n} \alpha_{15} \Delta \ln L_{t-i}$$
$$+ \sum_{i=1}^{n} \alpha_{16} \Delta \ln TFEC_{t-i} + \delta_{11} \ln GDP_{t-1} + \delta_{12} \ln KSM_{t-1} + \delta_{13} \ln L_{t-1} + \delta_{14} \ln TFEC_{t-1} + \varepsilon_{1t} \quad (2)$$

An F-test for the joint significance of the lagged level variables coefficients will be conducted to examine whether a cointegrating relationship exists among the variables. The null hypothesis of no cointegration (H_0) against the alternative (H_1) for each equation is as follows: H0: $\delta_{11} = \delta_{12} = \delta_{13} = \delta_{14} = 0$ and H1: $\delta_{11} \neq \delta_{12} \neq \delta_{13} \neq \delta_{14} \neq 0$. The F-test has a non-standard distribution and two sets of critical values have been provided by Pesaran et al. (2001).

[4] Even though the pre-testing of a unit root can be exempted when applying bounds testing approach to cointegration, according to Shahbaz et al. (2011), it is essential to determine the order of integration for each variable to avoid inclusion of I(2) variables. It is not necessary that all variables are I(0) and/or I(1). If any of the variables are indeed I(2) then the ARDL procedure will give spurious results.

One set refers to the I(1) series and the other to the I(0) series which are known as upper bounds (UCB) and lower bounds critical values (LBC), respectively. Given that Pesaran et al.'s (2001) critical values are computed for a large sample (namely, 500-1000 observations), Narayan (2005) estimated a new set of critical values for a small sample ranging from 30 to 80 observations. Since our sample size is 60 observations, we use the critical values provided by Narayan (2005).

A decision on whether cointegration indeed exists between the dependent variable and its regressors is then made as follows. If the computed F-statistic is higher than the upper bound of the critical value, the null hypothesis of no cointegration is rejected. If the computed F-statistic is lesser than the lower level band, we fail to reject H_0, which signifies the absence of cointegration. When the computed F-statistic falls inside the upper and lower bounds, a conclusive inference cannot be made.

3.2.3. Granger Causality

ARDL (or any other) cointegration method tests whether the existence or absence of long-run relationship between the variables. It does not indicate the direction of causality (Ozturk and Acaravci, 2011).

Thus, if we find no evidence of a long-run relationship among the variables, the traditional Granger causality test, i.e., a vector autoregressive (VAR) model specified in first difference form will be conducted as a valid causality testing solution.[5] However, if there is an evidence of cointegration between the variables, the Granger causality test should include a one period lagged error correction term (ECT_{t-1}) as an additional independent variable in the equation (Ouédraogo, 2010). Accordingly, we must estimate the following long-run and short-run models that are presented in equations (3) and (4):

[5]A VAR models may suggest a short-run relationship between the variables because long-run information is removed in the first differencing. An error correction model (ECM) can avoid such shortcomings (Vlahinic-Dizdarevic &Zikovic 2010, pp. 46). In other words, the ECM is a means of reconciling the variable's short-run behavior with its behavior in the long-run (Gujarati & Porter, 2009).

$$\ln GDP_t = \alpha_{20} + \alpha_{21} D1990_t + \alpha_{22} D2009_t + \sum_{i=1}^{n} \alpha_{23} \ln GDP_{t-i} + \sum_{i=1}^{n} \alpha_{24} \ln KSM_{t-i} + \sum_{i=1}^{n} \alpha_{25} \ln L_{t-i} + \sum_{t-1}^{n} \alpha_{26} \ln TFEC_{t-1} + \varepsilon_{2t}$$

(3)

$$\Delta \ln GDP_t = \alpha_{30} + \alpha_{31} D90 + \alpha_{32} D2009_t + \sum_{i=1}^{n} \alpha_{33} \Delta \ln GDP_{t-i} + \sum_{i=1}^{n} \alpha_{34} \Delta \ln KSM_{t-i} + \sum_{i=1}^{n} \alpha_{35} \Delta \ln L_{t-i} + \sum_{i=1}^{n} \alpha_{36} \Delta \ln TFEC_{t-i} + \varphi_1 ECT_{t-1} + \varepsilon_{3t}$$

(4)

where φ is the coefficient of the error correction term. It shows how quickly variables converge to equilibrium and it must have a statistically significant coefficient with a negative sign.

4. Empirical Results and Discussion

4.1. Unit Root Test Results

Both "intercept and trend" and "intercept" regressors were included in the test equation in all five previously mentioned unit root tests. For the purposes of ADF, DF-GLS and NG-P unit root test, the Schwarz information criterion (SIC) is used to determine the number of lags whereas Newey-West method is applied to choose the optimal lag length (or bandwidth) for the purposes of PP and KPSS unit root test. The critical values for ADF and PP test are taken from MacKinnon (1996). For KPSS, the critical values are from Kwiatkowski et al. (1992). The critical values for DF-GLS are from Elliott et al. (1996) while NG-P (MZ_t) critical values are taken from Ng and Perron (2001). All unit root tests have a null hypothesis stating that the series in question has a unit root against the alternative that it does not. The null hypothesis of KPSS, on the other hand, states that the variable is stationary. The results for all five unit root tests summarized Table 1 reveal that all variables are non-stationary at level but become stationary after first difference.

Table 1: Unit Root Test Results

	Variables	ADF	PP	KPSS	DF-GLS	NG-P (MZ_t)
	Panel A: Log levels					
Intercept and trend	lnGDP	-1.774678 (1)	-2.081557 (4)	0.212407[b] (6)	-0.964223 (1)	-1.01515 (1)
	lnK	-2.736872 (1)	-1.313444 (5)	0.226876 (6)	-2.282304 (1)	-2.78198[b] (1)
	lnL	-2.209397 (1)	-1.980041 (4)	0.221302 (6)	-1.219260 (1)	-1.35900 (1)
	lnTFEC	-2.194499 (1)	-1.473599 (2)	0.213523[b] (6)	-1.604199 (1)	-1.46536 (1)
	lnKSM*	-2.036284 (1)	-1.291062 (5)	0.224998 (6)	-1.426610 (1)	-1.31293 (1)
	Panel B: Log first differences					
Intercept and trend	lnGDP	-4.846048 (0)	-4.908813 (2)	0.115346 (4)	-4.521034 (0)	-3.33133[b] (0)
	lnK	-2.202118 (1)	-2.132854 (2)	0.119512[c] (5)	-2.148090 (1)	-2.17078 (1)
	lnL	-3.864181[b] (0)	-3.872742[b] (1)	0.082883 (4)	-3.930527 (0)	-3.11918 (0)
	lnTFEC	-4.840828 (0)	-4.942047 (1)	0.073038 (2)	-4.284857 (0)	-3.22673[b] (0)
	lnKSM*	-3.494746[b] (0)	-3.532204[b] (2)	0.117649 (5)	-2.920148[c] (0)	-2.49715 (0)
	Panel C: Log levels					
Intercept	lnGDP	-2.492388 (1)	-3.293755[a] (4)	0.714990[b] (6)	0.058811 (1)	0.13266 (1)
	lnK	-1.985301 (2)	-2.509414 (5)	0.863484 (6)	-0.334392 (2)	-0.59436 (2)
	lnL	-3.025856[a] (1)	-3.528875[a] (4)	0.689648[b] (6)	-0.527996 (1)	-0.42113 (1)
	lnTFEC	-2.766034[b] (1)	-2.346234 (2)	0.772562 (6)	-0.457216 (1)	-0.12035 (1)
	lnKSM*	-2.714557[b] (1)	-2.259716 (5)	0.861183 (6)	-0.250857 (1)	-0.22153 (1)
	Panel D: Log first differences					
Intercept	lnGDP	-4.476723 (0)	-4.480993 (2)	0.520704[a] (4)	-2.932493 (0)	-2.51135[b] (0)
	lnK	-1.809140 (1)	-1.654028 (2)	0.418114[c] (6)	-1.834444[b] (1)	-1.85090[b] (1)
	lnL	-3.247360[b] (0)	-3.247360[b] (0)	0.527035[a] (5)	-3.002914 (0)	-2.58565 (0)
	lnTFEC	-4.425697 (0)	-4.425697 (0)	0.355486[b] (3)	-3.710502 (0)	-3.00167 (0)
	lnKSM*	-2.866760[c] (0)	-2.838317[c] (2)	0.414624[b] (5)	-2.510837[b] (0)	-2.26446[b] (0)

Optimal lag lengths are in parenthesis. The maximum lag length considered is 10. [a, b, c] Indicates 1%, 5% and 10% significance level, respectively.

Source: Authors' calculation using EViews 7.1

The variable lnK was smoothed using Holt-Winters multiplicative model (Winters, 1960) since it remained non-stationary after first difference according to all unit root tests using both “intercept and trend” and “intercept” as exogenous regressors. Exponential smoothing resulted with the (new) variable lnKSM being stationary after first difference. The only exception is the NG-P unit root test solely under the “intercept and trend” assumption. In general, the combined results of all unit root tests suggest that all variables appear to be I(1) process, hence integrated of order 1.

4.2. Cointegration and Causality Results

After determining the order of integration of each variable, the next step is to evaluate if the variables used in the analysis are cointegrated. Even though the correlation between our variables is high (0.990744), it does not directly imply that they are cointegrated. An important issue in applying bounds testing approach to cointegration is the selection of the optimal lag length. We set the maximum lag length at 3 years which is sufficiently long enough for annual data to capture the dynamic relationship (Tang & Shahbaz, 2011), then the AIC statistic is used to choose a best ARDL model (Lütkepohl, 2005). The results of the ARDL cointegration test are reported in Table 2.

Table 2: ARDL Cointegration Test Results

Model 1		**Model 2**
Dependent variable	lnGDP	lnTFEC
Function	F_{lnGDP}(lnGDP|lnKSM, lnL, lnTFEC)	F_{lnTFEC}(lnTFEC|lnGDP, lnKSM, lnL,)
F-statistic	4.1012[c]	3.3918[b]
Decision	Cointegration	No cointegration

[a, b, c] Indicates 1%, 5% and 10% significance level, respectively. Critical values of the F-statistic for 60 observations are taken from Narayan (2005, p. 1988), case III: intercept and no trend with k=2 regressors.

Source: Authors' calculation using MICROFIT 4.1

The null hypothesis of no cointegration can be rejected when lnGDP is treated as the dependent variable since the calculated F-statistic (4.1012) is higher than the upper bound critical value (3.923) suggested by Narayan (2005) at the 10% level of significance. This indicates that there exists a long-run relationship between GDP and energy consumption (and other forcing variables). However, if we take total final energy consumption into consideration as the dependent variable, the calculated F-statistic (3.3918) is lower than the lower bound critical value (3.415) at 5% significance level.[6]

Having found that there is a long-run relationship between the variables when real GDP comes as dependent variable, the long-run and short-run coefficients are estimated using the associated ARDL and ECM. According to AIC statistics, the specification selected ARDL (1,1,2,0) as the best model. The results are presented in Table 3.

[6] In order to obtain more robust results we also applied the Johansen multivariate cointegration approach. The ARDL cointegration test results are verified by the Johansen's test (according to Trace statistics) indicating at least one cointegration. This, in turn, provides sufficient arguments for the existence of a valid long-run relationship among the variables. To preserve space, detailed results regarding Johansen's technique are not presented but are available upon request.

Table 3: Long-run and Short-Run Estimates – Model 1

Panel A: Long-run results Dependent variable: $lnBDP_t$			
Regressor	AIC (1,1,2,0)		
	Coef.	SE	T-ratio [Prob.]
lnKSM	-0.077404	0.15974	-0.48456[0.630]
lnL	0.28334	0.19459	1.4561[0.152]
lnTFEC	1.0472	0.19846	5.2764[0.000][a]
INPT	3.2432	1.0513	3.0851[0.003]
D1990	-0.45145	0.15634	-2.8876[0.006][a]
D2009	-0.12786	0.083141	-1.5378[0.131]
Panel B: Short-run results Dependent variable: $\Delta lnGDP_t$			
ΔlnKSM	0.55433	0.18079	3.0662[0.004][a]
ΔlnL	0.72167	0.15201	4.7475[0.000][a]
ΔlnL(-1)	-0.73709	0.14381	-5.1253[0.000][a]
ΔlnTFEC	0.27874	0.086027	3.2401[0.002][a]
INPT	0.86331	0.24802	3.4808[0.001]
D1990	-0.12017	0.019941	-6.0263[0.000][a]
D2009	-0.034034	0.018470	-1.8426[0.071][c]
ECT(t-1)	-0.26619	0.070716	-3.7642[0.000][a]
Adj. R^2	0.84311		
F-statistic	F(7,49)=44.2797[0.000][a]		
DW-stat.	2.4922		
RSS	0.029391		
Panel C: Diagnostic test results			
LM-test statistics	χ^2_{SC}	$\chi^2_{SC}(1)$=4.2907[0.038][a]	
	χ^2_{FC}	$\chi^2_{FC}(1)$ 5.8755[0.015][a]	
	χ^2_{N}	$\chi^2_{N}(2)$ 2.1025[0.350]	
	χ^2_{H}	$\chi^2_{H}(1)$=3.4652[0.063][b]	

[a, b, c] Indicates 1%, 5% and 10% significance level, respectively. Coef.=Coefficient; SE=Standard error; Prob.=Probability; INPT=Intercept; RSS=Residual sum of squares; LM-test statistic=Lagrange multiplier test statistic

Source: Authors' calculation using MICROFIT 4.1

The results in Panel A show that the long-run impact of total final energy consumption on real GDP is positive and statistically significant even at 1% level. A 1% increase in the total final energy consumption leads to 1.0472% increase in the dependent variable. The coefficients regarding dummy variables have the expected negative sign and are statistically significant, especially D1990. The results of the short-run dynamic coefficients are presented in Panel B. Again, the total final energy consumption is statistically significant at the 1% level and is around 0.28. Findings in Table 4 also reveal that capital stock and employment are significantly related with GDP but only in the short-run. Both dummy variables are statistically significant with negative signs in the short-run. The ECT is found to be negative and statistically significant as well. For instance, Model 1 with GDP as dependent variable implies that 26.62% of the preceding period's disequilibrium is eliminated in the current period.

The coefficient of determination (adjusted R^2) shows that the total final energy consumption accounted for 84.31% of the changes in the economic growth. The selected model passes the standard diagnostic tests of serial correlation (there was no evidence on the residual autocorrelation problem), functional form (the model is correctly specified), normality (the residuals are normally distributed) and heteroscedasticity (LM test statistics shows absence of heteroscedasticity problem in the residuals).

When lnTFEC was considered as a dependent variable, we found no evidence of cointegration. Therefore, the Granger causality test in a VAR framework is appropriate (see Table 4). The variables were transformed in first differences and an optimal lag was set to 2.[7]

[7] Detailed results regarding lag order selection criteria prior to multivariate VAR estimates are available upon request.

Table 4: Results of the Multivariate VAR(2) Estimates – Model 2

Panel A: Short-run results Dependent variable: $\Delta lnTFEC_t$			
Regressor	Coef.	SE	T-ratio [Prob.]
ΔlnTFEC(-1)	-0.10986	0.14885	-0.73807[0.464]
ΔlnTFEC(-2)	-0.57516	0.13697	-4.1991[0.000][a]
ΔlnGDP(-1)	0.59920	0.15572	3.8479[0.000][a]
ΔlnGDP(-2)	0.14013	0.13840	1.0125[0.317]
ΔlnKSM(-1)	-0.34747	0.30054	-1.1562[0.254]
ΔlnKSM(-2)	0.27639	0.25600	1.0796[0.286]
ΔlnL(-1)	-0.44908	0.24375	-1.8426[0.072][c]
ΔlnL(-2)	0.18954	0.23979	0.79043[0.433]
INPT	0.034261	0.0093132	3.6788[0.001][a]
D1990	-0.13950	0.028858	-4.8342[0.000][a]
D2009	-0.052158	0.023325	-2.2362[0.030][b]
Adj. R^2	0.58088		
F-statistic	F(10,46)=8.7613[0.000][a]		
DW-stat.	2.2205		
RSS	0.058269		
Panel B: Diagnostic test results			
LM-test statistics	χ^2_{SC}	$\chi^2_{SC}(1)=2.5187[0.113]$	
	χ^2_{FC}	$\chi^2_{FC}(1)=2.1066[0.147]$	
	χ^2_{N}	$\chi^2_{N}(2)=17.7535[0.000]$*	
	χ^2_{H}	$\chi^2_{H}(1)=11.8122[0.001]$**	

[a, b, c] Indicates 1%, 5% and 10% significance level, respectively. The estimated VAR satisfies the stability condition (no root lies outside the unit circle). *Taking into consideration normality test with residual correlation as an orthogonalization method (Doornik & Hansen, 1994), we can accept the null hypothesis of residuals being multivariate normal (Jarque-Bera test=12.47297, df=8, Prob.=0.1313). **According to White's test there was no evidence of heteroscedasticity (Chi-sq.=543.3125, df=510, Prob.=0.1487) when cross terms are included.

Source: Authors' calculation using MICROFIT 4.1 and EViews 7.1

VAR estimates from Table 5 indicate that a 1% increase in the real GDP in the period *t-1* raises the total final energy consumption by 0.59% in the period *t*.

There is also some evidence on employment affecting lnTFEC as well as lnTFEC being determined by its lagged value. The combined results from Tables 3 and 4 indicate unidirectional causality from lnTFEC to lnGDP in the long-run and bidirectional causality between those two variables in the short-run.[8]

4.3. Discussion

The multivariate cointegration analysis provided in the paper shows that there is a cointegration in a relationship including GDP, capital, labor and energy in Croatia and that energy is a significant factor in explaining GDP. Using a multivariate framework the analysis shows that energy Granger causes GDP in short and long-term period, as indicated by the results of the Model 1 and GDP Granger causes energy only in the short-run, as indicated by the second model examined. These results contradict the bivariate analysis of Gelo (2009) and Vlahinic-Dizdarevic and Zikovic (2010), which found bivariate causality running from GDP to energy consumption. However, Borozan (2013) found the same causality that runs from energy consumption to GDP, but only in the short-run. Different empirical results could be explained by different methodology and timeframe. This study differs from those three by including capital and labor variables and by using the longest time period from 1952 to 2011.

The obtained results imply that energy consumption bears the burden of the short-run adjustments to re-establish the long-run equilibrium. In other words, high energy consumption tends to lead high economic growth, especially in the long-run. A 1% increase in the total final energy consumption leads to 1.0472% increase in real GDP of Croatia in the long-run while in the short-run, a 1% increase in the total final energy consumption leads to 0.27874% increase in Croatia's real GDP. These empirical results have important implications for Croatian economic and energy policy.

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[8] In addition, we also analyzed the short-run dynamic coefficients associated with the long-run relationship obtained from the Johansen cointegration test. According to the results, the direction of causality remained the same if compared with the results from Tables 3 and 4. The coefficients are nearly the same (size, sings and statistical significance) with one unexpected exception: lnTFEC negatively affects lnGDP in the short-run. Also, diagnostic test statistics show existence of heteroscedasticity problem in the residuals. These results are also available upon request. Keeping in mind the discussion about the robustness of ARDL and Johansen method (and subsequently VECM) in small sample sizes, it seems to be advisable to follow the ARDL results in case of divergent results (Zachariadis, 2007).

The short-run causality running from energy consumption to GDP indicates that energy shortage can even in the short-term limit the dynamics of economic growth. The direction of causality in the long-run implies that Croatia should find ways not to adversely affect economic growth by reducing energy consumption. Total final energy consumption per capita in Croatia is lower than the EU average, although relatively high energy intensity indicates that there are considerable potentials to increase energy efficiency. Increased energy efficiency does not necessarily mean the reduction in total energy consumption. The explanation can be found in the so-called "rebound effect" or the situation when new technologies that yielded true cost savings would stimulate the demand for energy services.

This effect caused by more efficient technologies leads to increased use of energy, which is known as "macroeconomic feedback" (Howarth, 1997) or rebound effect. 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.

5. Conclusion

This paper examines cointegration and the causal relationship between total final energy consumption and real GDP in Croatia within a multivariate framework that includes capital stock and labor input during the 1952–2011 period. The results of the research fully support a positive long-run cointegrated relationship between production inputs and real GDP and important role of energy in economic growth. It is found that there is a unidirectional causality running from total final energy consumption to real GDP in the long-run and bidirectional causality in the short-run. These results contradict the other papers that were dealing with the causal relationship between energy 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 obtained results imply that energy consumption bears the burden of the short-run adjustments to re-establish the long-run equilibrium. Energy consumption tends to trigger economic growth, especially in the long-run. The results indicate that a 1% increase in the total final energy consumption leads to 1.0472% increase in real GDP of Croatia in the long run while in the short run a 1% increase in the total final energy consumption leads to 0.27874% increase in Croatia's real GDP. The results presented in this paper are important for policy makers because they show that energy can be a limiting factor in economic growth in a short- and long-run period. This means that Croatia should find ways not to adversely affect economic growth by reducing energy consumption. 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.

This is, as far as is known, the first causality analysis between energy and economic growth in Croatia that uses multivariate framework and a long time span. The obtained results have important policy consequences for similar new EU Member States that are going through a similar development path, especially in the context of the EU energy policy and its aim to reduce energy consumption and CO_2 emissions. In the future it may be interesting to investigate multivariate causality between CO_2 emissions, energy consumption and economic growth in Croatia and other EU Member States.

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