www.ees.uni.opole.pl
ISSN paper version 1642-2597
ISSN electronic version 2081-8319
Economic and Environmental Studies
Vol. 14, No.3 (31/2014), 221-238, Sept. 2014

Estimating energy intensity interactions among world's regions, world GDP per capita and world energy price

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Abstract: This study attempts to predict energy intensities of world's regions, the world gross domestic product per capita and the world energy price via developing VAR (2) model. Whether causalities exist between groups of variables are tested by proceeding Granger Wald Test to structure a VAR model inductively. There exist significant causal and dynamical interactions among the variables, implying that regions' energy use affect each others' energy intensity (adversely efficiency), each of which is also found interacting with the world gross domestic product per capita and world unit energy price at different magnitudes. Additional energy uses of regions per US$1000 output mostly lead to per capita world gross domestic product and energy price up except for Sub-Saharan Africa. Increases in the last year's world gross domestic product per capita mostly cause inefficiency, however, increases in the last two years' world gross domestic product per capita mostly improve efficiency of world regions. Except for South Asia, an increase in world energy price does not improve energy use efficiency of the world's regions for the period of 1971-2009.

Keywords: World's regions, energy intensity, VAR model, interaction

1. Introduction

This study aims to predict energy intensity interactions among world's regions, world GDP per capita and world energy price and so their effects on the efficiency of each region's energy use, GDP and world energy price by developing a VAR (Vector Auto Regressive) model inductively. The study also aims to shows how world GDP, energy prices and energy uses of world's regions drive each other under the argument that energy consumption has spillover effects over geographically separated countries.

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World's regions can be classified as having similar economic and energy use structure in view of economic development and geography. There are seven blocks, which are North America, European Union, South Asia, East Asia, Latin America, Sub-Saharan African all income countries and the rest of those regions. Energy has been used increasingly by the countries for various purposes for the years while its supply has been obtained from various sources in the world. However, the main contributor to increase energy consumption is the increase in economic activity in countries.

Energy efficiency encompasses all changes that result in a reduction in the energy used for a given level of output (Petchey, 2010). To produce US$1000 output South Asia's energy use increased by 3.94 %, East Asia's by 3.94%, Latin America's by 3.05%, Sub-Saharan African's by 2.9%, North America's by 0.89%, European Union's by 0.67%, and the rest of the regions by 1.59% annually on the average as calculated by the author for the sampling period of 1971- 2009 (International Energy Agency, 2012). According to these long run growth rates the least efficient world's region is the Asian blocks, on the other hand, the most efficient region is the European Union in using energy to produce US$1000 output for the period.

However, there has been efforts to increase efficiency of energy, sourcing from energy conservation and improvements in energy intensive capital stock and production processes since 1974 (Gardner and Joutz, 1996) even though world energy prices have been increasing for years while world demand expands for goods and services. British Petrol oil prices per barrel increased by 9.1% yearly (BP Statistical Review of World Energy, 2012), and the world GDP per capita grew by 6.3% annually (World Bank, 2012), calculations based the sampling period of 1971-2009. Both variables have gone up together for the years. There is no growth without energy and there is no energy without fee.

Consumers are expected to use energy more efficiently at higher energy prices. Firms may purchase new, more energy-efficient capital to replace elders as energy prices increase. The adoption of more energy-efficient technologies may improve efficiency of energy use. However, according to Herring and Roy (2007) promoting technical innovations reduces efficiency in energy consumption due to (i) its direct effect that exists as lowering the implicit price of energy towards leading to greater consumption and (ii) indirect effects of reducing energy costs through efficiency in that consumers may buy more products and choose larger, more powerful and more feature laden models.

The price increases promote technological innovations and lead to increases in energy efficiency, and energy taxes by governments on the promotion of energy efficiency and energy conservation improves energy efficiency in OECD countries, and it is found that a causality running from prices to technical efficiency and from prices and technical efficiency to oil consumption in most OECD members and a unidirectional causality running from prices to oil intensity in 12 countries (Bessec and Méritet, 2007) which shall be accepted for the improvement energy efficiencies of blocks by law of demand even the energy intensity is influenced by the structures of economies differently (European Commission, 2012). There exist ambiguous results in regarding to the direction of causality between energy use and growth depending on the literature review for different countries (Keppler, 2007).

Whether world economic growth can be explained by changes in the oil price is proved by a unidirectional relation from oil price to gross domestic product for the G-7 group (Ghalayini, 2011) but this interaction is not proved for the most countries and for the world unlike the finding is that there exists a relationship between oil price and economic growth in a result of running both linear and non-linear multivariate VAR models for oil exporting and importing OECD countries (Jiménez-Rodríguez and Sánchez, 2004). Shahbaz and Feridun (2012) theoretically state that economic development relies largely on manufacturing sector which requires more energy and efficient production for faster economic growth. This statement refers to the existence of bi-directional causality between energy consumption and economic output. However, faster economic growth may lead inefficient use of energy in less developed blocks whose countries have not completed industrialization yet.

Granger causality running from energy consumption to GDP in the long-run, but not vice versa, meaning high energy consumption tends to come with high GDP, but not the reverse for sixteen Asian economies from 1971 to 2002 (Lee and Chang, 2011). The authors also provide a comparative survey of the empirical results from various causality tests done by various authors for Asian countries individually. Their survey mostly refers the existence of either bi-directional or unidirectional causality between energy consumption and income for Asian countries.

There exists inverse relationship between energy demand regression and price of petroleum and industrial development, but positive relationship between energy demand and

GDP, population growth rate, and agricultural expansion for twenty Sub-Saharan African countries (Kebede et al., 2010). Since the authors found Sub-Saharan African countries' economic development dependent on energy consumption they suggest these countries diversify their energy sources and introduce energy-efficient devices and equipments at all levels of the economy to improve GDP growth rate and GDP per capita. The results show that roughly seven-tenths of the countries exhibit bi-directional Granger causality, two-tenths exhibit no Granger causality, and one-tenths exhibit unidirectional Granger causality between energy consumption and GDP in a study using a large VAR panel model of 79 countries for the period of 1980–2007 (Akkemik and Göksal, 2012).

Improving energy efficiency by investments in modern energy and the drives towards making the modern energy sector more efficient can promote economic growth (Wolde-Rufael, 2005). For this reason, knowledge of the direction of causality between energy consumption and economic growth and the interactions among energy uses of world’s regions are important for policy makers to manage energy regionally or globally and to coordinate the use of it.

2. Methodology and Modeling

As a requirement of VAR model whether group-causality exist between variables needs to be determined before presenting the models. For this purpose, Granger causality test is run for both pair and group variables, then a VAR model is established in an inductive approach.

2.1. Variables

The variables measuring energy intensity per economic output as kt. of oil equivalent per US$1000 GDPPP (Purchasing Parity Power Gross Domestic Product 1985=100) are defined for the regions as follows:

LNA_t= the natural logarithmic values of current year energy use of North America.

LEU_t= the natural logarithmic values of current year energy use of European Union.

LSA_t= the natural logarithmic values of current year energy use of South Asia.

$LEASP_t$= the natural logarithmic values of current year energy use of East Asia.

LLA_t= the natural logarithmic values of current year energy use of Latin America.

$LSSAF_t$= the natural logarithmic values of current year energy use of Sub-Saharan African all income countries.

$LRES_t$ = the natural logarithmic values of current year energy use of the rest of those regions.

The current year energy use data were obtained from IEA (International Energy Agency, 2012) database. Based on the International Energy Agency data definition "energy use refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport" (Business Directory, 2012).

LWGDPPC= the natural logarithmic values of current US$GDP per capita of the world, which is obtained from World Bank (2012) database.

LPBP = the natural logarithmic values of kt of oil equivalent current year energy basket prices, original values of which are calculated by "BP barrel oil prices x 7.4 barrels of oil" formula, which are obtained from BP Statistical Review of World Energy (2012).

2.2. Group Causalities within VAR Systems

By using the SAS (Statistical Analysis Software, 2005) CAUSAL statement fitting the VAR(p) model by dividing the variables into two groups; Group1 as dependent variables and Group2 as independent variables. The null hypothesis of the Granger causality test is that Group1 is influenced only by itself, and not by Group2 (SAS Enstitute, 2012)[1]; meaning that, in each case, *rejection* of the null hypothesis implies the existence of Granger causality from Group2 to Group1 variable(s).

Prior to testing non-causality, the order of integration must be determined. For this purpose Augmented Dickey-Fuller test (Dickey and Fuller, 1979) is carried out on the time series in levels and differenced forms for each variable. The first order of integration I (1) appears at different significance levels (1%, 5%, 10%) as seen in the third column in Table 1, however, it is I (2) at common 1% significance level for the variables as seen in the fourth column in Table 1.

[1] In the case of *X* and *Y* time-series variables, definition of Granger Causality (1969); "*X* is said to Granger-cause *Y* if *Y* can be better predicted using the histories of both *X* and *Y* than it can by using the history of *Y* alone". One can test for the absence of Granger causality by estimating the following VAR model:

$Y_t = \alpha_0 + \alpha_1 Y_{t-1} + ... + \alpha_p Y_{t-p} + \beta_1 X_{t-1} + ... + \beta_p X_{t-p} + u_t$

$X_t = \gamma_0 + \gamma_1 X_{t-1} + ... + \gamma_p X_{t-p} + \delta_1 Y_{t-1} + ... + \delta_p Y_{t-p} + v_t$

Then, testing H_0: $\beta_1 = \beta_2 = ... = \beta_p = 0$, against H_A: 'Not H_0', is a test that Group2 variable(s) *X does not* Granger-cause group1 variable(s) *Y*. In the same way; testing H_0: $\delta_1 = \delta_2 = ... = \delta_p = 0$, against H_A: 'Not H_0', is a test that group2 variable(s) *Y does not* Granger-cause Group1 variable(s) *X*.

Since series are integrated at the same significance and integration level at I(2) Granger causality test requirement is satisfied as seen in the last column in Table 1, referring third order differences Dickey-Fuller test equation (Dickey and Fuller, 1979) in the fourth column to test whether series integrated at the second order level.

Table 1: ADF Unit Root Test Results

	Calculated Tau Statistics for Dickey Fuller Test Equation (Dependent Variable)			Integration Level at Significance Levels		
Variables	First Order Differences N=38	Second Order Differences N=37	Third Order Differences N=36	Degree of Integration at a significance level	Degree of Integration at Common Significance Level (10%)	Degree of Integration at Common Significance Level (1%)
LEU	-3.06** WCNT	-4.37*** NCNT	-8.34*** NCNT	I(0)**	I(1)	I(2)
LNA	-1.73 WCNT	-3.84*** NCNT	-6.51*** NCNT	I(1)***	I(1)	I(2)
LSA	18.75 NCNT	-5.37*** WCNT	-10.34*** NCNT	I(1)***	I(1)	I(2)
LSSAF	-1.42 WCNT	-5.96*** WCNT	-17.30*** NCNT	I(1)***	I(1)	I(2)
LEASP	7.31 NCNT	-4.50*** WCWT	-5.15*** WCNT	I(1)***	I(1)	I(2)
LRES	-1.82 WCNT	-2.71*** NCNT	-7.48*** NCNT	I(1)***	I(1)	I(2)
LLA	-5.27*** WCWT	-4.62*** WCWT	-10.57*** NCNT	I(0)***	I(1)	I(2)
LWLD	4.51 NCNT	-3.96*** WCNT	-6.42*** NCNT	I(1)***	I(1)	I(2)
LWGDPPC	-2.41 WCNT	-2.82* WCNT	-5.55*** NCNT	I(1)*	I(1)	I(2)
LPBP	-2.68* WCNT	-5.27*** NCNT	-9.45*** NCNT	I(0)*	I(1)	I(2)

Note: "***" refers to significance level at 1%, "**" refers to significance level at 5%, "*" refers to significance level at 10% based on MacKinnon critical values. NCNT: No constant no trend, WCNT: With constant no trend, WCWT: With constant with trend. First order differences: ΔY_t, Second order differences: $\Delta^2 Y_t$, third order differences: $\Delta^3 Y_t$.

Source: Source: Author's own elaboration based on data sources mentioned in section 2.1.

Table 2 shows directions of Granger causalities for pair of variables through fitting various VAR (p) models based on optimal lags chosen according to minimized AIC. Pairwise causality test results are shown at 10% common significance level in the last column in Table 2. The statement; for example; "LEU→LNA" means LEU as Group2 variable causes LNA as Group1 variable, where the symbol "→" points out direction of unidirectional causality in the last column in Table 2. The causalities run from LEU to LNA, from LSA to LNA, from LNA to

LWGDPPC, from LLA to LEU, from LSSAF to LEU, from LEASP to LWGDPPC, from EASP to PBP, from LSSAF to LLA, from LSSAF to LWGDPPC, from WGDPPC to RES, from LPBP to LRES, and from LWGDPPC to LPBP as seen in the last column in Table 2 *ceteris paribus.*

And the symbol "↔" points out two sided causalities existing between the variables, which are shown as: "LLA ↔ LNA", "LSSAF ↔ LNA", "LNA↔LBPP", "LWGDPPC↔LEU", LLA↔LSA", "LWGDPPC↔LSA" and "LLA↔LEASP" in the last column in Table 2, *ceteris paribus.* A box without either "→" or "↔" symbols indicates non causality at 10% significance level, *ceteris paribus.* However, there exists a causality at weaker significance levels than 10%. For example at 31% significance level LEASP is found causal for LNA.

Table 2: Bidirectional Causalities at Optimal Lags within VAR (p) Models

Direction of Granger Causality Test	Opt lag VAR(p)	Degree of freedom	Obs no	MinimumAIC	Wald χ^2	$Pr > \chi 2$	%1	%5	%10	**VAR R^2**	Direction of Granger Causality at %10
LEU → LNA	2	2	39	-15.347	0.57	.7503	no	no	no	LNA=.9605	
LNA → LEU	2	2	39	-15.347	7.0	.0302	no	yes	yes	LEU=.9182	LNA → LEU
LSA → LNA	2	2	39	-16.1729	6.99	.0303	no	yes	yes	LNA=.967	LSA → LNA
LNA → LSA	2	2	39	-16.1729	4.43	.1093	no	no	no	LSA=.9992	
LLA → LNA	2	2	39	-15.6374	5.29	. 0710	no	no	yes	LNA=.9655	LLA ↔ LNA
LNA → LLA	2	2	39	-15.6374	11.49	.0032	yes	yes	yes	LLA=.9971	
LEASP → LNA	2	2	39	-14.9506	2.41	.3003	no	no	no	LNA=.9626	
LNA → LEASP	2	2	39	-14.9506	1.06	.5881	no	no	no	LEASP=.9972	
LSSAF → LNA	3	3	39	-15.8392	12.65	.0055	yes	yes	yes	LNA= .9737	LSSAF ↔ LNA
LNA → LSSAF	3	3	39	-15.8392	6.52	.0889	no	no	yes	LSSAF=.9978	
LRES → LNA	3	3	39	-14.792	2.96	0.3979	no	no	no	LNA=.9658	
LNA → LRES	3	3	39	-14.792	3.77	0.2870	no	no	no	LRES=.9709	
LWGDPPC → LNA	2	2	39	-13.5546	1.88	.3897	no	no	no	LNA=.9621	LNA → LWGDPPC
LNA →	2	2	39	-13.5546	6.58	0.0373	no	yes	yes	LWGDPPC	

LWGDPPC										=.9945	
LBPP → LNA	4	4	39	-10.4008	27.46	.0001	yes	yes	yes	LNA=.9819	
LNA → LBPP	4	4	39	-10.4008	9.59	0.0479	no	yes	yes	LPBP=.8263	LNA ↔ LBPP
LSA → LEU	2	2	39	-16.1034	3.04	0.2191	no	no	no	LEU= .9089	
LEU → LSA	2	2	39	-16.1034	0.79	0.6723	no	no	no	LSA =.9991	
LEASP → LEU	3	3	39	-14.98	6.09	.1071	no	no	no	LEU=.9142	
LEU → LEASP	3	3	39	-14.98	2.60	.4568	no	no	no	LEASP=.9972	
LLA → LEU	4	4	39	-15.669	10.00	0.0404	no	yes	yes	LEU= .9210	
LEU → LLA	4	4	39	-15.669	6.92	0.1401	no	no	no	LLA =.9968	LLA→ LEU
LSSAF → LEU	2	2	39	-15.746	4.93	0.0849	no	no	yes	LEU=.9136	LSSAF→ LEU
LEU → LSSAF	2	2	39	-15.746	0.53	0.7654	no	no	no	LSSAF =.9975	
LRES → LEU	2	2	39	-15.5248	0.74	0.6899	no	no	no	LEU=.9025	
LEU → LRES	2	2	39	-15.5248	4.38	0.112	no	no	no	LRES=.9741	
LWGDPPC → LEU	3	3	39	-13.9114	12.97	0.0047	yes	yes	yes	LEU=.9283	
LEU → LWGDPPC	3	3	39	-13.9114	7.78	0.0507	no	yes	yes	LWGDPPC =.9948	LWGDPPC ↔ LEU
LPBP → LEU	3	3	39	-9.98019	7.00	0.2206	no	no	no	LEU=.9229	
LEU → LPBP	3	3	39	-9.98019	3.75	0.5865	no	no	no	LPBP=.7862	
LEASP → LSA	3	3	39	-16.0914	3.30	0.3475	no	no	no	LSA=.9991	
LSA → LEASP	3	3	39	-16.0914	6.12	0.1058	no	no	no	LEASP=.9975	
LLA → LSA	1	1	39	-16.7446	3.35	0.0674	no	no	yes	LSA=.9992	
LSA → LLA	1	1	39	-16.7446	4.22	0.0401	no	yes	yes	LLA=.9969	LLA ↔ LSA
LRES → LSA	3	3	39	-15.7317	6.12	0.1060	no	no	no	LSA =.9992	
LSA → LRES	3	3	39	-15.7317	2.07	0.5574	no	no	no	LRES =.9693	
LWGDPPC → LSA	2	2	39	-14.7703	5.81	0.0549	no	no	yes	LSA =.9992	
LSA → LWGDPPC	2	2	39	-14.7703	5.33	0.0697	no	no	yes	LWGDPPC =.99	LWGDPPC ↔ LSA

LPBP → LSA	1	1	39	-11.0119	2.25	0.1337	no	no	no	LSA =.9992	
LSA → LPBP	1	1	39	-11.0119	0.74	0.3899	no	no	no	LPBP=.8322	
LLA → LEASP	1	1	39	-15.8065	3.20	0.0736	no	yes	yes	LEASP=.9971	
LEASP → LLA	1	1	39	-15.8065	14.32	0.0002	yes	yes	yes	LLA=.9975	LLA ↔ LEASP
LSSAF → LEASP	2	2	39	-15.8011	2.42	0.2983	no	no	no	LEASP=.9973	
LEASP → LSSAF	2	2	39	-15.8011	1.25	0.5283	no	no	no	LSSAF =.9976	
LRES → LEASP	2	2	39	-14.7965	0.1	0.9527	no	no	no	LEASP=.9971	
LEASP → LRES	2	2	39	-14.7965	0.86	0.6506	no	no	no	LRES =.9713	
LWGDPPC → LEASP	2	2	39	-13.9012	1.04	0.5952	no	no	no	LEASP=.9972	
LEASP → LWGDPPC	2	2	39	-13.9012	5.53	0.0630	no	no	yes	LWGDPPC =.9944	LEASP → LWGDPPC
PBP → EASP	1	1	39	30.09421	0.58	0.4451	no	no	no	EASP= 0.9965	
EASP → PBP	1	1	39	30.09421	3.48	0.0621	no	no	yes	PBP= 0.8016	EASP → PBP
LSSAF → LLA	1	1	39	-16.4067	2.27	0.1318	no	no	no	LLA =.9967	
LLA → LSSAF	1	1	39	-16.4067	3.98	0.0461	no	yes	yes	LSSAF =.9979	LSSAF → LLA
LRES → LLA	2	2	39	-15.1684	2.84	0.2414	no	no	no	LLA =.9964	
LLA → LRES	2	2	39	-15.1684	2.65	0.2663	no	no	no	LRES =.9728	
LPBP → LLA	1	1	39	-10.4197	1.51	0.2198	no	no	no	LLA =.9966	
LLA → LPBP	1	1	39	-10.4197	0.84	0.3589	no	no	no	LPBP =.8326	
LWGDPPC → LA	1	1	39	12.33671	0.03	0.8636	no	no	no	LWGDPPC = 0.9932	
LA → LWGDPPC	1	1	39	12.33671	2.64	0.1045	no	no	no	LA= 0.9554	

LRES → LSSAF	2	2	39	-15.6584	0.44	0.8015	no	no	no	LSSAF =.9975	
LSSAF → LRES	2	2	39	-15.6584	3.96	0.1383	no	no	no	LRES =.9738	
LWGDPPC →LSSAF	2	2	39	-14.5582	1.51	0.4695	no	no	no	LSSAF =.9976	
LSSAF → WGDPPC	2	2	39	-14.5582	12.75	0.0017	yes	yes	yes	LWGDPPC =.9953	LSSAF→LWGDPPC
LPBP → LSSAF	1	1	39	-10.6882	1.36	0.2436	no	no	no	LSSAF=.9977	
LSSAF → LPBP	1	1	39	-10.6882	0.59	0.4405	no	no	no	LPBP=.8315	
WGDPPC → RES	3	3	39	32.26949	10.72	0.0134	no	yes	yes	RES= 0.9747	WGDPPC → RES
RES → WGDPPC	3	3	39	32.26949	1.9	0.5942	no	no	no	WGDPPC= 0.9881	
LPBP → LRES	3	3	39	-9.59811	7.17	0.0665	no	no	yes	LRES =.9736	LPBP → LRES
LRES → LPBP	3	3	39	-9.59811	5.67	0.1288	no	no	no	LPBP =.7580	
LPBP →LWGDPPC	2	2	39	-8.48303	1.68	0.4324	no	no	no	LWGDPPC =.9937	
LWGDPPC → LPBP	2	2	39	-8.48303	10.09	0.0064	yes	yes	yes	LPBP =.8350	LWGDPPC→ LPBP

Source: Source: Author's own elaboration based on data sources mentioned in section 2.1.

However, the bi-directional causalities are acceptable for VAR models established only for pair variables, they are not satisfactory to build a VAR model which includes more than two variables. In other words, a VAR model with more than two variables to be set up appropriately requires the existence of bidirectional group causalities between each dependent (Group1) and the rest of variables called Group2 variables. For example, Table 3a shows that LEASP and LSSAF are influenced by themselves but they are not influenced by Group2 which consists of {LNA, LEU, LSA, LLA, LSSAF, LRES, LWGDPPC, LPBP} variables for variable LEASP (Group1), similarly; {LNA LEU, LSA, LEASP, LLA, LRES, LWGDPPC, LPBP} for variable LSSAF (Group1) at the 0.10 significance level. Likewise, the result of Table 3a can be interpreted.

Table 3b shows that each part of Group1 variables (for example; LNA, LEU, LSA, LLA, LSSAF, LRES, LWGDPPC, LPBP) on the top is influenced significantly by each of Group2 variable (each one of dependent variables separately; corresponding to the example, LEASP). Likewise, the result of Table 3b can be interpreted. Table 3b indicates that each individual variable is found Granger Cause for the rest which overcomes insufficiency of causality of Group2 variables for the dependent LEASP and LSSAF variables in part one of Table 3 at 0.01 significance level to be able to state VAR (2) model more appropriately. The results of VAR (2) model are presented in Table 4.

Table 3: Group Causalities for Model Structuring

3a. Causality Test from the group of the rest of a dependent to the dependent variable										
		Group 1 Variables								
		LNA	LEU	LSA	LEASP	LLA	LSSAF	LRES	LWGDPPC	LPBP
Causal Group 2 Variables √	LNA		√	√	√	√	√	√	√	√
	LEU	√		√	√	√	√	√	√	√
	LSA	√	√		√	√	√	√	√	√
	LEASP	√	√	√		√	√	√	√	√
	LLA	√	√	√	√		√	√	√	√
	LSSAF	√	√	√	√	√		√	√	√
	LRES	√	√	√	√	√	√		√	√
	LWGDPPC	√	√	√	√	√	√	√		√
	LPBP	√	√	√	√	√	√	√	√	
Degree of freedom		16	16	16	16	16	16	16	16	16
χ^2 Pr > $\chi2$		34.94 0.0041	46.49 .0001	32.04 0.0099	12.32 0.7216	113.34 .0001	17.97 0.3258	71.04 .0001	32.42 0.0088	23.81 0.0937
3b. Causality Test from the dependent variable to the group of the rest of a dependent variable										
		Group 1 Variables								
		LEU LSA LEASP LLA LSSAF LRES LWGDPPC LPBP	LNA LSA LEASP LLA LSSAF LRES LWGDPPC LPBP	LNA LEU LEASP LLA LSSAF LRES LWGDPPC LPBP	LNA LEU LSA LLA LSSAF LRES LWGDPPC LPBP	LNA LEU LSA LEASP LSSAF LRES LWGDPPC LPBP	LNA LEU LSA LEASP LLA LRES LWGDPPC LPBP	LNA LEU LSA LEASP LLA LSSAF LWGDPPC LPBP	LNA LEU LSA LEASP LLA LSSAF LRES LPBP	LNA LEU LSA LEASP LLA LSSAF LRES LWGDPPC
Causal Group 2 Variables		LNA	LEU	LSA	LEASP	LLA	LSSAF	LRES	LWGDPPC	LPBP
Degree of freedom		16	16	16	16	16	16	16	16	16
χ^2 Pr > $\chi2$		36.85 0.0022	75.74 .0001	47.96 .0001	98.28 .0001	59.82 .0001	74.62 .0001	82.30 .0001	47.09 .0001	38.14 0.0014

Source: Source: Author's own elaboration based on data sources mentioned in section 2.1.

2.3. Model

After satisfying with the existences of bi-directional groupal causalities to establish an appropriate VAR model in Table 3 one can construct a VAR model with satisfactions of the other estimation criteria. A VAR (2) model is found more appropriate than VAR (1) model in view of model acceptance statistical critea. For estimation, the VAR (2) model can be presented as follows:

$$\begin{pmatrix} LNA_t \\ LEU_t \\ LSA_t \\ LEASP_t \\ LLA_t \\ LSSAF_t \\ LRES_t \\ LWGDPPC_t \\ LPBP_t \end{pmatrix} = \begin{pmatrix} C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \\ C_7 \\ C_8 \\ C_9 \end{pmatrix} + \begin{pmatrix} \tau_{11} & \tau_{12} & \tau_{13} & \tau_{14} & \tau_{15} & \tau_{16} & \tau_{17} & \tau_{18} & \tau_{19} \\ \tau_{21} & \tau_{22} & \tau_{23} & \tau_{24} & \tau_{25} & \tau_{26} & \tau_{27} & \tau_{28} & \tau_{29} \\ \tau_{31} & \tau_{32} & \tau_{33} & \tau_{34} & \tau_{35} & \tau_{36} & \tau_{37} & \tau_{38} & \tau_{39} \\ \tau_{41} & \tau_{42} & \tau_{43} & \tau_{44} & \tau_{45} & \tau_{46} & \tau_{47} & \tau_{48} & \tau_{49} \\ \tau_{51} & \tau_{52} & \tau_{53} & \tau_{54} & \tau_{55} & \tau_{56} & \tau_{57} & \tau_{58} & \tau_{59} \\ \tau_{61} & \tau_{62} & \tau_{63} & \tau_{64} & \tau_{65} & \tau_{66} & \tau_{67} & \tau_{68} & \tau_{69} \\ \tau_{71} & \tau_{72} & \tau_{73} & \tau_{74} & \tau_{75} & \tau_{76} & \tau_{77} & \tau_{78} & \tau_{79} \\ \tau_{81} & \tau_{82} & \tau_{83} & \tau_{84} & \tau_{85} & \tau_{86} & \tau_{87} & \tau_{88} & \tau_{89} \\ \tau_{91} & \tau_{92} & \tau_{93} & \tau_{94} & \tau_{95} & \tau_{96} & \tau_{97} & \tau_{98} & \tau_{99} \end{pmatrix} \begin{pmatrix} LNA_{t-1} \\ LEU_{t-1} \\ LSA_{t-1} \\ LEASP_{t-1} \\ LLA_{t-1} \\ LSSAF_{t-1} \\ LRES_{t-1} \\ LWGDPPC_{t-1} \\ LPBP_{t-1} \end{pmatrix}$$

$$+ \begin{pmatrix} \lambda_{11} & \lambda_{12} & \lambda_{13} & \lambda_{14} & \lambda_{15} & \lambda_{16} & \lambda_{17} & \lambda_{18} & \lambda_{19} \\ \lambda_{21} & \lambda_{22} & \lambda_{23} & \lambda_{24} & \lambda_{25} & \lambda_{26} & \lambda_{27} & \lambda_{28} & \lambda_{29} \\ \lambda_{31} & \lambda_{32} & \lambda_{33} & \lambda_{34} & \lambda_{35} & \lambda_{36} & \lambda_{37} & \lambda_{38} & \lambda_{39} \\ \lambda_{41} & \lambda_{42} & \lambda_{43} & \lambda_{44} & \lambda_{45} & \lambda_{46} & \lambda_{47} & \lambda_{48} & \lambda_{49} \\ \lambda_{51} & \lambda_{52} & \lambda_{53} & \lambda_{54} & \lambda_{55} & \lambda_{56} & \lambda_{57} & \lambda_{58} & \lambda_{59} \\ \lambda_{61} & \lambda_{62} & \lambda_{63} & \lambda_{64} & \lambda_{65} & \lambda_{66} & \lambda_{67} & \lambda_{68} & \lambda_{69} \\ \lambda_{71} & \lambda_{72} & \lambda_{73} & \lambda_{74} & \lambda_{75} & \lambda_{76} & \lambda_{77} & \lambda_{78} & \lambda_{79} \\ \lambda_{81} & \lambda_{82} & \lambda_{83} & \lambda_{84} & \lambda_{85} & \lambda_{86} & \lambda_{87} & \lambda_{88} & \lambda_{89} \\ \lambda_{91} & \lambda_{92} & \lambda_{93} & \lambda_{94} & \lambda_{95} & \lambda_{96} & \lambda_{97} & \lambda_{98} & \lambda_{99} \end{pmatrix} \begin{pmatrix} LNA_{t-2} \\ LEU_{t-2} \\ LSA_{t-2} \\ LEASP_{t-2} \\ LLA_{t-2} \\ LSSAF_{t-2} \\ LRES_{t-2} \\ LWGDPPC_{t-2} \\ LPBP_{t-2} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \\ \varepsilon_{6t} \\ \varepsilon_{7t} \\ \varepsilon_{8t} \\ \varepsilon_{9t} \end{pmatrix}$$

, where, ε_{it} are the errors of the related i^{th} equation (i=1,2,..,9), which are distributed independently across equations and over time. *C*s are constants, τs are parameters in front of lag one variables, λs are parameters in front of lag two variables in the system to be estimated. *Furthermore, there will be restrictions on parameters {Cs, τs, λs} belonging to some autoregressive order variables to satisfy model structuring criteria.* Those restrictions are shown with the empty boxes in Table 4.

The estimated VAR (2) model passes normality and ARCH diagnostic criteria while VAR (1) fails to pass these criteria. The restrictions on parameters are chosen under these circumstances with an acceptable minimized AICC, HQC, AIC, SBC, FPEC simultaneously. All parameters are estimated significantly at least 10% significance level. The estimated models are free from model estimation problems as test statistics are shown in Table 4, except for AR diagnostics at lag 2 and at lag four for LEU and LLA equation at lag 4, however, their errors distributed normally and they are free from ARCH effect.

3. Results

There exist significant interactions among energy intensities (energy efficiencies) of world's regions as their interactions with world's GDP per capita and world energy prices around 83%-99% as seen from the determination ratios (R^2) in Table 4 for the period of 1971-2009.

A percentage increase in North America's last year's energy intensity brings about 0.80% increase in current year's energy intensity itself, *ceteris paribus,* implying that North America's current year's energy intensity depends on the last year's energy intensity and thus a decrease in the efficiency of energy use as seen in the second column in Table 4, and the current year's energy efficieny improves about 30% by the increases in energy intensity at the two year back. In cumulative terms, a percentage increases in earlier years' energy intensity of North America brings about 0.50% (80%-30%) increase in current year's energy intensity and thus causes inefficiency in current year's energy use of North America. Percentage increases in the other regions' energy use backwards lag two increase North America's energy use by 0.00067%, *ceteris paribus, as* in the second column in Table 4. In total, percentage increases in world's regions' energy intensity including North America's earlier energy uses backwards lag two brings about 0.30067% increase in North America's current year energy intensity, implying a decrease in inefficiency of North America's energy use overtime, *ceteris paribus*. North America's current year energy use has significant interactions with the earlier years' energy use of North America and earlier energy uses of South Asia, East Asia and Sub-Saharan Africa but it doesn't interact significantly with the rest, the world GDP per capita and the world energy prices. The results for the other regions can be interpreted in similar way depending on calculations. Each calculation or result shall have policy implications. The earlier years' energy uses of European Union does not have significant effect on the current year's energy use of EU and on energy intensity or energy efficiency as seen in the third column of Table 4.

Overall, additional energy use of a region affects the other's energy use at different magnitudes and directions. Except for Sub-Saharan Africa, additional energy uses by regions per output mostly leads to higher per capita world GDP and energy price. Additional energy consumption by North America in the last years brings about energy use inefficiencies in the other regions except for Latin America. An additional energy consumption by European Union in the last years increases energy use efficiencies in the other regions except for Sub-Saharan

Africa. An additional energy consumption by South Asia in the last years increases energy use efficiencies in Latin America, European Union and the rest while it decreases energy use efficiencies in North America and South Asia. An additional energy consumption by East Asia in the last years increases energy use efficiencies in North America, European Union and the rest while it decreases energy use efficiencies in South Asia and Latin America as well as itself. Additional energy consumption by Latin America in the last years increases energy use efficiencies only in East Asia and its earlier year energy consumption bring inefficiencies in current year's use of energy in East Asia. Additional energy consumption by Sub-Saharan African in the last years increases energy use efficiency only in North America and it decreases its efficient use in European Union, South Asia, and East Asia and in the rest as well as itself.

Table 4: Estimated VAR (2) Model with Restricted Parameters

VARIABLE	LNA_t	LEU_t	LSA_t	$LEASP_t$	LLA_t	$LSSAF_t$	$LRES_t$	$LWGDPPC_t$	$LPBP_t$
Constant	7.43420 (1.30387)***	3.51603 (1.1329)***			-1.62881 (0.6528)**			-19.88698 (2.61069)***	
LNA_{t-1}	0.80023 (0.11453)***	0.61274 (0.08202)***		0.66460 (0.12506)***			0.59789 (0.13939)***	0.82091 (0.14988)***	
LEU_{t-1}			-0.16194 (0.03437)***	-0.41931 (0.10151)***	0.44899 (0.06366)***	-0.06823 (0.03522)**	-1.06065 (0.16815)***		
LSA_{t-1}	0.62002 (0.09672)***	-0.19844 (0.08598)**	0.62351 (0.08206)***		-0.22327 (0.04141)***				
$LEASP_{t-1}$	0.28448 (0.12803)**			0.64610 (0.08065)***	0.44707 (0.04048)***		-0.35913 0.08341)***		1.89321 (0.6427)***
LLA_{t-1}				-0.75240 (0.1273)***					2.29536 (1.20438)**
$LSSAF_{t-1}$	-0.78679 (0.15892)***		0.25661 (0.07766)***	0.31873 (0.16066)*		0.68905 (0.06962)***			
$LRES_{t-1}$			0.13583 (0.06311)**		-0.11359 (0.0209)***		1.41389 (0.09046)***		
$LWGDPPC_{t-1}$		0.18643 (0.05245)***		0.08645 (0.03377)**		0.10135 (0.04422)***	0.29404 (0.06823)***	0.76159 (0.1276)***	
$LPBP_{t-1}$			-0.01343 (0.00476)***	0.02452 (0.00737)***					0.64999 (0.07475)***
LNA_{t-2}	-0.30368 (0.10701)***				-0.17388 (0.0493)***				
LEU_{t-2}							0.53527 (0.11094)***		
LSA_{t-2}							-0.38509 (0.11086)***		
$LEASP_{t-2}$	-0.50557 (0.13417)***	-0.37283 (0.06935)***	0.24969 (0.06207)***						
LLA_{t-2}	0.38853 (0.10298)***	0.27798 (0.08181)***			0.68191 (0.03323)***	0.40624 (0.08872)***		0.35602 (0.13271)***	
$LSSAF_{t-2}$		0.49160 (0.10884)***		0.50070 (0.16806)***			0.98359 (0.14206)***		-4.39283 (1.52694)***
$LRES_{t-2}$			-0.10599 (0.0542)*				-0.65968 (0.0874)***	0.51622 (0.07497)***	
$LWGDPPC_{t-2}$		-0.19811 (0.04999)***				-0.14667 (0.04589)***	-0.30976 (0.06162)***	-0.25476 (0.1054)***	
$LPBP_{t-2}$				0.01704 (0.00761)**			0.01899 (0.00577)***		
R^2	0.9729***	0.9403***	0.9995***	0.9975***	0.9988***	0.9982***	0.9886***	0.9955***	0.8342***
F	35.86	15.75	1832.75	402.36	865.05	547.35	86.97	219.52	5.03
DW	1.63418	1.32029	2.21973	1.89111	1.51026	1.93705	1.77918	1.40898	1.97151
Normality χ^2	1.65	0.95	0.14	4.06	1.67	0.29	1.70	1.11	0.03
$Pr > \chi^2$	0.4391	0.6225	0.9310	0.1312	0.4331	0.8645	0.4274	0.5754	0.9875
ARCH F Value	0.93	2.61	0.01	0.69	1.65	0.05	2.39	0.34	0.03
Pr > F	0.34201	0.1151	0.9334	0.4122	0.2070	0.8205	0.1310	0.5632	0.8732
AR Diagnostics	F Value Pr > F	F Value Pr > F	F Value Pr > F	F Value Pr > F	F Value Pr > F	F Value Pr > F	F Value Pr > F	F Value Pr > F	F Value Pr > F
AR1	0.88 0.3545	2.83 0.1014	1.00 0.3239	0.04 0.8404	0.70 0.4079	0.15 0.7014	0.01 0.9067	2.31 0.1379	0.01 0.9041
AR2	0.98 0.3845	4.98 0.0131	0.49 0.6179	0.44 0.6476	0.39 0.6800	0.38 0.6862	1.24 0.3023	2.36 0.1108	0.10 0.9091
AR3	0.73 0.5398	2.03 0.1312	1.12 0.3560	0.44 0.7262	2.10 0.1213	0.42 0.7377	1.16 0.3418	1.62 0.2057	0.33 0.8008
AR4	1.82 0.1538	4.62 0.0055	1.60 0.2007	0.31 0.8689	2.93 0.0383	0.32 0.8604	0.96 0.4431	1.16 0.3484	0.33 0.8582
Infor. Criteria	AICC=-55.6015, HQC= -62.7335, AIC= -65.3582, SBC=-57.9132, FPEC= 1.09E-28								
Note: "***" refers to significance level at 1%, "**" refers to significance level at 5%, "*" refers to significance level at 10%.									

Source: Author's own elaboration based on data sources mentioned in section 2.1.

A percentage increases in recent years' world GDP per capita reduces energy use per unit output and improves efficiency about 0.01168% significantly in European Union, about 0.04532% in Sub Saharan Africa, about 0.01572% in the rest of those blocks, however, it brings about 0.08645% inefficient use of energy in East Asian region. There exist a significantly positive North American, Latin American and the rest of the regions' energy using effects on the world GDP per capita. Increases in energy consumption of both East Asian and Latin American drive up world energy prices while additional energy consumption of Sub-Saharan Africa reduces world energy prices.

4. Conclusion

To determine whether the energy uses of world's regions, world GDP per capita and world energy price affect each others firstly bi-directional causalities were researched within VAR systems. There exist unidirectional causality by 36.2%, bi-directional causality by 19.4% and non-causality by 44.4% among pair wise variables at 10% significance level. However, each variable showed grouped causality relationship with the combination of the rest of the variable, which implies interactions and efficiency effects among energy uses of world's regions with world income per capita and world energy price and necessity of setting a VAR model inductively. A VAR (2) model is found eligible to explain the interactions among the variables by determination ratio above 90%. Estimated VAR (2) model with restrictions on parameters is found satisfactory in view of statistical criteria. Energy uses of world's regions affect each other's energy use efficiency which shall be expected under repetitive global economic activities in the world trade market, which has an implication is that it stands for the persistence of peace in the world or limiting conflicts among countries rather than coases and an existence of substitution effect between energy and a production factor which is cheaper than energy in a country to match increasing demand for goods and services worldwide.

On the other hand, the energy use efficiency has not been improved satisfactorily even the countries have invested in modern energy areas and have attempted to improve energy quality for the purposes of contributing to their economic growth and eliminating environmental pollution etc. for the years. In addition, energy uses of blocks have been interacting within the framework of varying economic activities. It is suggested that energy efficiency improvement policies must be advanced further via governmental cooperation across countries or blocks to overcome unfavorable effect of the fast expansion in the aggregate world demand.

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Ocena interakcji pod względem intensywności zużycia energii pomiędzy regionami świata, globalnym PKB per capita i światowymi cenami energii

Streszczenie

Badania przedstawione w artykule stanowią próbę przewidzenia intensywności wykorzystania energii w ramach regionów świata, a także energochłonności PKB per capita oraz światowymi cenami energii poprzez rozwój modelu VAR (2). Występowanie zależności pomiędzy grupami zmiennych przetestowano za pomocą testu przyczynowości Grangera, aby zbudować indukcyjnie model VAR. Istnieją znaczące przyczynowe oraz dynamiczne interakcje pomiędzy zmiennymi, sugerujące, iż zużycie energii przez regiony wpływa na energochłonność innych regionów (niekorzystna wydajność), a spośród nich każdy z różną siłą oddziałuje na globalny PKB per capita oraz jednostkową światową cenę energii. Dodatkowe zużycie energii przez regiony na 1000 USD produkcji przeważnie prowadzi do wzrostu globalnego PKB na jednego mieszkańca i cen energii poza Afryką Subsaharyjską. Rosnący w ostatnich latach światowy PKB per capita przeważnie powoduje brak efektywności i wydajności, chociaż w przeciągu dwóch ostatnich lat zazwyczaj wiązał się z większą wydajnością regionów. Jedynie w Azji Południowej wzrost cen energii nie doprowadził do wzrostu efektywności regionów świata w okresie 1971-2009.

Słowa kluczowe: regiony świata, intensywność zużycie energii, model VAR, interakcje