International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2016, 6(1), 65-75.

Elasticity of Energy Intensity on a Regional Scale: An Empirical Study of International Trade Channel

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ABSTRACT

This study examines the relationship between energy intensity in different world regions. To explain relationship between them we test a hypothesis of international trade channel and determine degree of sensitivity of national economy's energy intensity to actions of major competitors in export market. Based on data of energy intensity for more than 150 countries for the period from 1980 to 2011, using regression analysis, we built a number of unrestricted vector autoregression models reflecting relationship between energy intensity of different regions, and relationship between groups of economies, primary source of exports for which is fuel or engineering sector. To characterize elasticity of energy intensity in sampled countries, we use variance decomposition and impulse response techniques. The study shows the presence of a stable relationship between energy intensity for different regions of the world. Testing interlinkages between energy intensity of economies exporting raw materials (e.g. oil) and engineering production, for trade channel, confirms its existence. The sensitivity of economies exporting raw materials to shocks in energy intensity tends to be significantly lower than in economies exporting consumer goods.

Keywords: Energy Intensity, Elasticity of Energy Intensity, Credit Market
JEL Classifications: F14, O13, Q43

1. INTRODUCTION

Energy is an important factor for economic and social development, which ensures reliable functioning of economic and public relations, helps to achieve welfare of the world community. In regard to economic relations, energy is essential to maintain continuity of reproduction in conditions of modern technology. Lack of energy or its inefficient use has negative implications for economic development. One of the common indicators of energy efficiency is energy intensity. The energy intensity of the economy reflects amount of power needed to ensure stability of economic operations. At the same time, energy is an indirect manifestation of technology's effectiveness as a production factor. The problem of energy efficiency as a result of production factors' usage significantly increased in the 1970s, and has attracted increased attention from authorities, experts and research community. Even so, the problem of energy intensity of the economy remains relevant today. Reduction in energy intensity is the keynote of public policy of most countries in the world. The problem of energy stagnation - preservation of steadily high levels of consumption relative to gross domestic product (GDP), still exists.

The energy intensity of economy can be considered in light of technological factor of production, its efficiency. The classic model of production factors and competitive advantages (for example, the Hecksher-Ohlin model) states that the structure of exports and imports of the national economy directly, ceteris paribus, depends on existing competitive advantages when using factors of production. In conditions of perfect competition, with no barriers of market entry, the optimal functioning of institutions, and taking into account transaction costs, exported products should and will have a comparative advantage in relation to competitors. The same is true for imports. Thus, the classical model of international trade states that in a free market (absence of institutional and political barriers), elasticity of demand and supply for goods and services in international markets must tend to maximum values. A high level of competitive pressure should stimulate producers to the most efficient use of production factors. Otherwise, non-maximizing behavior is fraught with loss of competitive advantages. In other words, inefficient use of factors of production is fraught with the loss of a niche in the international market, reducing a share of exports and an increasing pressure of cheaper imports in the domestic market (in this case, the policy of exchange rate should be thought of as a barrier). With regard to energy intensity of the economy, this theory states that taking into account geographical features, transportation and other transaction costs, consumption of energy should have significant elasticity and technology, as a factor of production, determining energy intensity, to respond to competitors' actions in a manner of reaction to external technological shocks.

Unfortunately, in practice, the Hecksher-Ohlin theorem has proved, in certain cases, unviable due to unrealistic assumptions, which include full rationality of agents, maximizing behavior, lack of barriers to market entry, perfect information, stable risk aversion, no protectionism in the actions of national authorities etc. Therefore, an assumption about absolute elasticity of production factors also cannot be considered as realistic.

However, the field of international economic relations is developing rapidly. Depending on the specialization of economies in relation to various industries, there exist regional centers that are in competition with each other taking into account the spatial aspect. Competition between players is enhanced, which requires not only actions on maintaining comparative advantages, such as well managed exploitation of production factors (labor, land, capital, information), but also their development through technology upgrades, and, consequently, a reduction in energy intensity.

However, in practice, protectionist measures of national authorities begin to play an increasing role, establishing import quotas, import tariffs, implementing methods of unfair competition, which generally reduce efficiency of the national economy, making it more closed, less market-oriented. These actions also influence on elasticity production factors, in particular on energy intensity. Another consequence of such market imperfections lie in rising energy consumption, conserving an economy in the current technological state, which leads to lower economic growth, quality of life and level of prosperity.

Thus, it can be assumed that in the presence of dependence on export operations (if share of exports in GDP is at least 30%), the need for maintaining competitive advantages dictates the necessity of reducing energy intensity of GDP. The degree of sensitivity of exports to technological shocks on international markets at the same time may depend on the presence of protectionist policies, manipulating exchange rate in order to devaluate national currency, geographic features, and structure of exports.

Another important point for this study is to determine relationship between sectoral specialization of the national economy and elasticity of energy intensity (energy elasticity). In other words, one could assume that sensitivity of some industries in international markets to shocks in energy consumption is higher than in others and pace of changes is significantly higher. The basis of this assumption is still a same thesis about comparative advantages due to the natural barriers that protect the industry. For example, in case of economies dependent on oil exports, geographical position, specifics of transportation, could create in some cases a quasi-monopolistic position, which may substantially reduce sensitivity to actions of competitors, which could potentially lead to reduction in energy intensity, thereby reducing net costs of oil production. In absence of such barriers, sensitivity of an economy that depends on exports should be significantly higher.

Moreover, we can assume that in current conditions, the question of energy intensity of GDP, its elasticity to changes in international markets, lies not so much in maintaining competitive advantages, but in the survival of the national economy in the long term. And this exactly determines relevance of the present study.

The question of determining relationship between energy intensity of economies worldwide in a regional breakdown - presence or absence and its degree (sensitivity of energy intensity of individual economies to shocks of international markets), should allow to shed light on current status of international market for goods and services in the context of energy efficiency, as well as to determine patterns of energy elasticity for various types of economies.

Given the above, the aim of this study is to test hypotheses about relationship between energy efficiency of economies on a regional scale and to determine elasticity's level of their energy intensity in the context of international trade.

The paper is organized as follows: Section 2 reveals existing theory and presents a literature review on the issue. Section 3 presents methods used to test the hypotheses. Section 4 presents the results of hypotheses' empirical testing and identifies areas of further research. Section 5 presents concluding remarks of this research.

2. LITERATURE REVIEW

The issue of energy intensity of GDP is well researched. There is a large number of studies on energy efficiency, methods of its measurement, comparative analysis of energy efficiency. Much attention is paid to relationships between energy efficiency and economic growth of the economy; upgrading technological factor of production and changes in energy intensity. (Jorgenson, 1984; Rezitis and Ahammad, 2015).

Most of the studies conclude that there is significant relationship between economic growth and the level of energy intensity of production (Florax et al., 2011). The same is true for the impact of technology modernization on energy efficiency, provided significant energy intensity of GDP. These results allow us to assume that the role of energy in economies of most countries of the world to be high (Mulder and de Groot, 2004).

Concerning subject of our research, existing literature on the issue could be divided into several blocks.

The first block of literature discusses relation between energy intensity of GDP and technological factor of production and provisions of international trade theories. So, most of the studies reveal lack of conformity between energy efficiency trend and provisions of Hecksher-Ohlin theorem. Among the potential causes of impairment monopolistic or oligopolistic competition, territorial, geographic factors, low quality of institutions (absence of incentives to improve energy efficiency) are pointed out (Hillman and Bull, 1978; Burakov, 2015).

The second block of literature deals with the question of exports elasticity to competitive pressure on international markets. In these studies, sensitivity of energy intensity of GDP to shocks of international markets is analyzed. Thus, studies of Li (2010), Jacobsen (2013), demonstrate presence of energy-intensive industries' elasticity to actions of competitors at the level of national economies, creating a system of incentives to modernize production technology in order to reduce production costs. However, these incentives can be blocked under different causes, including low weight of energy in net costs of production, policy of export/import tariffs, and fixed exchange rate in times of currency wars and so on (Havlik, 1998; Srinivasan and Archana, 2009).

The third literature block includes cross-country studies of energy efficiency, identifies trends and linkages between different economic sectors at the global level. E.g., Mulder and De Groot (2011; 2012), using data of energy intensity in sample economies for 25 years, carried out a comparative analysis of energy efficiency and determined its degree in the context of particular industries. Also a detailed comparative analysis of national economies' efficiency and energy intensive industries are presented in Florax et al. (2011). For example, in Gunay and Ceylan (2010) a comparative study of energy efficiency is presented and potential of Turkey, compared with countries of the Eurozone is assessed. In the study by Amador (2011), comparative analysis of energy efficiency of 30 countries over a 10-year period is conducted and changes in a trend of energy efficiency is analyzed through the classical set of factors of international trade theory. All the studies of this literature block highlight a problem of lowering energy intensity in a number of countries, stating that interlinkages of energy intensity between different sectors exist, however energy elasticity does not solely explain growth rates of GDP, or economy's output (Nilsson, 1993; Eichhammer and Mannsbart, 1997; Howarth et al., 1998; Markandya et al., 2006). In some cases, authors even come to conclusion that labor efficiency (effort level) as a production factor nowadays play a more significant role rather than energy and technologies due to increasing imperfect competition on international markets (Miketa, 2001; Miketa and Mulder, 2005; Huntington, 2010; Mulder and de Groot, 2012).

The fourth block of literature is devoted to the study of energy elasticity - sensitivity of changes in energy consumption to changes in GDP. Most of research is concentrated around analysis of national economic patterns and energy elasticity (Liu and Ang, 2007; Phoumin and Kimura, 2014). The most commonly used factor in determining and explaining energy elasticity is energy price and associated prices of oil and gas. A key conclusion of this research block on our issue is identification of a low price elasticity of energy consumption: In case of a rise in electricity prices, a reduction in demand is either minimal or absent (e.g. Bernstein and Griffin, 2006).

Regarding a hypothesis of our research - cross-country regional analysis of interlinkages between energy intensities of GDP and dependence of elasticity on the type of exported goods, just a few works close to our subject of research were found. However, all the above-mentioned papers encapsulate essential parts of argumentation and theoretical provisions necessary to conduct our research.

3. METHODOLOGY OF RESEARCH

For verification of the hypotheses, we use unrestricted vector autoregression (VAR) model to reflect a statistically significant relationship between energy intensity of economies at a regional scale. The sample includes 156 developed and developing countries, characterized by different levels of energy intensity of GDP. We do not set ourselves a task to conduct a comparative analysis of energy efficiency, but to identify the relationship between changes in it. The sampling period is 31 years from 1980 to 2011.

The main source of information is data from United States Energy Information Administration. In the absence of data for some periods, we turn to national statistical offices to ensure the completeness and comparability of time series.

To measure energy intensity of national economy, we use data on total primary energy consumption per dollar of GDP (BTU per 2005 U.S. dollars [purchasing power parity]).

The sample of regions includes Western Europe, Eastern Europe, Southeast Asia, Middle East, sub-Saharan Africa, and Latin America. To determine energy intensity on a regional we average data on energy intensity of countries in the region with the aim of obtaining aggregated regional trend.

Obtained data are used to construct unrestricted VAR model, which allows reflecting the presence or absence of correlation between energy intensity of regional economies. In process of constructing the model, variables of regional trends are tested for presence of unit root in time series with the augmented Dickey-Fuller test.

Next, using obtained time-series sample, we construct a VAR model and test it for presence of heteroscedasticity and serial correlation of residuals. For heteroscedasticity of residuals, White test is used. Null hypothesis states that the residuals are homoscedastic. Serial correlation is tested with the residual autocorrelation LM test. The null hypothesis of the test is that there is no serial correlation in the residuals up to the specified order. In addition, normality test is used.

The resulting model reflects presence or absence of linkages between regional trends.

The second part of the study is devoted to identification of presence/absence and degree of elasticity of energy intensity in sampled countries depending on the type of exported goods. To conduct the study we form two samples of countries. The first sample includes largest countries-exporters of oil; the second - exporters of engineering products. Data for time series is obtained from the same sources.

For analysis of relationships, we built two unrestricted VAR models, which were also tested for stationary (using second difference), serial correlation and heteroscedasticity.

To assess the degree of elasticity we use techniques of variance decomposition and impulse response function.

4. EMPIRICAL FINDINGS

Results of augmented Dickey-Fuller test for regional model show that time series used in the study are not stationary. Therefore the null hypothesis of non-stationary could not be rejected, but after second differencing of the variables, the T-bar test statistics are well less than the corresponding critical values at 5% signification level, which indicate that the null hypothesis of non-stationary should be rejected and the alternative hypothesis of stationary be accepted (Table 1).

After differencing the variables and confirming that time series used for VAR model are stationary we turn to identifying the optimal lag structure for our model (Table 2).

Value of each information criterion speaks in favor of choosing two lags as an optimal number for the model. After determining that time series used to construct the model are stationary, setting the optimal number of lags for the model, we can proceed to the construction of the model itself (Table 3).

Before we start analysis of the obtained results, it is necessary to ensure that serial correlation and heteroscedasticity are absent, as well as to ensure that the model meets the requirement of normality and stability. For this, we conduct tests of the residuals, the results of which are presented in Table 4. As can be seen from the data presented in this Table 4, the model we have built meets the requirement of normality, is characterized by stability and absence of serial correlation as well as heteroscedasticity.

Table 1: Results of unit root test

Variable	T statistics	P value
ADF test at level with intercept and trend		
Western Europe	−4.24	0.109
Eastern Europe	−3.69	0.367
Sub-Saharan Africa	−2.84	0.193
South Asia	−2.04	0.554
Latin America	−2.41	0.068
Middle East	−1.85	0.654
ADF test at 2nd difference with intercept and trend		
Western Europe	−5.24	0.009
Eastern Europe	−5.62	0.005
Sub-Saharan Africa	−6.44	0.000
South Asia	−7.18	0.000
Latin America	−6.42	0.000
Middle East	−6.19	0.001

ADF: Augmented Dickey–Fuller

The results of the VAR models built, reflecting presence or absence of statistically significant correlation between energy intensity of economies at the regional scale, allow drawing several important conclusions.

Firstly, according to classical international trade theory, the relationship between energy intensities of economies on a regional scale exists. Positive values of diagnostic tests of the regression model allow us to argue that false results caused by the effect of autocorrelation do not exist and the model cannot be thought of as spurious.

Secondly, regression model reflects existence of statistically significant dependencies in case of not all regions, which also speaks in favor of international trading channel on the one hand. On the other hand, according to Hecksher-Ohlin theorem, elasticity of production factors (including energy as a technological factor) should be present in all situations determined by the existence of trade relations. Elasticity values should tend to maximum. This theorem gets only partial confirmation according to constructed regression model. A possible explanation for lack of statistically significant correlation between energy intensity of economies on a regional scale may be due to imperfections of international market for goods and services on the one hand, and internal imperfections of institutional nature on the other.

Thirdly, we can assume that there are alternative endogenous variables that explain changes in a trend of energy intensity in the region. This model does not serve determining regression equation, which allows explaining structure of the trend in energy intensity completely, nor does it attempt to predict changes in this trend. Among the alternative variables one could point out intra-regional links between the region's economies, structure of GDP, level of human capital, development of science-intensive production techniques to reduce capital intensity of production and others.

Fourthly, existing regional correlation of energy intensities is partly explained by structure of export-import operations, as well as participation of other regions' economies in development of the energy sector and the economy. For example, changes in energy intensity in countries of the Middle East have a significant impact on the Eastern, Western Europe, South Asia and Latin America (value of T statistics correspond to the criterion of statistical significance at 5% confidence level). A possible explanation may

Table 2: Optimal lag selection criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	−1180.329	NA	2.55e+29	84.73780	85.02327	84.82507
1	−1137.445	64.32656	1.66e+29	84.24606	86.24437	84.85696
2	−1059.347	83.67649*	1.22e+28*	81.23906*	84.95020*	82.37359*

*Indicates lag order selected by the criterion. LR: Sequential modified LR test statistic (each test at 5% level). FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion

Table 3: Unrestricted VAR model of cross-country relationship of energy intensity on a regional scale

Variable	D(EASTERN_ EUROPE,2)	D(LATIN_ AMERICA,2)	D(MIDDLE_ EAST,2)	D(SOUTH_ ASIA,2)	D(SUB_ SAHARAN_ AFRICA,2)	D(WESTERN_ EUROPE,2)
D(EASTERN_EUROPE(-1),2)	−0.356905	0.206054	0.172839	−0.022654	−0.073350	0.189832
	(0.19326)	(0.09016)	(0.25313)	(0.05596)	(0.10097)	(0.09660)
	[−1.84672]	[2.28531]	[0.68280]	[−0.40480]	[−0.72643]	[2.01520]
D(EASTERN_EUROPE(-2),2)	−0.477671	−0.155735	−0.457269	−0.118191	−0.193488	−0.213438
	(0.18342)	(0.08557)	(0.24024)	(0.05311)	(0.09583)	(0.09168)
	[−2.60419]	[−1.81990]	[−1.90336]	[−2.22529]	[−2.01903]	[−2.32812]
D(LATIN_AMERICA(-1),2)	1.533237	0.023762	0.932412	0.207372	0.113479	0.672804
	(0.53028)	(0.24740)	(0.69455)	(0.15355)	(0.27705)	(0.26504)
	[2.89135]	[0.09605]	[1.34246]	[1.35051]	[0.40959]	[2.53845]
D(LATIN_AMERICA(-2),2)	1.078727	−0.494300	0.054513	0.119859	0.018385	−0.452173
	(0.41633)	(0.19423)	(0.54529)	(0.12055)	(0.21752)	(0.20809)
	[2.59106]	[−2.54492]	[0.09997]	[0.99425]	[0.08452]	[−2.17300]
D(MIDDLE_EAST(-1),2)	0.885411	0.263749	0.184649	0.116699	0.019929	0.253858
	(0.19424)	(0.09062)	(0.25441)	(0.05624)	(0.10148)	(0.09708)
	[4.55842]	[2.91056]	[0.72580]	[2.07489]	[0.19639]	[2.61486]
D(MIDDLE_EAST(-2),2)	−0.115693	−0.126110	−0.367053	−0.137098	−0.095033	0.143300
	(0.18394)	(0.08581)	(0.24092)	(0.05326)	(0.09610)	(0.09194)
	[−0.62897]	[−1.46958]	[−1.52356]	[−2.57405]	[−0.98888]	[1.55870]
D(SOUTH_ASIA(-1),2)	−1.903523	−1.419570	−0.798446	−1.056143	0.239828	−1.389004
	(0.70562)	(0.32919)	(0.92420)	(0.20432)	(0.36866)	(0.35268)
	[−2.69768]	[−4.31226]	[−0.86393]	[−5.16906]	[0.65054]	[−3.93844]
D(SOUTH_ASIA(-2),2)	−2.300689	−0.840694	−1.317366	−0.540969	0.247682	−0.595230
	(0.68983)	(0.32183)	(0.90352)	(0.19975)	(0.36041)	(0.34479)
	[−3.33515]	[−2.61223]	[−1.45803]	[−2.70824]	[0.68722]	[−1.72636]
D(SUB_SAHARIAN_AFRICA(-1),2)	−0.680842	−0.418264	−1.264230	−0.063494	−0.816125	−0.633580
	(0.46412)	(0.21653)	(0.60790)	(0.13439)	(0.24249)	(0.23198)
	[−1.46694]	[−1.93167]	[−2.07968]	[−0.47245]	[−3.36564]	[−2.73122]
D(SUB_SAHARIAN_AFRICA(-2),2)	1.985314	0.763081	1.913982	0.321079	0.034191	0.407403
	(0.43778)	(0.20424)	(0.57340)	(0.12677)	(0.22873)	(0.21881)
	[4.53491]	[3.73617]	[3.33796]	[2.53285]	[0.14949]	[1.86188]
D(WESTERN_EUROPE(-1),2)	−2.387753	−1.066336	−2.491786	0.073962	−0.002967	−1.610367
	(0.54537)	(0.25443)	(0.71431)	(0.15792)	(0.28494)	(0.27258)
	[−4.37824]	[−4.19103]	[−3.48838]	[0.46836]	[−0.01041]	[−5.90778]
D(WESTERN_EUROPE(2),2)	0.931983	0.974775	0.881618	0.699331	0.339859	0.600718
	(0.56637)	(0.26423)	(0.74181)	(0.16400)	(0.29591)	(0.28308)
	[1.64555]	[3.68913]	[1.18846]	[4.26425]	[1.14854]	[2.12208]
C	32.16083	−6.563987	−11.84519	−20.37299	−11.37931	5.568610
	(72.4475)	(33.7992)	(94.8899)	(20.9781)	(37.8512)	(36.2105)
	[0.44392]	[−0.19421]	[−0.12483]	[−0.97116]	[−0.30063]	[0.15378]

VAR: Vector autoregression

Table 4: Results of model's diagnostic testing

Type of test	Results		
	Lags	LM-stat	P value
VAR residual serial correlation LM test	1	43.45706	0.1835
	2	29.16504	0.7832
	3	41.83999	0.2321
Stability condition test	All roots lie within the circle VAR satisfies stability condition		
Heteroscedasticity test (white)	0.2931		
Normality test	0.7513		

VAR: Vector autoregression

be due to changes in energy intensity of Middle East economies due to changes in energy prices (oil), which is the main export commodity. The change in oil prices affects domestic consumption and the energy intensity of production in the importing countries - with increasing energy prices, growing domestic consumption (with a lag) leads to higher energy intensity in other countries. In addition, a significant dependence of regions' energy intensity is seen in case of Latin America, Western and Eastern Europe, South Asia and Sub-Saharan Africa. The explanation of the statistically significant interlinkages is, in our opinion, in export operations. Most of exports of Latin America (and Africa) is food products, where Latin America is opposed to Asia, Africa and Europe. A surprising feature of the results is lack of dependence of African region's energy intensity from other regions. This feature is explained on the one hand by territorial remoteness of the region, climatic characteristics, and the structure of economies that are not too energy-intensive, which follows general principles of the theory of international trade.

If our assumptions about the international trade channel of influence on energy intensity of economies at the regional scale are correct, then these assumptions could be confirmed by presence of energy elasticity's impact on degree of correlation between sampled countries. The sample of countries is formed in such a way, so that to test patterns of elasticity of energy intensity of economies depending on export for compliance with theoretical positions of classical Hecksher-Ohlin theorem.

For building models of sampled countries in order to verify trade channel and its impact on elasticity of energy intensity of countries in the sample, we have selected countries that are the main competitors from export structure point of view. In the first model, countries competing in the extraction and delivery of oil as a key energy source are represented. In the second model, countries competing in the supply of final consumption goods (mostly machinery industry) are included. The algorithm for constructing these models is identical to the previous one. It involves testing for presence of unit root, transformation of time series in the second difference to resolve the problem (Tables 5 and 6). Further, optimal values of the time lag for regression models are determined (Tables 7 and 8). The models themselves, reflecting correlation of energy intensity depending on actions of competing countries are presented in Tables 9 and 10. Diagnostic testing results of models for the presence of heteroscedasticity, serial correlation, test for normality and stability are presented in Tables 11 and 12. Assessment of the degree of energy elasticity of sampled economies, depending on the action of competitors on international markets for oil, goods and services presented using the tools of variance decomposition and impulse response (Graphs 1a-f, 2a-f, 3a-f, and 4a-f).

Table 5: Results of unit root test for oil-exporting countries

Variable	T statistics	P value
ADF test at level with intercept and trend		
Saudi Arabia	−2.85	0.188
Russian Federation	−2.11	0.520
United Arab Emirates	−2.31	0.418
Qatar	−1.81	0.670
Venezuela	−1.88	0.636
Norway	−3.48	0.058
ADF test at 2nd difference with intercept and trend		
Saudi Arabia	−6.43	0.000
Russian Federation	−7.91	0.000
United Arab Emirates	−7.16	0.000
Qatar	−9.41	0.000
Venezuela	−9.71	0.000
Norway	−7.31	0.000

ADF: Augmented Dickey–Fuller

Table 6: Results of unit root test for manufacturing export countries

Variable	T statistics	P value
ADF test at level with intercept and trend		
USA	−3.60	0.058
China	−0.76	0.956
Germany	−2.03	0.559
France	−2.50	0.325
Spain	−2.92	0.169
Netherlands	−3.22	0.097
ADF test at 2nd difference with intercept and trend		
USA	−5.28	0.001
China	−7.44	0.000
Germany	−9.37	0.000
France	−5.59	0.000
Spain	−8.86	0.000
Netherlands	−7.30	0.000

ADF: Augmented Dickey–Fuller

The results of the VAR models developed, confirm the correlation between energy intensity of sampled economies, as in case of countries that export mainly energy and in case of countries exporting industrial consumer goods. In case of countries-exporters of oil, statistically significant correlations exist due to territorial proximity, elimination of high transportation costs (as in the case of Russia and Norway), or of a common pool of consumers (as in the case of Russia and Venezuela, which is actively entering the market of Eastern Europe). At the same time, in the case of, for example, Russia there is no statistically significant dependence of its energy intensity from technology investments in countries of the Middle East (e.g. Saudi Arabia and UAE) due to geographical distance. The dependence of Norway from major players of oil market remains. An explanation for this peculiarity lies in the quasi-monopolistic position of Russia as supplier of oil in the region, naturally protected on one side by the effect of scale of oil supply (from Norway) and low transportation costs (from the Middle East). This, in turn, leads to decreased elasticity of energy intensity of the Russian economy to shocks on the international energy market and the deterioration of the oil industry. In case of geographical proximity of competitors on one side and a shared pool of consumers on the other (Saudi Arabia and UAE) sensitivity to shocks increases energy efficiency.

Analysis of energy elasticity of countries-oil exporters allows making several conclusions.

Firstly, in presence of limited competition and a quasi-monopolistic position on the market, sensitivity to shocks of international market tends to zero, or is of a minor value and reveal itself with a significant time lag (in case of Russia, for example, only at the 4th period; the same is true for Saudi Arabia - sensitivity to shocks in the long run is almost unchanged). Secondly, in case of geographical proximity, competitive pressure on the market forces players to react on actions of competitors, reducing production costs by investing in technologies of oil extraction and refinery (in case of Saudi Arabia and the UAE). Thirdly, in absence of competitive advantages and presence of tough competition (Russia and Norway), countries are forced to respond to energy intensity shocks with a lag period of 1-2 and in a very significant range. Analysis of responses by the countries in the sample confirm identified patterns.

Turning to analysis of the model, describing energy intensity elasticity of economies, exporting consumer goods, we can draw the following conclusions. First, a hypothesis about existence of relationship between energy intensity of sampled economies is confirmed due to presence of statistically significant correlations between the countries. E.g., there exist a strong relationship between energy intensities of Germany and China, the USA, Spain and Holland. In addition, a significant impact on energy intensity of the US economy has a Chinese trend. Explanation of these interlinkages may be found in strong competition between the US, China and Germany in various markets for goods and services. Specifics of China is that the trend of its energy intensity does not

Table 7: Optimal lag selection criteria for oil-exporting countries

Lag	LogL	LR	FPE	AIC	SC	HQ
0	−1420.501	NA	7.19e+36	101.8929	102.1784	101.9802
1	−1348.493	108.0121	5.86e+35	99.32092	101.8277*	99.93183
2	−1295.631	56.63755*	2.61e+35*	98.11651*	101.3192*	99.25105*

LR: Sequential modified LR test statistic (each test at 5% level). FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion

Table 8: Optimal lag selection criteria for manufacturing export countries

Lag	LogL	LR	FPE	AIC	SC	HQ
0	−1140.825	NA	1.52e+28	81.91606	82.89734	82.00333
1	−1100.800	60.03709	1.21e+28	81.62858	83.62688	82.23948
2	−1030.607	75.20702*	1.57e+27*	79.18620*	82.20153*	80.32074*

LR: Sequential modified LR test statistic (each test at 5% level). FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion

Table 9: Unrestricted VAR model of cross-country relationship of energy intensity for oil-exporting countries

Variable	D(SAUDI_ARABIA,2)	D(RUSSIA,2)	D(UNITED_ARAB_EMIRATES,2)	D(QATAR,2)	D(NORWAY,2)	D(VENEZUELA,2)
D(SAUDI_ARABIA(-1),2)	−0.826284	−0.170586	1.763550	−1.131395	−0.101294	−0.106971
	(0.26437)	(0.33107)	(0.28865)	(0.64946)	(0.12879)	(0.27362)
	[−3.12549]	[−0.51526]	[6.10975]	[−1.74205]	[−0.78648]	[−0.39095]
D(SAUDI_ARABIA(-2),2)	−0.075446	−0.304098	1.157584	−1.242975	−0.268155	−0.140668
	(0.30740)	(0.38496)	(0.33563)	(0.75517)	(0.14976)	(0.31815)
	[−0.24543]	[−0.78996]	[3.44901]	[−1.64594]	[−1.79060]	[−0.44214]
D(RUSSIA(-1),2)	0.050865	−0.312557	0.346238	0.117718	0.258528	−0.225594
	(0.20255)	(0.25365)	(0.22115)	(0.49760)	(0.09868)	(0.20964)
	[0.25112]	[−1.23222]	[1.56563]	[0.23657]	[2.61994]	[−1.07612]
D(RUSSIA(-2),2)	−0.172165	−1.052301	−0.614680	−0.357589	0.218454	−0.614791
	(0.23751)	(0.29743)	(0.25931)	(0.58347)	(0.11571)	(0.24581)
	[−0.72489]	[−3.53803]	[−2.37041]	[−0.61287]	[1.88801]	[−2.50106]
D(UNITED_ARAB_EMIRATES(-1),2)	−0.072248	0.161494	−0.509373	0.532044	0.008496	0.260652
	(0.17407)	(0.21799)	(0.19006)	(0.42764)	(0.08480)	(0.18016)
	[−0.41504]	[0.74083]	[−2.68009]	[1.24414]	[0.10018]	[1.44675]
D(UNITED_ARAB_EMIRATES(-2),2)	−0.273213	0.062751	−0.240731	0.124978	0.111642	−0.180425
	(0.11124)	(0.13930)	(0.12145)	(0.27327)	(0.05419)	(0.11513)
	[−2.45615]	[0.45047]	[−1.98213]	[0.45734]	[2.06015]	[−1.56718]
D(QATAR(-1),2)	−0.025555	−0.074618	−0.031972	−0.265284	−0.147855	−0.084272
	(0.09834)	(0.12315)	(0.10737)	(0.24158)	(0.04791)	(0.10178)
	[−0.25987]	[−0.60592]	[−0.29778]	[−1.09811]	[−3.08625]	[−0.82800]
D(QATAR(-2),2)	−0.014468	0.172968	−0.062339	0.289711	−0.035773	0.029333
	(0.10325)	(0.12929)	(0.11273)	(0.25364)	(0.05030)	(0.10686)
	[−0.14013]	[1.33778]	[−0.55301]	[1.14221]	[−0.71121]	[0.27451]
D(NORWAY(-1),2)	0.077425	1.147199	−1.346619	2.220011	−0.805764	1.156541
	(0.42838)	(0.53645)	(0.46771)	(1.05237)	(0.20869)	(0.44336)
	[0.18074]	[2.13849]	[−2.87917]	[2.10954]	[−3.86100]	[2.60858]
D(NORWAY(-2),2)	0.404326	0.839206	0.093490	0.330439	−0.336213	1.285753
	(0.50932)	(0.63782)	(0.55609)	(1.25123)	(0.24813)	(0.52714)
	[0.79385]	[1.31573]	[0.16812]	[0.26409]	[−1.35499]	[2.43911]
D(VENEZUELA(-1),2)	0.178154	0.437371	−1.817894	1.189869	−0.241868	−0.184729
	(0.30102)	(0.37697)	(0.32866)	(0.73951)	(0.14665)	(0.31155)
	[0.59183]	[1.16023]	[−5.53115]	[1.60900]	[−1.64929]	[−0.59293]
D(VENEZUELA(-2),2)	0.066003	1.183208	−0.282184	1.850497	−0.213837	0.643888
	(0.43158)	(0.54047)	(0.47121)	(1.06025)	(0.21026)	(0.44668)
	[0.15293]	[2.18923]	[−0.59885]	[1.74534]	[−1.01704]	[1.44150]
C	−51.81977	51.90932	−29.81161	−21.78037	−64.23873	10.92664
	(145.838)	(182.632)	(159.230)	(358.274)	(71.0485)	(150.940)
	[−0.35532]	[0.28423]	[−0.18722]	[−0.06079]	[−0.90415]	[0.07239]

VAR: Vector autoregression

depend on other countries in the sample. This result is explained by the presence of comparative competitive advantages in the use of labor as a factor of production, reducing possible effects on the Chinese economy.

A sensitivity analysis of countries in the sample to technological shocks that affect the energy intensity of GDP allows allocating the following features. First, low elasticity is inherent to countries that have a competitive advantage in the framework of

Table 10: Unrestricted VAR model of cross-country relationship of energy intensity for manufacturing export countries

Variable	D(CHINA,2)	D(FRANCE,2)	D(GERMANY,2)	D(SPAIN,2)	D(USA,2)	D(NETHERLANDS,2)
D(CHINA(-1),2)	−0.254451	0.110341	0.105300	0.090578	0.031424	0.268896
	(0.20897)	(0.06889)	(0.04934)	(0.04556)	(0.07204)	(0.08397)
	[−1.21766]	[1.60168]	[2.13432]	[1.98795]	[0.43622]	[3.20212]
D(CHINA(-2),2)	0.038419	0.106855	−0.025158	−0.009328	0.138679	0.112511
	(0.17854)	(0.05886)	(0.04215)	(0.03893)	(0.06155)	(0.07175)
	[0.21518]	[1.81538]	[−0.59680]	[−0.23960]	[2.25312]	[1.56813]
D(FRANCE(-1),2)	−1.761863	−0.383745	−0.772653	−0.042688	−0.176686	−0.190097
	(0.94605)	(0.31189)	(0.22336)	(0.20628)	(0.32613)	(0.38017)
	[−1.86234]	[−1.23040]	[−3.45921]	[−0.20694]	[−0.54176]	[−0.50003]
D(FRANCE(-2),2)	−1.570775	0.365377	0.361713	0.480917	−0.649575	0.983176
	(1.07526)	(0.35449)	(0.25387)	(0.23445)	(0.37068)	(0.43210)
	[−1.46083]	[1.03072]	[1.42480]	[2.05122]	[−1.75240]	[2.27534]
D(GERMANY(-1),2)	1.940901	−0.212446	−0.794480	0.543077	−0.234250	−0.010816
	(0.87372)	(0.28804)	(0.20628)	(0.19051)	(0.30120)	(0.35111)
	[2.22142]	[−0.73755]	[−3.85138]	[2.85068]	[−0.77772]	[−0.03081]
D(GERMANY(-2),2)	0.625334	−0.181126	−0.423527	0.205164	−0.056646	−0.708988
	(0.91867)	(0.30286)	(0.21690)	(0.20031)	(0.31670)	(0.36917)
	[0.68069]	[−0.59805]	[−1.95266]	[1.02423]	[−0.17887]	[−1.92048]
D(SPAIN(-1),2)	−0.678678	−0.014833	−0.364513	−0.386597	−0.335335	−0.579673
	(0.85141)	(0.28069)	(0.20102)	(0.18564)	(0.29351)	(0.34214)
	[−0.79712]	[−0.05284]	[−1.81334]	[−2.08246]	[−1.14250]	[−1.69423]
D(SPAIN(-2),2)	−1.872148	0.150102	0.461050	−0.462302	−0.359663	−0.078446
	(0.85400)	(0.28154)	(0.20163)	(0.18621)	(0.29440)	(0.34318)
	[−2.19221]	[0.53314]	[2.28662]	[−2.48271]	[−1.22167]	[−0.22858]
D(USA(-1),2)	0.323341	−0.281083	0.003633	0.218068	−0.546308	−0.554621
	(0.65679)	(0.21653)	(0.15507)	(0.14321)	(0.22642)	(0.26393)
	[0.49231]	[−1.29815]	[0.02343]	[1.52273]	[−2.41284]	[−2.10136]
D(USA(−2),2)	0.000359	0.057893	0.579845	−0.241848	−0.279448	−0.167368
	(0.67635)	(0.22297)	(0.15968)	(0.14747)	(0.23316)	(0.27179)
	[0.00053]	[0.25964]	[3.63118]	[−1.63996]	[−1.19853]	[−0.61579]
D(NETHERLANDS(-1),2)	0.344824	−0.003784	0.582067	−0.210818	0.048885	−0.168971
	(0.83110)	(0.27399)	(0.19622)	(0.18122)	(0.28651)	(0.33398)
	[0.41490]	[−0.01381]	[2.96637]	[−1.16336]	[0.17063]	[−0.50593]
D(NETHERLANDS(-2),2)	0.096747	−0.553355	−0.279843	−0.234655	0.472684	−0.513454
	(0.76235)	(0.25132)	(0.17999)	(0.16622)	(0.26281)	(0.30635)
	[0.12691]	[−2.20175]	[−1.55477]	[−1.41168]	[1.79861]	[−1.67602]
C	41.23731	1.678408	−5.789537	−16.42414	10.07712	−7.478694
	(100.579)	(33.1583)	(23.7467)	(21.9306)	(34.6729)	(40.4183)
	[0.41000]	[0.05062]	[−0.24380]	[−0.74892]	[0.29063]	[−0.18503]

VAR: Vector autoregression

Table 11: Results of model's diagnostic testing for oil-exporting countries

Type of test	Results		
	Lags	LM statistics	P value
VAR residual serial correlation LM tests	1	38.94815	0.3385
	2	33.12311	0.6062
	3	40.07817	0.2941
Stability condition	All roots lie within the circle. VAR satisfies stability condition		
Heteroscedasticity test (white)	0.3369		
Normality test	0.6993		

VAR: Vector autoregression

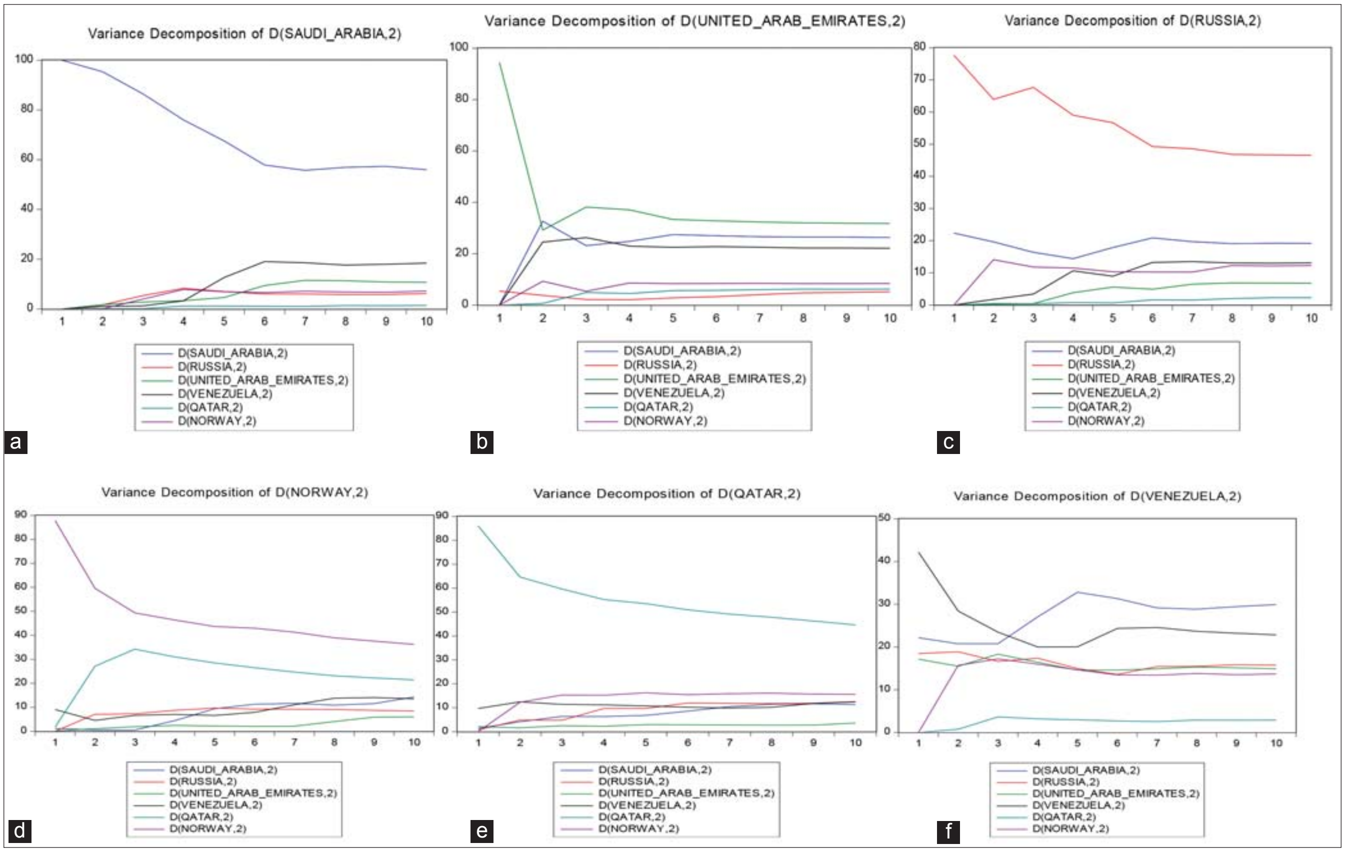
Table 12: Results of model's diagnostic testing for manufacturing export countries

Type of test	Results		
	Lags	LM statistics	P value
VAR residual serial correlation LM Tests	1	45.21587	0.1396
	2	38.49125	0.3574
	3	35.30519	0.5014
Stability condition	All roots lie within the circle. VAR satisfies stability condition		
Heteroscedasticity test (white)	0.2904		
Normality test	0.9307		

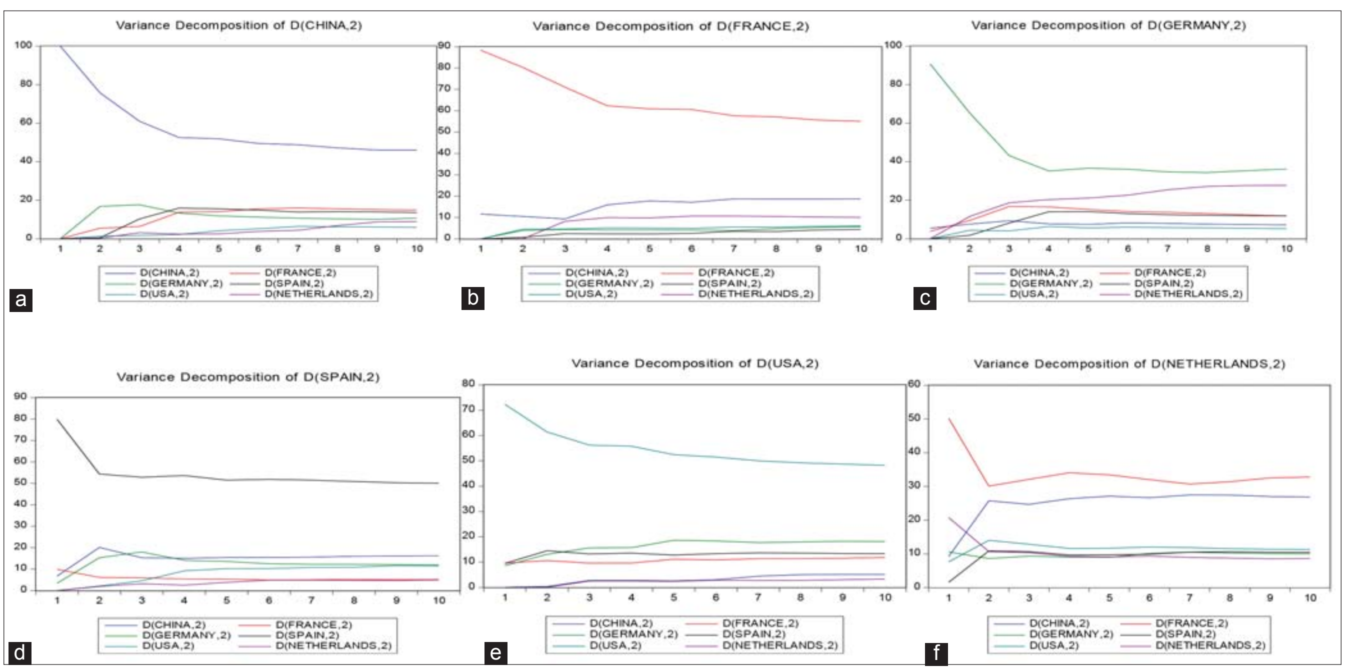
VAR: Vector autoregression

export-import transactions (such as China), or countries whose GDP does not depend significantly on exports (as in the case of the United States and France - export share less than 30%). Secondly, in cases of economies that are heavily reliant on exports (e.g., the Netherlands), sensitivity to changes in energy intensity (technological shocks) tends to be high, and reaction occurs within 1-2 periods. Third, on average, countries exporting consumer goods are more responsive to changes in international markets (expressed through technological shocks) than countries that export oil. Variance decomposition of the two samples shows that, on average, the response in the first sample (oil exporters) occurs after 4-6 periods (with the exception of countries with a low energy elasticity), while, reaction to technological shocks of countries exporting consumer goods occurs with a lag of 1-3 periods. This result confirms our assumption about a higher sensitivity

Graph 1: (a-f) Variance decomposition (energy elasticity of oil-exporting countries to competitors' shocks in energy intensity)



Graph 2: (a-f) Variance decomposition (energy elasticity of manufacturing export countries to competitors' shocks in energy intensity)

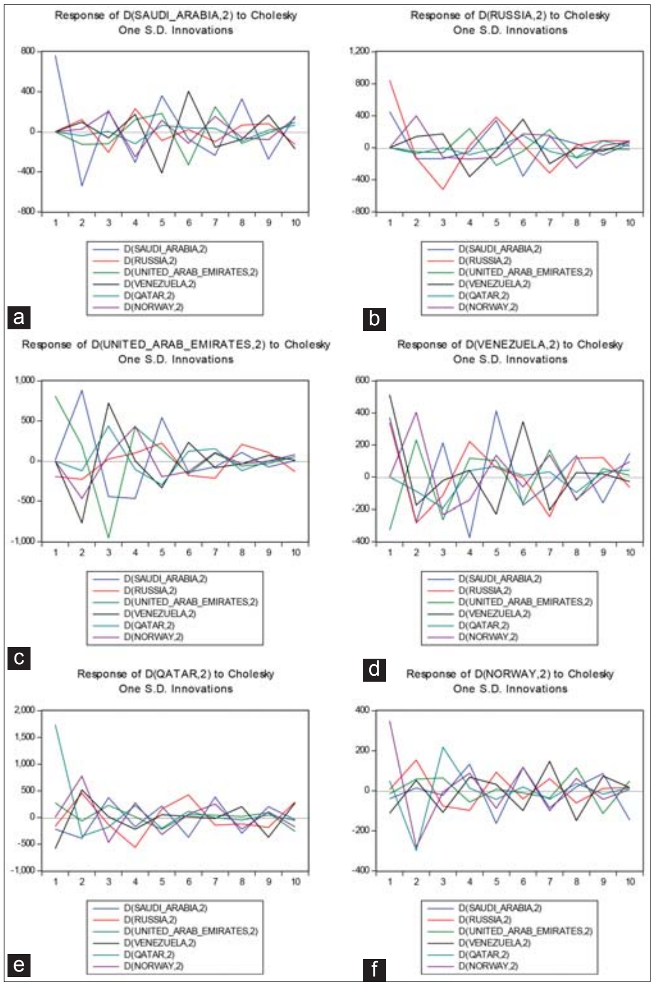


of economies that export consumer goods due to availability of substitute products on markets for consumer goods.

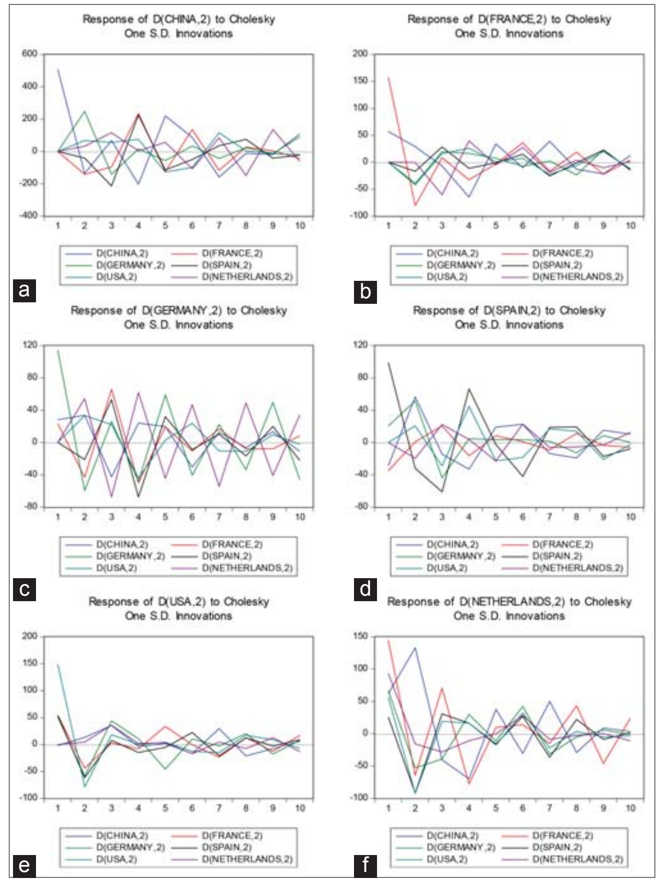
5. DISCUSSION AND CONCLUSION

This study is devoted to the issue of energy elasticity at the regional scale. We have posed a question, whether dependence of energy intensity of one regions from others does exist at global (regional) scale. The second task is closely related with an attempt of testing energy elasticity dependence on the channel of international trade. The hypothesis is that in conditions of competitive pressure, a technological shock (reducing energy intensity), ceteris paribus, should lead to a similar reduction in energy intensity in countries-competitors. Verification of the first hypothesis

Graph 3: (a-f) Impulse responses for oil exporting countries



Graph 4: (a-f) Impulse responses for manufacturing export countries



confirmed existence of dependencies between energy intensities of different economies at the regional level. Verification of the second hypothesis also confirmed existence of energy intensity's sensitivity to technological shocks in international markets for sampled countries. In this case, energy elasticity of countries-oil exporters is significantly lower and the reaction pace is slower in contrast to consumer goods' exporting countries.

Confirmation of these hypotheses provides space for further research. In particular, perspective areas of research are definition of intra-regional dependencies of energy intensity. Also development of indicators to assess energy intensity's elasticity is of great importance as well as development of strategies for managing elasticity of energy efficiency at the national level, especially in case of energy market anemia and energy stagnation in a number of countries.

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