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The role of energy in economic growth: the case of Croatia*[1]

Nela Vlahinić-Dizdarević[2], *Saša Žiković*[3]

Abstract

The purpose of this research is to examine the causal relationship between energy and economic growth in Croatia using data for the period from 1993 to 2006. We use a bivariate model of real GDP and five energy variables: energy consumption in industry and households, oil consumption, primary energy production and net energy imports. Since we found cointegration for all of the tested relationships, we use an Error Correction Model (ECM) which also allows us to distinguish between long and short term relationship among the variables. The empirical results provide clear support of causality that runs from real GDP growth to all energy variables. Our results differ from most of the studies analysing developing countries and are similar to those investigating developed, post-industrial economies with strong tertiary sector. Our research results reflect relatively low energy intensity in Croatia as a consequence of transition depression during the 1990s and the process of deindustrialization.

Key words: e*nergy, economic growth, Error Correction Model (ECM), Croatia*

JEL classification: *Q43, C52, O13*

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2 *Full Professor, University of Rijeka, Faculty of Economics, I. Filipovića 4, 51000 Rijeka, Croatia. Scientific affiliation: macroeconomics, energy economics. Phone: +385 51 355 111. E-mail: nela@efri.hr.*

3 *Assistant Professor, University of Rijeka, Faculty of Economics, I. Filipovića 4, 51000 Rijeka, Croatia. Scientific affiliation: banking, risk management, quantitative modelling. Phone: +385 51 355 111. E-mail: szikovic@efri.hr.*

1. Introduction

During the last two decades there have been a number of papers dealing with the causality between economic growth and energy, especially energy consumption. Strong interdependence and causality between economic growth and energy consumption is a stylized economic fact, but the existence and direction of causality is still not clearly defined. Broadly speaking, all papers could be divided in two groups. The first one consists of papers that argue that energy is a crucial input of production and therefore the necessary requirement for economic and social development, but potentially it could also be a limiting factor to economic growth. On the other hand, the other group of papers argued that energy has no significant impact, which is known as neutrality hypothesis. To the best of the author's knowledge, except a paper by Gelo (2009) which uses a different methodology there are no studies addressing the causal relationship between energy and economic growth in the case of Croatia. The purpose of the paper is, therefore, to investigate the existence and direction of causality between economic growth and energy consumption (in industry and households) and specifically oil consumption. The paper will also examine the causal relationship between economic growth and net energy imports, as well as the causality between economic growth and primary energy production in Croatia and to obtain policy implications from the research results. Our hypothesis is that, similarly to most of the developing countries, in Croatia there is a causal relationship running from energy consumption, production and import to GDP growth.

There are several reasons why such an analysis is worthwhile. First, in the light of escalating tensions with some large oil and gas producers, there has been an ongoing debate, in Croatia and worldwide, on how to reduce dependence on foreign (import) energy supply in a reasonable time-frame without reducing economic growth. Therefore it is very important to know the direction of the causality between energy imports and consumption on one hand, and GDP growth on the other. If causality runs from energy to GDP, it would imply that the reduction in energy net imports would considerably harm economic activities. Second, pollution and global warming has become an important issue for economic policy. 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 issue for economic and energy policy. Third, in the context of Croatia's goal to increase energy efficiency, it is important to know what this target would mean for the GDP growth in the short and long run.

The paper is organized in the following way. Section 2 gives the overview of the theoretical and empirical findings on the role of energy in economic growth. Section 3 describes the econometric methodology and presents the obtained empirical results. Final section contains the conclusions.

2. Energy and economic growth within the theoretical and empirical framework

2.1. Theoretical findings on the role of energy in economic growth

The mainstream theory of economic growth pays little attention to the role of energy in economic growth. However, in order to understand the importance of energy in economic growth, it is necessary to start with the role of energy in the production. Considering the theories of production, the neo-classical economic theory explains the economy as a closed system where output is produced by inputs of labour and capital. 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. According to Stern (1999), the mainstream economists have accepted the concept of primary and intermediate factors of production. Primary factors of production are inputs that exist at the beginning of the period under consideration and are not directly used up in production (though they can be degraded and can be added to), while intermediate inputs are those created during the production period under consideration and are used up entirely in production. Capital, labour and land are the primary factors of production, while goods such fuels and materials are intermediate inputs. This approach has led to a focus in mainstream growth theory on the primary inputs, especially capital and labour, while intermediate inputs like energy have got an indirect role. According to them, the quantity of energy available to the economy is endogenously given, though determined by biophysical and economic constraints (Stern and Cleveland, 2004:5). The importance of energy in the economic system was first stressed by Georgescu-Roegen (1971) who argued that the physical dimension of economic production needed more explicit attention in growth theory. After the first oil crisis in 1973-74 other economists started to formulate energy-dependent production functions that included energy and materials besides conventional labour and capital inputs (for example; Tintner et al., 1974; Berndt and Wood, 1979).

Generally, neo-classical production function explains economic growth with an increase in labour, capital and technology where total factor productivity (TFP) is the portion of output that cannot be explained by the amount of inputs used in the production. TFP growth is usually measured by the Solow residual, although it accurately measures TFP growth only if the production function is neoclassical, if there is perfect competition in factor markets and if the growth rates of the inputs are measured accurately (Comin, 2006:1). Solow (1956) also showed that cross-country differences in technology may generate important cross-country differences in income per capita, which has also been confirmed in Hall and Jones (1999) study. The technological progress is the only cause of continuing economic growth, though the Solow model did not explain the sources of technology upgrading.

Understanding the determinants of technology progress and technology adoption is the key for understanding cross-country variations in TFP. More recent models, known as endogenous growth theories, explain the reasons for technological progress with economic choices and decisions taken by firms and individuals. While the neoclassical theory of growth is based on two "growth engines" – population growth and the traditional savings-investment-capital accumulation mechanism, the endogenous growth theory focuses on two growth mechanisms – capital investment and R&D, or accumulation of physical and knowledge capital. The AK models were the first version of endogenous growth theory and they got their name because they result in a production function of the form Y=AK, with A constant. In the newer version, capital K also includes human capital (population and labour force). The growth of human capital is not subject to declining return, as in Solow model, because of the technology spillover effects. Neo-AK models began with Romer (1986, 1990). Romer argued that knowledge can be monopolized long enough to be profitable to the discoverer, but that it almost immediately becomes available as a free good (spillover) accessible to others. Lucas (1988) presented a closely related approach and focused on "social learning" and the trade-off between consumption and the development of "human capital".

The second approach to endogenous growth theory followed Schumpeter's ideas and focused on active and deliberate knowledge creation. Romer (1990), Grossman and Helpman (1990, 1991) and Aghion and Howitt (1992) created models where economic growth is based on research and development (R&D models) and the production of new technologies is of crucial importance. Most models assumed that inventors and innovators have negligible success at appropriating the benefits of their efforts (Ayres and Warr, 2009:164). Other models link the adoption of technologies to the role of institutions (Acemoglu et.al., 2006), financial markets (Aghion et.al, 2006) and policies (Holmes and Schmitz, 2001). The important implication of endogenous growth theories is related to the role of policy measures like subsidies to R&D and investments in education that might be the key to long-term economic growth. However, all endogenous growth models based on human capital and knowledge share a fundamental drawback: they are and likely to remain essentially qualitative and theoretical since none of the proposed core variables (knowledge, human capital etc.) is easily quantifiable. At best, the obvious proxies (education expenditure, years of schooling and R&D spending) exhibit significant multinational cross-sectional correlation with economic growth (Ayres and Warr, 2009).

Regarding technology in energy sector, each technology has its own costs and benefits and there is no technology which can be seen as the ideal answer to the energy crisis (Chevalier, 2009:264). Among all technologies, the GHG (greenhouse gas emissions) technologies do not pay for the damage to the climate that they are generating. One important component of energy policy is to correct this asymmetric situation: to tax or to limit emissions and to set up well designed incentives for promoting and accelerating low carbon technology options. The pace at which low-emissions technologies emerge depends in great part on national energy policies.

Although these new growth theories have successfully addressed the problem of endogenising growth by linking growth performance to profit incentives, according to Zon and Yetkiner (2003) they continued to neglect the fact that equally endogenous energy-saving technical change will be necessary to make these growth paths sustainable in practice. They have incorporated energy as an explicit factor of production in an endogenous growth model and concluded that rate of growth depends negatively on the rate of growth of real energy prices. This conclusion implies that continuously rising real energy prices will tend to slow-down economic growth. The reason is that the rise in real energy prices will lower the profitability of using new intermediate goods and hence, the profitability of doing research, and therefore has a negative impact on growth. There have been some other recent studies that analyse the role of resources in growth models with endogenous technological change. Ayres and van den Bergh (2005) proposed a more disaggregated view on growth engines or mechanisms. They offered a model of economic growth with energy resources and dematerialization, and considered three growth mechanisms: 1) the resource use (fossil fuel) growth engine, 2) the scale-cum-learning growth mechanism and 3) the value creation ("dematerialization") growth engine. They concluded that for sufficiently high growth rates, required resource input increases almost linearly with income. Although theoretical results provide insufficient information on future patterns of growth in relation to resource use, the most relevant policy tool is R&D investment, supplemented by regulation as applied to natural resource utilization, especially energy use efficiency and "dematerialization". Smulders and de Nooij (2003) argue that energy use has a positive growth rate apart from a possible on-time reduction in the level of energy use. The level of technology affects the use of energy, while the availability of investment capital has considerable impact on the energy consumption and economic growth (Dahl, 2008:56). Tahvonen and Salo (2001) develop a model with renewable and non-renewable energy resources and include extraction costs for fossil fuels and production costs for renewable energy resources. Their model very realistically explains the growth process for the economy passes through pre-industrial, industrial and post-industrial stage of development as the use of fossil fuels rises in the beginning and then falls later.

After the oil crisis in 70s and 80s the energy resources and their prices have gained much more research attention. According to the macroeconomic theory, in the short run an increase in energy prices leads to an increase in the domestic price level and a decrease in output due to higher costs. This situation decreases the aggregate demand and may lead firms to change or even cancel their investment plans, especially because increased energy prices can result in higher interest rates. The impact on output and employment is determined by the relative supply responses of labour and capital. To the extent that labour market institutions inhibit the adjustment of real wages to the shocks - i.e. higher energy prices imply higher input prices which reduce profitability - the deterioration in terms of trade following an energy shock can affect the equilibrium of employment by creating a wedge between the value-added and consumer prices. In general, the smaller the short-term economic impact of an energy shock on output and employment, the higher the proportion of the price rise that can be passed on to consumers and/or the more flexible the wages, if the price rise cannot be passed on (OECD, 2004). However, today we are talking about the new energy crisis, which is not related only to high oil prices or to the exhaustion of oil and gas reserves. According to Chevalier and Ouédraogo (2009), this new crisis comes from the recent intrusion of climate change issues into energy economics and geopolitics and it requires collective action.

Development literature in the 1970s and 1980s focuses the question of natural resources impact on economic growth and development. It has been observed that the possession of oil, natural gas or other valuable natural resources does not necessarily lead to economic success, while some East Asian economies like Japan, Korea, Taiwan, Singapore and Hong Kong have achieved high growth rates with no exportable natural resources. This puzzling phenomenon is known as "natural resource curse" coined by Auty (1993, 2001). The question about the long-term growth effects of natural resource production and natural resource price booms was studied implicitly through the issue of whether natural resource production promoted de-industrialization. These models are known as Dutch Disease models and they argue that the existence of large natural resource sectors or booms in these natural resource sectors, will affect the distribution of employment throughout the economy, as wealth affects pull resources in and out of non-traded sectors. Therefore, these sectoral shifts can affect long term growth. The process is painfully reversed when the world price of the export commodity goes back down, as it happened with oil during the 90s. Another interpretation (Frankel, 2010:20) is that, even if the perceived longevity of the increase in world price turns out to be accurate, the crowding out of non-commodity exports is undesirable because the manufacturing sector has greater externalities for long-run growth. Sachs and Warner (1997) found the empirical evidence for a negative relation between natural resource intensity and subsequent growth in the period from 1970 to 1990. Their findings remain significant even after controlling for a large number of additional variables that other studies have claimed to be important in explaining cross-country growth.[4]

One of the most widely stressed causes of the hypotheses that natural resources could be a curse to long-run development is related to the quality of institutions and governance. During the last few years there has been a considerable growth in research on "good governance" and the quality of government institutions.

[4] The list of additional variables includes initial GDP, open policy, investment rates, human capital accumulation rates, changes in the external terms of trade, government expenditure ratios, terms of trade volatility and the efficiency of government institutions.

This development has been induced by empirical findings among economists that such institutions can be considered as the key to understanding economic growth in developing countries (Acemoglu, Johnson, and Robinson, 2002; Acemoglu, Johnson, and Robinson, 2001; Easterly, 2001, Easterly and Levine 2003, Rodrik, Subramanian, and Trebbi, 2004). Consequently, the neoclassical economic thought has been expanded and incorporated such new ideas. New institutional economics has been developed and provided with new evidence of the role of institutions in market economies. Overall institutional environment and especially economic institutions, influence the structure of economic incentives in an economy. Access to energy and to economic development in developing countries relies heavily on state support and government commitment. It is government's responsibility to establish a clear institutional framework and to decide the role that is to be given to state-owned companies, private national capital and international investors. Therefore the relationship between energy resources, energy policy and economic development is heavily determined by the type of political governance that is in place (Chevalier, 2009:136). Institutional economists have especially contributed to the understanding of the role of energy in economic development by introducing the impact of economic, social and political institutions on efficient use of energy (Paavola and Adger, 2005). However, environment has not been a central concern for new institutional economics which has focused on industrial organization and public choice, but it has demonstrated under what circumstances environmental governance institutions are likely to be effective. This raises the potential for amending institutional structures, for example by altering financial incentives or creating communication networks, to facilitate individual and collective behaviour in order to reach low-carbon economy (Ockwell, 2008: 4603).

During the time, the alternative views on economic growth have appeared. There are much of the relevant literature outside the mainstream known as ecological economics that emphasis 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 labour are treated as flows of capital consumption and labour 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. The previously mentioned ecological economists focus on the material basis of the economy and consider an economy as an open subsystem of the global ecosystem. Although various schools of thought exist in the field, they all come from common principles – the laws of thermodynamics. The first law of thermodynamics states that energy cannot be created nor destroyed, only transformed. This means that the only available energy source is solar energy that can be used directly or in an embodied state such as fossil fuels. The second law states that the entropy of an isolated system, which is not in equilibrium, will tend to increase over time. It implies that energy can be reused, but it will increasingly reach a less useful state and therefore additional energy is required. This also implies limits to the extend to which energy can be substituted for by other inputs into the production process (Ockwell, 2008: 4601).

2.2. Empirical findings on the role of energy in 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. In the last two decades, a number of academic papers explored the relationship between economic growth and energy, mostly energy consumption, as it is stated in the remainder of this section. On one hand, it is argued that energy is a vital and necessary input along with other factors of production (such as labour 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 and El-Sakka, 2004:225). 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. One of the first relevant studies was the one from Kraft and Kraft (1978) that examined energy consumption and GNP of the USA within the period 1947 - 1974. They found out that the causality runs from GNP to energy consumption. This pioneering study intensified the interest in the research of the relationship between economic growth and energy consumption. Akarca and Long (1980) changed the time period used in Kraft and Kraft and found no statistically significant causal relationship. Erol and Yu (1987) found a significant causal relationship between energy consumption and income in the case of Japan for the period 1950-1982, supporting the view that Granger causality runs from energy consumption to income. Inconsistent results for the causality direction might be due to the methodological differences and the choice of different time periods. Mozumder and Marathe (2007) find unidirectional causality running from GNP to energy consumption in Bangladesh. Shiu and Lam (2004) report unidirectional causality running from energy consumption to GNP in China, while Jumbe (2004) found bidirectional causality between energy consumption and GNP in Malawi. On the other hand, the neutrality hypothesis is found by Yu and Hwang (1984), Yu and Choi (1985), Yu and Jin (1992) and Cheng (1995). For Taiwan, Yang (2000) investigated the causal relationship between real gross domestic product (GDP) and several disaggregate categories of energy consumption, including coal, oil, natural gas, and electricity, and found that there is unidirectional causality running from economic growth to oil consumption in Taiwan without any feedback effect. Similarly, in the case of South Korea, Yoo (2006) finds unidirectional short term causality from economic growth to coal consumption, and long term bidirectional causality.

Most studies focus developing countries, which is understandable because these countries are economies with the highest energy intensity aiming to increase the energy efficiency. Still, the empirical evidence is mixed for industrialized countries as well. Erol and Yu (1987) found a significant causal relationship between energy consumption and income in the case of Japan for the period 1950-1982, supporting the view that Granger causality runs from energy consumption to income. Inconsistent results for the causality direction might be due to the methodological differences and the choice of different time periods. Chontanawat, Hunt and Pierse (2008) tested the causality between GDP and energy on large sample of OECD and non-OECD countries. They find that causality from energy to GDP is found to be more prevalent in the developed OECD countries compared to the developing non-OECD countries, implying that a policy to reduce energy consumption aimed at reducing emissions is likely to have greater impact on the GDP of the developed rather than the developing world. Gelo (2009) found causality running from GDP growth to total primary energy consumption in Croatia for the period 1953-2005. Unfortunately the results are dubious since a faulty methodology was used – using a VAR model in the presence of cointegration when an error correction model should have been employed.

The most recent study on the sample of 22 small European countries, conducted by Žiković and Vlahinić-Dizdarević (2009), resulted in findings that in less developed countries oil consumption causes economic growth, while in highly developed European countries economic growth causes oil consumption. The exception is the group of four countries (Croatia, Latvia, Lithuania and Moldova) which experienced transition depression and deindustrialization that had resulted in sharp industrial decline and decreased industrial oil demand.

Although the direction or the intensity is not clear, based on the published research one may conclude that there is strong evidence to support the thesis of bidirectional or unidirectional causality between economic growth and energy consumption. The direction of causality has significant policy implications because knowing the direction of causality has direct implications on forming government policies regarding the energy conservation and subsidies system. Under the assumption that there exists unidirectional causality going from economic growth to energy consumption, it means that energy conservation policies will have little or no adverse effects on economic growth of a country. The policymakers may then use these findings in decreasing the tax burden and attracting the investments or in increased government spending. On the other hand, if unidirectional causality runs from energy consumption to economic growth, state should employ additional resources in subsidizing energy prices and securing long term and stable energy sources for its economy. In such a situation, reducing energy consumption, for example through bringing domestic energy prices in line with market prices, could lead to a fall in income and employment.

3. Data and the model

Data used in the analysis of Croatian causality between economic growth and use of energy is real GDP annual series in millions of US$, final energy consumption of industry and households, primary energy production, net import of energy in thousands tons of oil equivalent and oil consumption in thousands of barrels/daily. Time period used in this analysis used is 1993 – 2006. A serious problem of the analysis is the length of the analysed time period due to the short period of Croatia's independence. Analysis would be far more robust if the quarterly data were available but the lack of the quarterly data on energy consumption prevents this approach.

The variables that are analysed in the paper are given in abbreviations, as follows:

GDP – natural logarithm of real gross domestic product in millions of US$,

FEC_H – natural logarithm of final energy consumption (households) in thousands tons of oil equivalent (TOE),

FEC_I – natural logarithm of final energy consumption (industry) in TOE,

PEP – natural logarithm of primary energy production in TOE,

NIE – natural logarithm of net imports of energy in TOE,

OIL – natural logarithm of oil consumption in thousands of barrels per day

Tables 1 and 2 present the descriptive statistics and normality test for level and first differenced variables.

Table 1: Descriptive statistics and normality tests for analysed variables within the period 1993 – 2006

Main statistics	GDP	FEC_H	FEC_I	PEP	NIE	OIL
Descriptive statistics						
Mean	14,882.95	1,638.64	1,422.50	3,935.29	4,100.29	86.52
Median	14,436.24	1,664.50	1,416.00	3,928.50	4,179.00	88.97
Minimum	10,902.62	1,220.00	1,257.00	3,569.00	2,568.00	62.82
Maximum	19,278.98	1,926.00	1,637.00	4,494.00	5,262.00	99.00
St.Dev.	2,536.95	224.28	110.13	270.43	901.00	9.28
Skewness	0.17	-0.59	0.39	0.37	-0.31	-1.09
Kurtosis	2.07	2.39	2.50	2.33	1.78	4.08
Normality tests						
Jarque-Bera test	0.577	1.042	0.493	0.584	1.096	3.467
(p value)	0.500	0.325	0.500	0.500	0.297	0.044
Lilliefors test	0.119	0.156	0.198	0.138	0.164	0.172
(p value)	0.500	0.453	0.141	0.500	0.377	0.307
Shapiro-Wilk/Francia	0.973	0.921	0.947	0.951	0.924	0.901
(p value)	0.914	0.225	0.522	0.583	0.254	0.233

Source: Authors' calculations

Table 2: Descriptive statistics and normality tests for the first differenced logarithms of analysed variables within the period 1993 – 2006

Main statistics	GDP	FEC_H	FEC_I	PEP	NIE	OIL
Descriptive statistics						
Mean	0.044	0.032	0.016	-0.006	0.049	0.035
Median	0.047	0.023	0.014	-0.002	0.027	0.033
Minimum	-0.009	-0.036	-0.086	-0.111	-0.075	-0.127
Maximum	0.066	0.116	0.133	0.087	0.175	0.224
St.Dev.	0.020	0.046	0.055	0.055	0.077	0.085
Skewness	-1.370	0.255	0.190	-0.534	0.104	0.347
Kurtosis	4.611	2.042	3.249	2.930	1.910	3.758
Normality tests						
Jarque-Bera test	5.472	0.638	0.111	0.621	0.667	0.573
(p value)	0.018	0.500	0.500	0.500	0.500	0.500
Lilliefors test	0.228	0.114	0.193	0.174	0.151	0.221
(p value)	0.062	0.500	0.203	0.335	0.500	0.078
Shapiro-Wilk/Francia	0.854	0.974	0.948	0.937	0.966	0.916
(p value)	0.141	0.933	0.490	0.422	0.841	0.305

Source: Authors' calculations

While changes in the real GDP is border line normally distributed, energy variables are normally distributed with slight positive skew and platokurtotic, meaning that extreme changes were not recorded in the observed period. We use the Augmented Dickey-Fuller method to test for the existence of unit roots and identify the order of integration for each variable. If the tested variables have unit roots, we can capitalize on the likelihood of co-movements in their behaviour hence the possibilities that they trend together towards a stable long-run equilibrium. Unit root tests are performed allowing for an intercept and a time trend. The Newey and West method is applied to choose optimal lag lengths. Unit root test for level and first differenced GDP and energy variables in the period 1993-2006 is presented in table 3.

Table 3 shows us that we can reject stationarity of levels for all tested variables and that the variables are integrated of order 1. For final energy consumption in industry, primary energy production, net import of energy and oil consumption differencing transformed them into stationary variables. GDP and final energy consumption in household remained nonstationary after differencing and had to be filtered with an ARMA model to become stationary.

Table 3: Unit root test of tested variables

Variables	Level ADF values	First difference ADF values
GDP	0.592	-1.924
FEC_H	-2.002	-2.355
FEC_I	-0.583	-3.527*
PEP	-2.501	-3.437*
NIE	-1.663	-3.345*
OIL	-3.081	-4.033*

* Signification at the 10% level. The critical value of the ADF statistic at the 10% level is approximately 3,17.

Source: Authors' calculations

Recent developments of the cointegration concept indicate that a vector autoregressive (VAR) model specified in differences is valid only if the variables under study are not cointegrated. If they are cointegrated, an error correction model (ECM) should be estimated rather than a VAR as in a standard Granger causality test (Granger, 1988). Hendry and Juselius (2000) emphasize the importance of correct model specification. Following Granger (1988), we use an ECM instead of a VAR model, since the VAR model is misspecified in the presence of cointegration. VAR models may suggest a short run relationship between the variables because long run information is removed in the first differencing, while an ECM can avoid such shortcomings. In addition, the ECM can distinguish between a long run and a short run relationship among the variables and can identify sources of causation that cannot be detected by the usual Granger causality test.

ECM model used in this paper can be written as:

$$X_t = \alpha_{12} + \sum_{i=1}^{n} \beta_{11i} \Delta X_{t-i} + \sum_{j=1}^{m} \beta_{12j} \Delta Y_{t-j} + \theta ECM_{t-1} + u_t \qquad (1)$$

$$\Delta Y_t = \alpha_{22} + \sum_{j=1}^{m} \beta_{21j} \Delta Y_{t-j} + \sum_{i=1}^{n} \beta_{22i} \Delta X_{t-i} + \lambda ECM_{t-1} + \varepsilon_t \qquad (2)$$

Regardless of the formulation used, similar studies have shown that the result of causality is very sensitive to the lag length adopted in the models. Fortunately, Hsiao (1981) introduced a way to help determine the optimum lags to be used, by combining the Granger definition of causality and Akaike's FPE criterion. The Hsiao procedure involves two steps. For the first step Eq. (2 and 4) or Eq. (5 and 6) are estimated with various lag lengths for ΔGDP but with the energy variables and ECM terms omitted. The final prediction error (FPE) is computed for each lag length of ΔGDP with the optimal lag (n*) being the one with the minimum FPE, denoted as FPE(I). For the second step Eq. (1 and 2) is estimated, with the lag length on the ΔGDP terms predetermined by step one, but different lag lengths for energy terms. Again a form of the FPE is calculated with the optimal lag length (m*) being that with the minimum FPE, denoted as FPE(II). Finally FPE(II) is compared with FPE(I): if FPE(II) < FPE(I) then energy (Granger) causes GDP; whereas if FPE(II) > FPE(I) then energy does not (Granger) cause GDP. These tests determine whether energy variables cause GDP. These can be confirmed by using a number of statistical tests. For the error correction model, Eq. (1 and 2), where causality comes from two sources, the ECM term and the lagged energy variables, causality can be confirmed by undertaking a joint *F*-test of the ECM coefficient and the lagged energy coefficients. The Hsiao (1981) procedure enables a systematic approach which minimizes arbitrary decisions on an individual level.

By using standard Wald test we evaluate Granger weak causality by testing H_0: $\beta_{12j} = 0$ for all *j* in Eq. (1) or H_0: $\beta_{22i} = 0$ for all *i* in Eq. (2). Asafu-Adjaye (2000) interpreted the weak Granger causality as short run causality in the sense that the dependent variable responds only to short-term shocks from the stochastic environment. ECM terms in Eqs. (1 and 2) provide for another possible source of causation. The coefficients on the ECMs represent how fast deviations from the long run equilibrium are eliminated following changes in each variable. If, for example, θ is zero, then GDP does not respond to a deviation from the long run equilibrium in the previous period. This can be tested using a simple *t*-test. If there is no causality in either direction, the "neutrality hypothesis" holds.

The maximum likelihood approach to cointegration developed by Johansen (1988, 1991) makes it possible to test for the cointegration rank, that is, the number of cointegrating vectors. It also allows the estimation of these vectors and to test linear restrictions on the vectors using standard asymptotic inference. In addition, the small sample biases and normalization problems inherent in the OLS approach do not arise in the Johansen method. When testing for cointegration using the Johansen procedure, we employed the specification that allows for a linear trend in the data with an intercept but no trend in the co-integrating vector.

4. Empirical results and discussion

Since our unit root test results confirm the nonstationarity of the variables in the VAR model, we can then apply Johansen methodologies in testing for cointegration (Johansen, 1988, 1991). To determine the number of the cointegrating vectors, we make use of both the Trace test and the Maximum Eigenvalue test using the critical values of MacKinon–Haug–Michelis (1999). In the cases of the GDP OIL, GDP PEP and GDP FEC_I models, both tests identify one cointegrating vector at the 5% critical level as presented in Table A1 in the appendix. The cointegration in the case of these models is for the case where we have an intercept (no trend) in the cointegrating equation and test VAR with a single cointegrating vector against other alternatives. The suitability of this choice was tested using Akaike Information Criterion (AIC) and Schwarz Information Criterion (SIC). The assumption of no deterministic trend and restricted constant in the GDP OIL, GDP PEP and GDP FEC_I models was able to confirm the existence of long-run relationships within them. The intercept and linear deterministic trend model of GDP NIE and GDP FEC_H models also confirms the existence of long-run relationship as shown in Table A1.

After obtaining cointegration relations among GDP and energy variables we can estimate our EC models for the real GDP and energy variables to derive their short-run elasticities. The EC model has the obtained cointegration relations built into the specification so that it restricts the long-run behaviour of the endogenous variables to converge to their cointegrating relationships while allowing for short-run adjustment dynamics. The cointegration term is known as the error correction term since the deviation from long-run equilibrium is corrected gradually through a series of partial short-run adjustments. The results were evaluated using conventional diagnostic tests. Results of Johansen cointegration test as well as short and long-term causality between GDP and energy consumption, production and import are presented in table 4 and A2 in the appendix.

Table 4: GDP and energy variables causality in Croatia

Variable	Cointegrating rank	Causality	Variable
GDP	1	➔	OIL
GDP	1	➔	PEP
GDP	1	➔	NIE
GDP	1	➔	FEC_H
GDP	1	➔	FEC_I

Source: Authors' calculations

The direction of causality has significant policy implications because knowing the direction of causality has direct implications on the forming of government policies regarding the energy conservation and subsidies system. As we found that in Croatia real GDP growth is cointegrated with energy consumption, primary energy production and net energy imports, there must be either unidirectional or bidirectional Granger causality, since at least one of the error correction terms (ECMs) is significantly nonzero by the definition of cointegration.

The results of the oil consumption in column 1 of table A2 are logical and expected. While the first lag of differenced GDP shows an insignificant negative relationship, the second lag shows strong positive short-run relationship with oil consumption. The result can be explained by the fact that it takes some time for the increase in GDP to spill over into increased oil consumption. Oil consumption increases with a lag when real GDP increases, a 1% increase in the real GDP raises oil products consumption by 0.72%. The error-correction estimate of 0.517 indicates that 51.7% of the preceding period's disequilibrium is eliminated in the current period, with immediate adjustments captured by the difference terms. Real GDP accounted for 93.7% of the variations in the dependent variable.

Primary energy production is found to have a positive relationship with the GDP in the first lag, the second lag of GDP indicates negative relationship with primary energy production. The sample of goodness fit measure, the adjusted R^2, indicates that 32.2% of the variation in primary energy production is attributable to the GDP. Nevertheless, 27.5% of last period's disequilibrium is removed in the current period.

The results for net import of energy are quite troubling and shed light on Croatian energy policy, or lack of it, and peculiar behaviour of primary energy production. Net imports of energy are strongly positively connected to growth in real GDP at both lags. A 1% increase in the real GDP raises net import of energy by 2.35% in the first lag and 3.2% in the second. The error-correction estimate indicates a feedback of 20.5% of previous period's disequilibrium from the long-run relationship. The coefficient of determination shows that the real GDP account for 54.5% of the changes in net imports of energy.

Findings for relationship between real GDP and final energy consumption households and industry are very similar. In both cases the first lag of real GDP shows an insignificant positive relationship, while at the second lag a strong positive short-run relationship with final energy consumption is revealed. Explanation of this result is similar to the explanation for the oil consumption, meaning that the increase in real GDP is not immediately reflected in increased final energy consumption but with a lag. Once the increase in real GDP is filtered into the households and industry its effect is very strong so that 1% increase in real GDP results in an increase in final energy consumption for households of 2.4% and 1.3% for industry. In case of households 22.2% of the preceding period's disequilibrium is eliminated in the current period, while for the industry the feedback is 9.66%. Real GDP accounted for 68.8% and 66.5% of the variations in the dependent variables respectively.

To summarize we can conclude that all the diagnostic test statistics are satisfactory. Considered by the significance of the t statistics, the coefficients are well determined. The disequilibrium error term is statistically significant in all equations which confirms the existence of long-run relationship between the variables in the error-correction models. In addition, all the equations are statistically significant and the overall statistical goodness of fit is acceptable. It can be concluded that the regression coefficients are significantly different from zero. In assessing the robustness of the estimated EC model residual tests were conducted and their results are presented in tables A3-A5 in the appendix. Tables A3, A4 and A5 present the ECM residual Portmanteau autocorrelation tests, ECM residual normality and pairwise Granger causality/Block exogeneity Wald tests for the estimated bivariate real GDP-energy variables models. For example, the ECM residual Portmanteau autocorrelation test in Table A3 show that there is no residual autocorrelation in the bivariate GDP- energy variables models even up to the 5th lag except in the case of oil consumption. The residual normality test is computed using the Jaque–Berra statistic with Cholesky (Urzua) orthogonalization and shows that residuals for all EC models can be viewed as being multivariate normally distributed. Pairwise Granger causality/Block exogeneity Wald test reported in table A5 tests whether an endogenous variable can be treated as exogenous. For each equation in the VAR, the output displays (Wald) statistics for the joint significance of each of the other lagged endogenous variables in that equation.

We find the short term dynamics for all energy variables moving in the same direction, from real economic growth to energy variables. Our results are different from most of the studies analysing developing countries, which found that causality runs from energy variables to economic growth. On the other hand, opposite causality is common in developed, post-industrial economies with strong tertiary sector. The interdependence between energy, other inputs and economic activity changes significantly as an economy moves through different stages of development. Energy consumption in developed countries is mostly used in final consumption (transport, heating and cooling) rather than in production processes. In such cases the external shocks have less effects on economic growth, while, at the same time, economic growth has a more significant impact on the level of energy consumption, production and imports. Although Croatia is developing and transition country, it shows similar economic structure to developed countries with dominant service sector that makes up to 60% of its GDP. These similar structural characteristics are the consequence of completely different reasons. Privatisation process in Croatia has resulted with brown-field investments in service sector, especially telecommunications and financial sector, (Kersan-Škabić, Orlić, 2009; Škuflić, Botrić, 2006; Demekas et.al., 2005) because of the high profits in these oligopolistic markets. On the other hand, the industrial production dropped sharply due to the closure and restructuring of heavy industry which was 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 liberalisation which led to further decline in industrial production and industrial energy consumption. An important problem that negatively impacts the competitiveness of Croatian industry is related to higher energy prices for industry in comparison to prices for households. During the 90s in most transition countries industrial tariffs used to be higher than residential tariffs, which is in sharp contrast with the situation in Western Europe where industrial tariffs have been on average two-third of the price charged to households, reflecting the relative costs of supplying these two customer categories (Broadman et.al., 2004: 171). Regarding electricity, prices for industry in EU-27 in 2009 are even 23.8% lower than prices for households, while in EU-27 gas industry the relationship between industry and households prices is even more favourable for industry and is 26.15% lower than for residential costumers (Eurostat, 2010). Despite regular increases in household tariffs in Croatia, cross-subsidisation still exists from industry to households and latest increase in gas prices for Croatian industry has further deteriorated its competitiveness. Croatian energy policy should tackle this problem, but it should include support measures to neutralize the negative economic impact of cost-reflective energy prices on socially vulnerable households.[5]

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. Our research results reflect relatively low energy intensity in Croatia (0.17 toe per thousand USD of GDP in PPP year 2000) comparing with the Western Balkan average (0.28 toe per thousand USD of GDP in year 2000), though 13% higher than the average for OECD Europe. According to OECD and IEA (2008), Croatia's estimated energy saving potential is significant – in the range of 25% of total primary energy supply (TPES). These savings can be reached economically on both supply and demand side. Declaratively, the government has put high priority on enhancing energy efficiency, but the impact on energy intensity in the particular sub-sectors, as well as in the whole economy, has been limited. The largest saving potentials are in transport sector, especially in road transport, and in building sector. Estimates indicate that more than 83% of existing buildings have inadequate thermal insulation and that average consumption is about 50% higher than in existing buildings in Germany (OECD/IEA, 2008). Despite many national programmes that are focusing energy efficiency and renewable energy, both vertical and horizontal, the level of renewable investments has remained limited.

All above mentioned arguments explain why the causal relationship cannot run from energy to economic growth, as in other developing countries, while relatively high GDP growth in Croatia has induced net imports of energy, energy consumption in industry and households.

5. Conclusion

This paper examines the causal relationship between energy and economic growth in Croatia over the period 1993–2006. The results of the research show that we may reject our hypothesis set in the beginning of the paper. The findings show that, unlike

[5] These measures may combine social support for households that suffer from energy poverty with support for increased energy efficiency.

other developing countries, in Croatia the causality runs from real GDP growth to energy consumption, production and import, making it more similar to developed countries. These findings can be related to strong transition depression in Croatia during the 1990s and the process of deindustrialization that had resulted in sharp industrial decline and decreased industrial and overall energy demand. Therefore the causation between economic growth and energy consumption, production and imports is more related to personal transportation and heating (cooling) needs than industrial demand. Under the assumption that there exists unidirectional Granger causality going from economic growth to energy, it means that policies aimed at decreasing energy consumption and oil dependency may have little effects on economic growth of a country. The state may then use proceeds from increased taxes or lower incentives to increase government spending, which is especially welcomed in the current global crisis or decrease the tax burden and attract domestic and foreign investors. The limitation of this study is the short time period available for Croatia and questionable quality of data in the early '90. In the future it may be interesting to investigate causality over a longer time span and higher frequency data, for example, quarterly data, since temporal aggregation of higher frequency to annual data may weaken causal relationships between the variables. Despite these limitations this is, as far as is known, the first systematic analysis of causality between energy and economic growth performed on Croatia. The results we obtained have important consequences for similar transitional countries in light of the ongoing desire to reduce energy consumption and reduce CO_2 emissions

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Uloga energije u ekonomskom rastu: primjer Hrvatske

Nela Vlahinić-Dizdarević[1], *Saša Žiković*[2]

Sažetak

Rad istražuje kauzalnu povezanost između energije i ekonomskog rasta u Hrvatskoj na temelju podataka u razdoblju između 1993 i 2006. godine. Koristimo bivariatni model realnog bruto domaćeg proizvoda i pet energetskih varijabli: potrošnja energije u industriji i kućanstvima, potrošnja nafte, proizvodnja primarne energije i neto uvoz energije. S obzirom da smo utvrdili postojanje kointegracije za sve testirane međuzavisnosti, koristimo Error Correction Model (ECM) koji nam omogućava razlikovanje dugoročnih i kratkoročnih veza između varijabli. Empirijski rezultati jasno potvrđuju postojanje kauzalnosti, dugoročne i kratkoročne, između rasta bruto domaćeg proizvoda i svih energetskih varijabli. Naši rezultati se razlikuju od većine studija koje analiziraju zemlje u razvoju i slični su rezultatima razvijenih, post-industrijskih ekonomija s razvijenim jakim uslužnim sektorom. Rezultati istraživanja odražavaju relativno nisku energetsku intenzivnost u Hrvatskoj, što je posljedica tranzicijske depresije tijekom 1990-tih godina i procesa deindustrijalizacije.

Ključne riječi: *energija, ekonomski rast, Error Correction model (ECM), Hrvatska*

JEL klasifikacija: *Q43, C52, O13*

[1] *Redoviti profesor, Sveučilište u Rijeci, Ekonomski fakultet, I. Filipovića 4, 51000 Rijeka, Hrvatska. Znanstveni interes: makroekonomija, energetska ekonomija.. Tel: +385 51 355 111. E-mail: nela@efri.hr.*

[2] *Docent, Sveučilište u Rijeci, Ekonomski fakultet, I. Filipovića 4, 51000 Rijeka, Hrvatska. Znanstveni interes: bankarstvo, upravljanje rizicima, kvantitativno modeliranje. Tel: +385 51 355 111. E-mail: szikovic@efri.hr.*

Appendices

Table A1: Unrestricted Cointegration Rank test (Trace) for Croatian real GDP and energy variables, period 1993 - 2006

	GDP OIL (No deterministic trend, restricted constant)		GDP PEP (No deterministic trend, restricted constant)		GDP NIE (Intercept and linear deterministic trend)		GDP FECH (Intercept and linear deterministic trend)		GDP FECI (No deterministic trend, restricted constant)	
Hypothesized no. of CE(s)	Trace Statistic	Max-Eigen Statistic	Trace Statistic	Max-Eigen Statistic	Trace Statistic	Max-Eigen Statistic	Trace Statistic	Max-Eigen Statistic	Trace Statistic	Max-Eigen Statistic
None *	39.53457	39.04959	25.02074	24.99896	22.41448	22.36554	32.61132	25.72599	19.15178	18.97449
At most 1	0.484979	0.484979	0.021781	0.021781	0.048938	0.048938	6.885332	6.885332	0.177298	0.177298
	Trace test indicates 1 cointegrating equation at the 5% level		Trace test indicates 1 cointegrating equation at the 5% level		Trace test indicates 1 cointegrating equation at the 5% level		Trace test indicates 1 cointegrating equation at the 5% level		Trace test indicates 1 cointegrating equation at the 5% level	
	Max-eigenvalue test indicates1 cointegrating equation at the 5% level		Max-eigenvalue test indicates1 cointegrating equation at the 5% level		Max-eigenvalue test indicates1 cointegrating equation at the 5% level		Max-eigenvalue test indicates1 cointegrating equation at the 5% level		Max-eigenvalue test indicates1 cointegrating equation at the 5% level	
* denotes rejection of the hypothesis at the 5% level										

Source: Authors' calculation

Table A2: Johansen's error correction estimates for Croatian real GDP and energy variables, period 1993 - 2006

Depend. var.	D(GDP)	D(OIL)
CointEq1	0.143937	0.516980
	[0.62429]	[2.17960]
D(GDP(-1))	0.535585	-0.516206
	[1.51686]	[-1.42110]
D(GDP(-2))	-0.522294	0.718477
	[-1.61927]	[2.16522]
D(OIL(-1))	0.017790	0.116697
	[0.07621]	[0.48593]
D(OIL(-2))	0.198433	-0.214746
	[1.19417]	[-1.25621]
Constant	0.032912	0.006753
	[2.29092]	[0.45694]
R2	0.736856	0.968442
Adj. R2	0.473712	0.936884
SSR	0.001088	0.001152
S.E. equation	0.014752	0.015177
F-statistic	2.800198	30.68757
likelihood	35.10806	34.79614
Akaike AIC	-5.292.374	-5.235.663
Schwarz SC	-5.075.341	-5.018.629
Mean dep.	0.040627	0.010234
SD depend.	0.020335	0.060410

Depend. var.	D(GDP)	D(PEP)
CointEq1	-0.059612	0.275736
	[-0.76558]	[1.71399]
D(GDP(-1))	0.379144	1.955128
	[0.79139]	[1.97526]
D(GDP(-2))	-0.540971	-1.691.994
	[-1.46697]	[-2.22079]
D(PEP(-1))	0.198930	-0.641144
	[0.85673]	[-1.33647]
D(PEP(-2))	0.188117	-0.267766
	[1.02813]	[-0.70833]
Constant	0.052045	-0.017026
	[2.19758]	[-0.34796]
R2	0.510549	0.661071
Adj. R2	0.021098	0.322142
SSR	0.002024	0.008639
S.E. equation	0.020120	0.041568
F-statistic	1.043106	1.950471
likelihood	31.69486	23.71288
Akaike AIC	-4.671.792	-3.220.524
Schwarz SC	-4.454.759	-3.003.491
Mean dep.	0.040627	-0.000614
SD depend.	0.020335	0.050488

Depend. var.	D(GDP)	D(NIE)
CointEq1	-0.142998	-0,20478
	[-0.65124]	[-3.18086]
D(GDP(-1))	0.636725	2.353691
	[1.90664]	[2.40386]
D(GDP(-2))	-0.073107	3.200099
	[-0.18468]	[2.75720]
D(NIE(-1))	-0.139962	-1142836
	[-1.05721]	[-2.94427]
D(NIE(-2))	-0.176176	-0.814414
	[-1.75026]	[-2.75959]
Constant	0.035168	-0.082794
	[2.22889]	[-1.78972]
R2	0.629728	0.772378
Adj. R2	0.259455	0.544756
SSR	0.001531	0.013162
S.E. equation	0.017499	0.051308
F-statistic	1.700715	3.393247
likelihood	33.22961	21.39725
Akaike AIC	-4.950.838	-2.799.500
Schwarz SC	-4.733.804	-2.582.466
Mean dep.	0.040627	0.046519
SD depend.	0.020335	0.076043

Depend. var.	D(GDP)	D(FECH)
CointEq1	-0.424715	-0,222123
	[-1.21761]	[-4.38328]
D(GDP(-1))	0.491902	0.334142
	[1.65541]	[0.77402]
D(GDP(-2))	-0.233469	2.399365
	[-0.56254]	[3.97934]
D(FECH(-1))	0.169804	-0.301498
	[1.16518]	[-1.42404]
D(FECH(-2))	0.038313	0.298232
	[0.25409]	[1.36141]
Constant	0.021796	-0.093550
	[1.26067]	[-3.72453]
R2	0.677502	0.844205
Adj. R2	0.355004	0.688410
SSR	0.001334	0.002815
S.E. equation	0.016332	0.023727
F-statistic	2.100792	5.418685
likelihood	33.98938	29.88096
Akaike AIC	-5.088.979	-4.341.993
Schwarz SC	-4.871.945	-4.124.959
Mean dep.	0.040627	0.025551
SD depend.	0.020335	0.042505

Depend. var.	D(GDP)	D(FECI)
CointEq1	-0.035815	-0.096551
	[-1.95635]	[-2.21789]
D(GDP(-1))	0.730882	0.459033
	[3.14649]	[0.83104]
D(GDP(-2))	-0.057001	1.298163
	[-0.23684]	[2.26830]
D(FECI(-1))	-0.349746	-0.772488
	[-2.63884]	[-2.45105]
D(FECI(-2))	-0.352891	-1211465
	[-2.94572]	[-4.25269]
Constant	0.021775	-0.024656
	[2.04977]	[-0.97608]
R2	0.820080	0.832396
Adj. R2	0.640160	0.664792
SSR	0.000744	0.004207
S.E. equation	0.012198	0.029007
F-statistic	4.558019	4.966442
likelihood	37.19910	27.67057
Akaike AIC	-5.672.563	-3.940.104
Schwarz SC	-5.455.529	-3.723.070
Mean dep.	0.040627	0.024012
SD depend.	0.020335	0.050101

Source: Authors' calculation

Table A3: VEC residual Portmanteau autocorrelation test

	GDP OIL		GDP PEP		GDP NIE		GDP FECH		GDP FECI	
Lags	Q-Stat	Prob.	Q-Stat	Prob.	Q-Stat	Prob.	Q-Stat	Prob.	Q-Stat	Prob.
1	9.287897	NA*	5.492014	NA*	7.369288	NA*	4.761089	NA*	7.548791	NA*
2	14.46035	NA*	10.18740	NA*	12.63517	NA*	5.684271	NA*	12.79701	NA*
3	20.26342	0.0025	11.93581	0.0634	15.96150	0.0140	8.343307	0.3033	14.25135	0.0270
4	29.96131	0.0009	12.70850	0.2404	17.70437	0.0602	9.966935	0.5334	15.66072	0.1098
5	34.71296	0.0016	13.49430	0.4880	20.16686	0.1250	10.70857	0.7730	18.04638	0.2047
H0: no residual autocorrelations up to lag h										

Source: Authors' calculation

Table A4: VEC residual normality test

	GDP OIL		GDP PEP		GDP NIE		GDP FECH		GDP FECI	
Component	Jarque-Bera	Prob.	Jarque-Bera	Prob.	Jarque-Bera	Prob.	Jarque-Bera	Prob.	Jarque-Bera	Prob.
1	0.398377	0.8194	0.344058	0.8420	0.155396	0.9252	1.488345	0.4751	NA	NA
2	2.008959	0.3662	1.726800	0.4217	0.853778	0.6525	4.731194	0.0939	NA	NA
Joint	3.703825	0.9298	3.036475	0.9628	2.374929	0.9841	8.270053	0.5072	4.824447	0.8493
Orthogonalization: Residual Covariance (Urzua)										
H0: residuals are multivariate normal										

Source: Authors' calculation

Table A5: VEC Granger Causality/Block Exogeneity Wald tests

GDP OIL			GDP PEP			GDP NIE			GDP FECH			GDP FECI		
Dependent variable: D(GDP)			Dependent variable: D(GDP)			Dependent variable: D(GDP)			Dependent variable: D(GDP)			Dependent variable: D(GDP)		
Excluded	Chi-sq	Prob.	Excluded	Chi-sq	Prob.	Excluded	Chi-sq	Prob.	Excluded	Chi-sq	Prob.	Excluded	Chi-sq	Prob.
D(OIL)	6.720107	0.0347	D(PEP)	1.301251	0.5217	D(NIE)	3.063701	0.2161	D(FECH)	1.430352	0.4891	D(FECI)	9.256699	0.0098
Dependent variable: D(OIL)			Dependent variable: D(PEP)			Dependent variable: D(NIE)			Dependent variable: D(FECH)			Dependent variable: D(FECI)		
Excluded	Chi-sq	Prob.	Excluded	Chi-sq	Prob.	Excluded	Chi-sq	Prob.	Excluded	Chi-sq	Prob.	Excluded	Chi-sq	Prob.
D(GDP)	7.238633	0.0268	D(GDP)	6.415591	0.0404	D(GDP)	16.30845	0.0003	D(GDP)	20.04456	0.0000	D(GDP)	8.037815	0.0180

Source: Authors' calculation