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A re-examination of causal relation between economic growth and energy consumption: Evidence from 91 countries

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Abstract

This paper empirically examines the causal relationship between energy consumption and economic growth, by controlling with CO2 emission and economic globalization in multivariate models, in a sample of the 91 less developed, developing and developed countries individually, in the period of 1970-2013. I apply the Toda-Yamamoto augmented Granger non-causality testing procedure. I observe a significant unidirectional causality running from energy consumption to economic growth in twenty-one countries. In thirty-one countries, conservation hypothesis is valid. Empirical evidence also shows that there is a feedback hypothesis in sixteen countries and no causal relation in only twenty-three countries.

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1. Introduction

The relation between economic and energy policies became a vital issue relies on its economic, political and cultural consequences for all countries since the 1970s. As developing countries made an attempting by integrating their economies into the global economic system for achieving the economic development, they changed the structure of their economies through trade and energy policies. While after 2000, less developed countries made an improvement in their economic welfare, such as developing countries, they are still energy poor economies. Energy shortage leads to weak macroeconomic management and poor governance that could generate poverty, inequality, corruption and political instability, under high rates of population growth and adversely affects the stability of the economic growth of these countries. Although the causality between energy consumption and economic growth has attracted significant attention in the current literature of energy economics and energy policy, there are ambiguous results.

Many scholars in the current literature have examined the relationship between energy consumption and economic growth to determine whether there is a linkage between economic and energy policies in a developing country. In a pioneering study, Kraft and Kraft (1978) firstly applied causality analysis between energy consumption and economic growth. They showed that there is causality from economic growth to energy consumption for the United States in the period of 1947-1974.

The relation between energy consumption and economic growth reflects the economic structure of an economy. The direction of the causality in this relation determines the qualification of the energy policies that a country would imply. While the causal relation from energy use to economic growth represents that the economic activities in a developing country rely on energy and this characteristic feature give impulsion to the achievement of the economic growth. According to this kind of casual relation, if the country is an energy importer it will face with the high volatile energy prices that are set in the global financial markets, and due to a decrease in the energy use, macroeconomic variables will be influenced by adversely such as, a reduction in the GDP and an increase in the unemployment rate of the country. On the other hand, if there is causality from growth to the energy use, energy conservation policies affect the economic growth will be little or none (Asafu-Adjaye, 2000; Chontanawat et al., 2008).

This paper empirically investigates the causal relationship between energy consumption and economic growth in 91 countries given their level of economic level, by controlling with CO2 emission and economic globalization in multivariate models. There are three main contributions of this study to the existing body of literature. The paper is the first to examine the causal linkage between energy consumption and economic growth in the selected countries in this period of time, country by country. Second, this is the first study to employ the Toda-Yamamoto augmented Granger non-causality procedure for this relationship and to provide a large sample of countries. Third, this is the first paper to use the KOF economic globalization index to examine the causal relation of growth and energy consumption in the current literature. Therefore, the econometric methodology provides additional empirical evidence on the causal relationship between energy consumption and economic growth in a global point of view.

While in twenty-one countries 'energy-led' growth hypothesis is valid, I find a significant causality from energy consumption to economic growth in twenty-one countries. Empirical results also present that there is a feedback hypothesis in sixteen countries and neutrality hypothesis is valid in only twenty-three countries.

The remainder of this paper is organized as follows. Section 2 surveys the literature review on the causal relation between energy consumption and economic growth in less, developing and developed countries. Section 3 describes data and presents the model and the methodology of the procedure of the Toda-Yamamoto Modified Wald causality framework. Section 4 provides and discusses the empirical results and the policy outcomes. Section 5 offers concluding remarks.

2. Literature Review

Since then, the literature consider this relation for individual countries, for group of countries by different methodologies and abstracted into four strands of this relation as; no causality, unidirectional causality from energy consumption to economic growth, causality from economic growth to energy consumption and bidirectional causality.

In the first strand, there are several papers in the current literature showing there is no causality between energy consumption and economic growth that is called 'neutrality hypothesis' which shows that there is no association between energy consumption and economic growth and energy policies have no influence on the GDP. For developing countries, Cheng (1997) presents that there is no causality between these variables by using Granger causality test that Mexico and Venezuela, for the periods of 1949-1993 and 1952-1993, respectively. Soytas and Sari (2003) shows that there is has no causality in India, while Chiou-Wei et al. (2008) presents that there is no causality in Thailand and South Korea. In addition, Chontanawat et al. (2008) also found that Bahrain, Benin, Cameroon, China, Dem. Congo, Cote d'Ivoire, Ecuador, Gabon, Haiti, Honduras, Hong Kong, India, Indonesia, Iraq, Jamaica, Libya, Malaysia, Malta, Nicaragua, Nigeria, Pakistan, Senegal, Singapore, Sri Lanka, Tanzania, Togo, and Zambia. Besides, Akinlo (2008) also shows that in Cote d'Ivoire, Nigeria, Kenya, and Togo there is no causality. Akinlo (2008) and Wolde-Rufael (2009) have the same results that there is no causality between variables in Cameroon. Wolde-Rufael also presents that in Kenya there is no causality. Halicioglu (2009) shows by using co-integration and Granger causality with ARDL tests for the period of 1960-2005 Turkey has no causality. Moreover, Yildirim and Aslan (2012) present the neutral causal linkage in Austria, Denmark, Finland, France, Germany, Sweden, Turkey, UK and the US. Yildirim et al. (2014), using bootstrapped autoregressive metric causality method with different time spans of countries, find that the neutrality hypothesis is valid for the economies of Bangladesh, Egypt, Indonesia, Iran, Korea, Mexico, Pakistan, and Philippines. Further, in their study, Kivyiro and Arminen (2014) present evidence that there is no causal relation in Democratic Republic of Congo, Kenya, South Africa and Zimbabwe for the period of 1971-2009 by using a Granger causality test. In a late study, Rahman and Mamun (2016) show that there is no Granger causal relationship between energy consumption and GDP growth per capita for Australia, over the period of 1960-2012. Using ARDL bounds testing procedure in their study, they reach a conclusion that macro economy of Australia depends on trade-led growth hypothesis instead of energy-led growth hypothesis.

In the second strand of the relation, there is causality from economic growth to energy consumption, which is referred to as 'conservation hypothesis'. In this kind of causal relation, energy consumption policies have either no or a little negative influence on economic growth and the structure of the economy. According to that, Aqeel and Butt (2001) examined Pakistan as a developing economy and found that there is causality from economic growth to energy consumption in the period of 1955-1996 by using Hsiao's version of Granger test. In a prominent paper Chontanawat et al. (2008) also shows that Albania, Algeria, Bolivia, Bulgaria, Costa Rica, Cuba, El Salvador, Ethiopia, Panama, Paraguay, Peru, Saudi Arabia, Thailand, Venezuela, Zimbabwe has a similar unidirectional causal relation between variables using the Granger causality test in the period of 1971-2000, implying these countries are less energy dependent economies. Chiou-Wei et al. (2008) show that there is a unidirectional nonlinear Granger causality running from economic growth to energy use for Philippines and Singapore in the period of 1954-2006. Akinlo (2008) reaches similar results for Sudan and Zimbabwe in the period of 1980-2003 through the Granger test based on vector error correction model. In addition, Ang (2008) and Azam et al. (2015) find unidirectional causality runs from growth to energy consumption for Malaysia for the periods of 1971-1999 and 1980–2012, respectively. In the findings of Yildirim and Aslan (2014), GDP causes energy use in Australia, Canada, and Ireland for the period of 1964-2009, 1971-2009 and 1971-2009, respectively. Kivyiro and Arminen (2014) present the evidence that there is a unidirectional causal relation from growth to energy in Zambia for the period of 1971-2009. Hwang and Yoo (2014) also show empirical results that the economy of Indonesia has causality from growth to energy consumption, depending on an error-correction model through co-integration and Granger causality method for the period of 1965-2006. Moreover, Bastola and Sapkota (2015) examine the causal relation in Nepal and through Johansen co-integration and ARDL bounds test procedure over the period of 1980-2011, they find that GDP growth causes to energy consumption.

The third strand of the literature presents the causality from energy consumption to economic growth that is also referred as ‘growth hypothesis’ or ‘energy-led’ growth hypothesis. This kind of causality suggests that energy policies have significant influences on the economic growth of the country and also indicates that energy use became an important part of the production structure either direct or indirect effects. Under this causal relation, energy supply shocks and volatile energy prices in the world trading system could adversely affect the development process of the country and lead to more vulnerable to external shocks. Asafu-Adjaye (2000) finds that for India and Indonesia there is causality from energy consumption to economic growth. According to Chontanawat et al. (2008), developing countries such as Bangladesh, Chile, Colombia, Congo Republic, Cyprus, Dominican Republic, Egypt, Israel, Kenya, Nepal, Oman, Philippines, Uruguay, Vietnam have the same unidirectional causality relation between energy use and income. Chiou-Wei et al. (2008) using a nonlinear Granger causality test find that in Taiwan, Hong Kong, Malaysia and Indonesia there is causality from energy use to economic growth for the period of 1954-2006. Odhiambo (2009) provides evidence that energy consumption promotes economic growth in Tanzania. Moreover, Menyah and Wolde-Rufael (2010) and Tsani (2010) applying Toda-Yamamoto version of Granger causality test, show that South Africa and Greece also have the similar causal relation in the periods of 1965-2006 and 1960-2006, respectively. Yildirim and Aslan (2012) show by using the Toda-Yamamoto procedure for Granger causality test, there is a unidirectional causality from energy to real GDP in Japan. Alam et al. (2012) find causality for Pakistan for the period of 1972-2006 in the short and the long run, by using a vector error correction model. In addition, Kivyiro and Arminen (2014) and Alshehry and Belloumi (2015) present causality from energy usage to economic growth in Congo Republic and Saudi Arabia, by using Granger causality test for the period of 1971-2009 and 1971-2010, respectively. Furthermore, in a recent study, Tang et al. (2016) show that Vietnam has also a unidirectional causality from energy to GDP in the period of 1971-2011, by using Toda-Yamamoto Granger causality test procedure.

The final strand of the causal relation between energy consumption and economic growth represents the bidirectional linkage between them, which refers to ‘feedback hypothesis’. Energy policy and growth strategy redesign each other according to their expecting behaviors. Asafu-Adjaye (2000) shows that there is a feedback relation in Thailand and Philippines. Yang (2000) also presents that, using an Hsiao’s Granger causality test, Taiwan has a bidirectional causal relation between variables in the period of 1955-1990. Moreover, Soytas and Sari (2003) find that Argentina also has a feedback relation between energy consumption and GDP for the period of 1950-1990. Paul and Bhattacharya (2004) examined India for the causal relation and they find the evidence that there is a similar empirical result for the Indian economy. In addition, Chontanawat (2008) finds that Angola, Argentina, Brazil, Brunei Darussalam, Ghana, Gibraltar, Guatemala, Iran, Jordan, Kuwait, Lebanon, Morocco, Mozambique, Myanmar, Qatar, Romania, Sudan, Taiwan, Trinidad and Tobago, Tunisia, United Arab Emirates and Yemen have bidirectional causal relation between energy use and economic growth. Akinlo (2008) shows that Gambia, Ghana, and Senegal have the similar causal relation for the period of 1980-2003. In a recent paper, Yildirim and Aslan (2012) present the evidence for Italy, New Zealand, Norway and Spain for bidirectional causality. In a panel data analysis on 14 MENA countries, Omri (2013), using simultaneous-equations models for the period of 1990-2011, finds that there is a bi-directional causality between growth and energy consumption for the region as a whole.

3. Data and Methodology

3.a. Data

This paper analyses the causal linkage between energy consumption and economic growth, focusing on 91 countries, which consists of 27 OECD and 64 non-OECD countries, for the period of 1970-2013. The determination of countries is based on continuous data availability for the period under consideration. I employ data on indicators of economic growth, consisting of GDP per capita at 2010 constant prices, energy consumption by the kg oil equivalent per capita and CO2 emission and denoted by *lnGDP*, *lnEn* and *lnCO2* in the model, respectively. Furthermore, all these data are in logarithmic form and obtained from the World Development Indicators, 2017. In addition, I use the KOF economic globalization index that consists of two sub-indices, actual flows and trade restrictions. The measure of actual flows presents the effects of total inflows to a country by four weighted components: trade 21.77%, foreign direct investment, stocks 26.62%, portfolio investment 24.31% and income payments to foreign nationals 27.30%. The restrictions on trade contain hidden import barriers 23.59%, mean tariff rate 27.80%, taxes on international trade 25.90%, capital account restrictions 22.71%. The index of economic globalization is obtained from the globalization index of KOF (Dreher, 2006; 2008) and denoted by *EcoG.*[1]

3.b. Model and Econometric Methodology

To explore the causal relation between energy consumption and economic growth for long-run causality in equations (1) and (2), I use the Toda and Yamamoto (1995) augmented Granger non-causality test, maintaining the robustness of the co-integration properties of the process. The Toda-Yamamoto procedure does not necessitate the information on the co-integration features of the model and allows an application without pre-testing for co-integration and for any level of integration (Zapata and Rambaldi, 1997). According to this procedure, I estimate an augmented vector autoregressive (VAR) model and a standard Wald test, even if the series of the variables are non-stationary. Since this procedure secures the asymptotic distribution of the Wald statistic, in spite of the standard Granger causality test, which ensures a standard asymptotic distribution, I determine to apply the Toda-Yamamoto procedure. This procedure initially requires two steps. The first step is the determination of the optimal lag length (k), and

[1] See the Supplemental Appendix for the descriptive statistics of the series used in the study.
[2] See the Supplemental Appendix for the results of the unit root test for the variables in their levels and

the following step is the detection of the maximum order of integration (d_{max}) for the variables in the model. The Toda-Yamamoto analysis also involves a modified Wald Test for constraints on the parameters of a VAR (k) and holds an asymptotic $\chi 2$ distribution while a VAR (k+d_{max}) is estimated. This procedure is employed in this study by estimating the following VAR models computed with the seemingly unrelated regression (SUR) technique to augment the efficiency of testing the Granger non-causality analysis (Rambaldi and Doran, 1996).

To provide white noise errors, in this paper, I choose the Akaike Information Criterion (AIC) and Schwarz Information Criterion (SIC) in order to select the optimal lag length of the VAR model. I apply the Augmented Dickey-Fuller (ADF) unit root test, which is introduced by Dickey and Fuller (1981), for the determination of the maximum order of integration.

As discussed in the literature review section, economic growth can significantly influence energy consumption, and economic growth can be affected by energy consumption. Following the current literature, I focus on the causal linkage between growth and energy consumption of a country in the models to have the causal relation and the direction of causality running among considered variables with the control variables, CO2 emission, and economic globalization.

Accordingly, the models can be specified in the VAR system as follows:

Energy Consumption equation (1):

$$lnEn_t = \alpha_0 + \sum_{i=1}^{k} \beta_{1i} lnEn_{t-i} + \sum_{j=k+1}^{d_{max}} \beta_{2j} lnEn_{t-j} + \sum_{i=1}^{k} \gamma_{1j} lnGDP_{t-i} + \sum_{j=k+1}^{d_{max}} \gamma_{2j} lnGDP_{t-j} + \sum_{i=1}^{k} \delta_{1i} lnCO2_{t-i} + \sum_{j=k+1}^{d_{max}} \delta_{2j} lnCO2_{t-j} + \sum_{i=1}^{k} \varphi_{1j} EcoG_{t-j} + \sum_{j=k+1}^{d_{max}} \varphi_{2j} EcoG_{t-j} + \varepsilon_{1t}$$

Economic Growth equation (2):

$$lnGDP_t = \tilde{\alpha}_0 + \sum_{i=1}^{k} \tilde{\beta}_{1i} lnEn_{t-i} + \sum_{j=k+1}^{d_{max}} \tilde{\beta}_{2j} lnEn_{t-j} + \sum_{i=1}^{k} \tilde{\gamma}_{1j} lnGDP_{t-i} + \sum_{j=k+1}^{d_{max}} \tilde{\gamma}_{2j} lnGDP_{t-j} + \sum_{i=1}^{k} \tilde{\delta}_{1i} lnCO2_{t-i} + \sum_{j=k+1}^{d_{max}} \tilde{\delta}_{2j} lnCO2_{t-j} + \sum_{i=1}^{k} \tilde{\varphi}_{1j} EcoG_{t-j} + \sum_{j=k+1}^{d_{max}} \tilde{\varphi}_{2j} EcoG_{t-j} + \varepsilon_{2t}$$

where $lnEn_t$ and $lnEn_{t-1}$ are the current and lagged levels of the natural logarithm of energy consumption of a country at periods t and t-1; $lnGDP_{t-1}$ is the lagged natural logarithm of real per capita GDP of a country at time t-1. k is the optimal lag order, d_{max} is the maximal order of integration of the series in the system and ε_1, ε_2 are the error terms that are assumed to be white noise. Conventional Wald tests are then applied to the first k coefficient matrices using the standard $\chi 2$- statistics.

4. Empirical Results

In this section, I report the results of unit root tests and Toda-Yamamoto (1995) augmented Granger non-causality tests for the VAR models (1) and (2) for each country in Tables 3 and 4. I also present summarized results in Table 3.

To determine the order of integration, I apply the Augmented Dickey-Fuller (ADF) unit root test frequently used in the literature, to determine the stationarity of the series. The test is performed on a country-by-country basis.[2] The results demonstrate that the first differences of the *lnEn*, *lnGDP*, *lnCO2* and *EcoG* series are stationary, implying that these variables are integrated of order one, I(1) at the 5% significance level for all countries, except Angola, Brunei Darussalam, Chile, Dem. Congo, El Salvador, Gabon, Myanmar, Nepal, Trinidad and Tobago in which the variables are integrated of order two.

In addition, the Akaike Information Criterion (AIC) and Schwarz Information Criterion (SIC) are employed for the selection of the optimal order of the lag length of the VAR model for each country. The results of the determination of the optimal lag length of each VAR models are reported in Tables 3 and 4, out of a maximum of 4 lengths, as determined by AIC. The $\chi2$ (1) statistics also demonstrate that there is no serial correlation against order 1 for these lag lengths determined by AIC and SIC.

As mentioned above, a Granger causality procedure developed by Toda and Yamamoto is employed to determine the direction of causality. Unit root test results report the optimal lag length (k), VAR order ($k+d_{max}$), MWald statistics, p values and direction of causality in the VAR model for each country. The results in Table 1 suggest that both the null hypothesis of "Granger non-causality from Growth to Energy" could be rejected at the 1 percent and 5 percent significance level. Moreover, the results in Table 2 suggest that both the null hypothesis of "Granger non-causality from Energy to Growth" could be rejected at the 1 percent and 5 percent significance level.

The results present evidence showing that there is an existence of causality from economic growth to energy consumption in thirty-one and energy to growth in twenty-one countries. The bidirectional causality exists in sixteen countries and no causality in twenty-three countries.

Table 1. Toda and Yamamoto non-causality test results for Eq. (1)

		KOF>Energy		***CO2>Energy***		***GDP>Energy***	
Country	**Lags**	**Wald Stat.**	**P-value**	**Wald Stat.**	**P-value**	**Wald Stat.**	**P-value**
Albania	2 (d=1, lags=1)	1.024	0.311	1.386	0.239	9.192***	0.002
Algeria	2 (d=1, lags=1)	0.444	0.505	2.185	0.139	7.197***	0.007
Angola	3 (d=2, lags=1)	2.937	0.230	10.215***	0.006	20.911***	0.001
Argentina	2 (d=1, lags=1)	0.587	0.443	2.744	0.097	2.427	0.119
Australia	2 (d=1, lags=1)	9.291***	0.002	1.492	0.221	1.231	0.267
Austria	2 (d=1, lags=1)	2.126	0.144	2.869	0.090	4.087**	0.043
Bahrain	2 (d=1, lags=1)	4.006**	0.045	2.795	0.094	17.109***	0.001
Bangladesh	2 (d=1, lags=1)	1.670	0.196	11.942***	0.001	17.251***	0.001
Belgium	2 (d=1, lags=1)	2.005	0.156	4.327**	0,037	13.546***	0.001
Benin	2 (d=1, lags=1)	0.079	0.778	2.477	0.115	0.216	0.642
Bolivia	2 (d=1, lags=1)	9.494***	0.002	15.060***	0.001	3.121	0.077
Botswana	2 (d=1, lags=1)	0.145	0.703	0.108	0.742	7.173***	0.007
Brazil	2 (d=1, lags=1)	9.340***	0,002	6.288**	0.012	4.659**	0.030
Brunei D.	3 (d=2, lags=1)	0.797	0.671	0.798	0.670	1.663	0.435
Bulgaria	2 (d=1, lags=1)	1.994	0.157	4.698**	0.030	6.272**	0.012

[2] See the Supplemental Appendix for the results of the unit root test for the variables in their levels and first differences.

Cameroon	2 (d=1, lags=1)	18.546***	0.001	2.843	0.091	2.324	0.127
Canada	2 (d=1, lags=1)	8.131***	0.004	2.369	0.123	0.353	0.552
Chile	3 (d=2, lags=1)	8.563**	0.013	4.266	0.118	9.138**	0.010
China	2 (d=1, lags=1)	0.526	0.468	8.968***	0.002	8.707***	0.003
Colombia	2 (d=1, lags=1)	3.444	0.063	1.675	0.195	1.537	0.215
Dem. Congo	3 (d=2, lags=1)	5.522	0.063	1.737	0.419	14.518***	0.001
Congo Rep.	2 (d=1, lags=1)	12.895***	0.001	0.350	0.554	4.475**	0.034
Costa Rica	2 (d=1, lags=1)	2.276	0.131	2.976	0.084	2.022	0.155
Cote d'Ivoire	2 (d=1, lags=1)	6.981***	0.008	3.789	0.051	2.771	0.095
Cyprus	2 (d=1, lags=1)	1.043	0.307	8.243***	0.004	3.656	0.055
Denmark	2 (d=1, lags=1)	1.967	0.160	7.773***	0.005	1.193	0.274
Domin. Rep.	2 (d=1, lags=1)	1.898	0.168	3.163	0.075	2.846	0.091
Ecuador	2 (d=1, lags=1)	9.188***	0.002	2.359	0.124	24.112***	0.001
Egypt	2 (d=1, lags=1)	2.259	0.132	0.472	0.492	4.019**	0.044
El Salvador	4 (d=2, lags=2)	15.925***	0.001	6.538	0.088	22.901***	0.001
Finland	2 (d=1, lags=1)	7.887***	0.004	6.027**	0.014	2.323	0.127
France	2 (d=1, lags=1)	0.273	0.601	8.893***	0.002	1.403	0.236
Gabon	3 (d=2, lags=1)	2.780	0.249	0.650	0.722	3.613	0.164
Ghana	2 (d=1, lags=1)	2.397	0.191	0.593	0.441	7.746***	0.005
Greece	2 (d=1, lags=1)	17.806***	0.001	8.976***	0.002	16.298***	0.001
Guatemala	2 (d=1, lags=1)	9.709***	0.001	2.867	0.090	3.165	0.075
Honduras	2 (d=1, lags=1)	3.459	0.062	0.464	0.495	2.939	0.086
Iceland	2 (d=1, lags=1)	6.222**	0.012	4.910**	0.026	3.752	0.052
India	2 (d=1, lags=1)	2.049	0.152	9.377***	0.002	0.436	0.509
Indonesia	2 (d=1, lags=1)	0.704	0.401	1.256	0.262	2.463	0.116
Iran	2 (d=1, lags=1)	0.401	0.526	4.809**	0.028	1.063	0.302
Ireland	2 (d=1, lags=1)	9.905***	0.001	1.020	0.312	5.116**	0.023
Israel	2 (d=1, lags=1)	1.246	0.264	3.108	0.077	19.163***	0.001
Italy	2 (d=1, lags=1)	6.541**	0.010	7.647***	0.005	2.095	0.147
Jamaica	2 (d=1, lags=1)	6.319**	0.011	10.083***	0.001	11.061***	0.001
Japan	2 (d=1, lags=1)	1.724	0.189	3.427	0.064	0.207	0.649
Jordan	2 (d=1, lags=1)	3.931**	0.047	2.599	0.106	2.098	0.147
Kenya	2 (d=1, lags=1)	5.795**	0.016	7.456***	0.006	1.185	0.276
Korea	2 (d=1, lags=1)	13.982***	0.001	3.384	0.065	17.003***	0.001
Luxembourg	2 (d=1, lags=1)	0.620	0.431	0.304	0.581	0.372	0.541
Malaysia	2 (d=1, lags=1)	0.014	0.905	1.607	0.204	4.019**	0.440
Malta	2 (d=1, lags=1)	3.968**	0.046	0.748	0.387	4.274**	0.038
Mauritius	2 (d=1, lags=1)	10.994***	0.001	0.730	0.392	22.060	0.001
Mexico	2 (d=1, lags=1)	29.770***	0.001	34.785***	0.001	30.698***	0.001
Morocco	2 (d=1, lags=1)	5.763**	0.016	4.413**	0.001	17.749***	0.001
Mozambique	2 (d=1, lags=1)	1.942	0.163	6.993***	0.008	2.846	0.091
Myanmar	3 (d=2, lags=1)	3.380	0.184	0.692	0.707	9.880***	0.007
Nepal	3 (d=2, lags=1)	20.926***	0.001	4.852	0.088	5.994**	0.049
Netherlands	2 (d=1, lags=1)	17.500***	0.001	1.104	0.293	15.207***	0.001
New Zealand	2 (d=1, lags=1)	2.337	0.126	3.872**	0.049	1.832	0.175
Nicaragua	2 (d=1, lags=1)	11.001***	0.001	3.510	0.060	8.257***	0.004

Nigeria	2 (d=1, lags=1)	3.669	0.055	0.324	0.569	0.223	0.636
Norway	2 (d=1, lags=1)	1.997	0.157	0.063	0.801	15.680***	0.001
Oman	2 (d=1, lags=1)	0.964	0.326	6.249**	0.012	1.959	0.161
Pakistan	2 (d=1, lags=1)	4.334**	0.037	6.869***	0.008	11.407***	0.001
Panama	2 (d=1, lags=1)	2.523	0.112	0.619	0.431	7.721***	0.005
Paraguay	2 (d=1, lags=1)	0.420	0.516	0.224	0.636	2.229	0.135
Peru	2 (d=1, lags=1)	7.294***	0.006	4.433**	0.035	2.287	0.130
Philippines	2 (d=1, lags=1)	11.389***	0.001	10.074***	0.001	7.856***	0.005
Portugal	2 (d=1, lags=1)	2.979	0.084	0.969	0.324	5.089**	0.024
Saudi Arabia	2 (d=1, lags=1)	4.966**	0.025	4.009**	0.045	4.300**	0.038
Senegal	2 (d=1, lags=1)	10.649***	0.001	13.022***	0.001	3.272	0.070
Singapore	2 (d=1, lags=1)	0.619	0.431	7.913***	0.004	3.141	0.076
South Africa	2 (d=1, lags=1)	0.724	0.394	2.771	0.095	0.493	0.482
Spain	2 (d=1, lags=1)	0.505	0.477	6.360**	0.011	14.729***	0.001
Sudan	2 (d=1, lags=1)	1.108	0.292	5.023**	0.025	0.928	0.335
Sweden	2 (d=1, lags=1)	1.938	0.163	4.383**	0.036	7.506***	0.006
Switzerland	2 (d=1, lags=1)	8.343***	0.001	13.444***	0.001	6.128**	0.013
Thailand	2 (d=1, lags=1)	1.874	0.171	4.801**	0.028	0.626	0.428
Togo	2 (d=1, lags=1)	6.269**	0.012	0.680	0.409	6.636***	0.009
Trinidad & T.	3 (d=2, lags=1)	2.888	0.235	3.085	0.213	1.543	0.462
Tunisia	2 (d=1, lags=1)	4.021**	0.044	7.822***	0.005	6.673***	0.009
Turkey	2 (d=1, lags=1)	3.348	0.067	8.794***	0.003	10.193***	0.001
UAE	2 (d=1, lags=1)	15.650***	0.001	0.278	0.598	5.224**	0.022
UK	2 (d=1, lags=1)	3.586	0.058	19.776***	0.001	14.549***	0.001
Uruguay	2 (d=1, lags=1)	5.204**	0.022	0.486	0.485	10.187***	0.001
US	2 (d=1, lags=1)	1.753	0.185	0.857	0.354	1.208	0.271
Venezuela	2 (d=1, lags=1)	0.881	0.347	2.889	0.089	6.641***	0.009
Zambia	2 (d=1, lags=1)	0.749	0.389	5.438**	0.019	2.667	0.102
Zimbabwe	2 (d=1, lags=1)	48.804***	0.001	10.299***	0.001	34.257***	0.001

*** Denotes significant at 1% level.
** Denotes significant at 5% level.

According to the results in Table 1, conservation hypothesis, which shows that a change of economic growth causes a change in the energy consumption of a country, is valid in 31 countries. These countries consist of only nine European developed economies, which are Austria, Bulgaria, Greece, Ireland, Malta, Netherlands, Norway, Spain, and Switzerland. The Democratic Republic of the Congo, Myanmar, Nepal and Togo are the less developed countries while Albania is the only transition country, which has a significant causality from economic growth to energy consumption substantially. Furthermore, the validity of this unidirectional causal relation is mostly in developing countries; Algeria, Botswana, Chile, China, Ecuador, Ghana, Jamaica, Korea, Malaysia, Morocco, Panama, S. Arabia, Tunisia, Turkey, Uruguay and Venezuela, Zimbabwe. It could be seen from the empirical results that implying energy policies in these economies would have no significant effect on the economic growth. In addition, the economic structure of these countries does not rely on energy use. According to this type of causal linkage despite economic growth generates energy consumption, energy consumption has no or a weak effect on growth. The results are in line with the empirical findings of Chontanawat et al. (2008) on Albania, Algeria, Panama, Saudi Arabia, and Venezuela, Zimbabwe, Akinlo (2008) on Zimbabwe, Ang (2008) and Azam et al. (2015) on Malaysia, Yildirim and Aslan (2014) on Ireland and Bastola and Sapkota (2015) on Nepal. Further, there is a statistically significant causality running from economic globalization to energy use in Greece, Ireland, Malta, Netherlands, Switzerland, Nepal, Togo, Chile, Ecuador, Korea, Morocco, S. Arabia, Tunisia, Uruguay, and Zimbabwe. This causal relation could be seen through scale, technique, composite and comparative advantage effects in these countries (Shahbaz et al., 2014). In addition, CO2 emission significantly leads to energy use in Bulgaria, Greece, Spain, Switzerland, China, Jamaica, Morocco, S. Arabia, Tunisia, Turkey, and Zimbabwe.

Table 2. Toda and Yamamoto non-causality test results for Eq. (2)

		KOF>GDP		*CO2>GDP*		*Energy>GDP*	
Country	**Lags**	**Wald Stat.**	**P-value**	**Wald Stat.**	**P-value**	**Wald Stat.**	**P-value**
Albania	2 (d=1, lags=1)	6.849***	0.008	6.965***	0.008	1.869	0.171
Algeria	2 (d=1, lags=1)	14.830***	0.001	0.213	0.644	0.176	0.674
Angola	3 (d=2, lags=1)	33.668***	0.001	24.692***	0.001	15.231***	0.001
Argentina	2 (d=1, lags=1)	0.627	0.428	1.283	0.257	0.462	0.496
Australia	2 (d=1, lags=1)	10.952***	0.001	9.529***	0.002	4.279**	0.038
Austria	2 (d=1, lags=1)	8.325***	0.003	0.071	0.789	2.067	0.150
Bahrain	2 (d=1, lags=1)	0.204	0.651	4.113**	0.042	9.077***	0.002
Bangladesh	2 (d=1, lags=1)	10.220***	0.001	3.734	0.053	4.884**	0.027
Belgium	2 (d=1, lags=1)	0.537	0.463	4.207**	0.040	6.706***	0.009
Benin	2 (d=1, lags=1)	2.966	0.085	1.255	0.262	0.373	0.541
Bolivia	2 (d=1, lags=1)	4.155**	0.041	12.901***	0.001	9.060**	0.010
Botswana	2 (d=1, lags=1)	0.049	0.824	0.226	0.634	1.479	0.229
Brazil	2 (d=1, lags=1)	5.508**	0,018	7.026***	0.008	19.867***	0.001
Brunei D.	3 (d=2, lags=1)	6.650**	0.035	21.052***	0.001	9.774***	0.007
Bulgaria	2 (d=1, lags=1)	1.942	0.163	0.915	0.338	0.548	0.459
Cameroon	2 (d=1, lags=1)	2.944	0.086	2.725	0.098	0.625	0.429
Canada	2 (d=1, lags=1)	6.187**	0.012	0.724	0.394	9.768***	0.001
Chile	3 (d=2, lags=1)	7.858**	0.019	4.182	0.123	3.036	0.219
China	2 (d=1, lags=1)	2.785	0.095	1.474	0.224	0.070	0.791
Colombia	2 (d=1, lags=1)	1.240	0.265	0.045	0.832	1.578	0.209
Dem. Congo	3 (d=2, lags=1)	1.472	0.479	0.347	0.840	2.189	0.334
Congo Rep.	2 (d=1, lags=1)	8.121***	0.004	13.787***	0.001	5.713**	0.016
Costa Rica	2 (d=1, lags=1)	1.475	0.224	7.578***	0.005	0.704	0.401
Cote d'Ivoire	2 (d=1, lags=1)	4.742**	0.029	2.227	0.135	5.173**	0.022
Cyprus	2 (d=1, lags=1)	3.361	0.066	3.609	0.057	1.352	0.244
Denmark	2 (d=1, lags=1)	3.606	0.57	3.041	0.081	6.190**	0.012
Dominican Rep.	2 (d=1, lags=1)	1.777	0.182	2.067	0.150	0.144	0.704
Ecuador	2 (d=1, lags=1)	1.706	0.191	0.132	0.716	0.408	0.522
Egypt	2 (d=1, lags=1)	5.350**	0.020	16.117***	0.001	5.935**	0.014
El Salvador	4 (d=2, lags=2)	17.907***	0.001	2.774	0.427	30.667***	0.001

Finland	2 (d=1, lags=1)	10.525***	0.001	1.060	0.303	2.769	0.096
France	2(d=1, lags=1)	0.244	0.621	3.233	0.072	0.195	0.658
Gabon	3 (d=2, lags=1)	4.628	0.098	4.193	0.122	23.558***	0.001
Ghana	2 (d=1, lags=1)	0.078	0.780	0.680	0.409	1.078	0.299
Greece	2 (d=1, lags=1)	8.737***	0.003	1.813	0.178	3.323	0.068
Guatemala	2 (d=1, lags=1)	1.616	0.203	0.074	0.785	14.184***	0.001
Honduras	2 (d=1, lags=1)	2.030	0,154	8.569***	0.003	7.064***	0.007
Iceland	2 (d=1, lags=1)	7.140***	0.007	2.013	0.155	0.668	0.413
India	2 (d=1, lags=1)	6.722***	0.009	3.327	0.068	6.526**	0.010
Indonesia	2 (d=1, lags=1)	0.572	0.449	1.143	0.285	0.578	0.447
Iran	2 (d=1, lags=1)	2.757	0.096	5.253**	0.021	16.187***	0.001
Ireland	2 (d=1, lags=1)	8.494***	0.003	1.815	0.177	2.448	0.117
Israel	2 (d=1, lags=1)	1.271	0.259	2.415	0.120	3.860**	0.049
Italy	2 (d=1, lags=1)	1.818	0.177	3.083	0.079	4.534**	0.033
Jamaica	2 (d=1, lags=1)	4.389**	0.036	0.070	0.791	2.339	0.126
Japan	2 (d=1, lags=1)	3.343	0.067	4.529**	0.033	2.013	0.155
Jordan	2 (d=1, lags=1)	12.211***	0.001	4.459**	0.034	1.954	0.162
Kenya	2 (d=1, lags=1)	3.561	0.059	5.319**	0.021	20.683***	0.001
Korea	2 (d=1, lags=1)	1.180	0.277	6.013**	0.014	1.185	0.276
Luxembourg	2 (d=1, lags=1)	3.916**	0.047	0.127	0.721	0.129	0.719
Malaysia	2 (d=1, lags=1)	2.229	0.135	9.812***	0.001	2.909	0.088
Malta	2 (d=1, lags=1)	2.647	0.103	0.748	0.387	1.358	0.243
Mauritius	2 (d=1, lags=1)	4.428**	0.035	6.226**	0.012	12.617	0.001
Mexico	2 (d=1, lags=1)	1.647	0.199	6.876***	0.008	7.121***	0.007
Morocco	2 (d=1, lags=1)	4.754**	0.029	1.253	0.262	3.171	0.074
Mozambique	2 (d=1, lags=1)	4.032**	0.044	3.316	0.068	7.876***	0.005
Myanmar	3 (d=2, lags=1)	18.151***	0.001	10.202***	0.006	4.173	0.124
Nepal	3 (d=2, lags=1)	9.343***	0.009	4.879	0.087	1.512	0.469
Netherlands	2 (d=1, lags=1)	0.778	0.377	1.255	0.262	0.596	0.440
New Zealand	2 (d=1, lags=1)	15.700***	0.001	0.656	0.417	4.360**	0.036
Nicaragua	2 (d=1, lags=1)	25.567***	0.001	11.613***	0.001	7.885***	0.004
Nigeria	2 (d=1, lags=1)	8.678***	0.003	3.923**	0.047	6.056**	0.013
Norway	2 (d=1, lags=1)	2.000	0.157	2.237	0.134	0.300	0.583
Oman	2 (d=1, lags=1)	5.754**	0.016	15.664***	0.001	19.485***	0.001
Pakistan	2 (d=1, lags=1)	0.834	0.361	18.103***	0.001	16.633***	0.001
Panama	2 (d=1, lags=1)	2.487	0.114	0.053	0.817	1.280	0.257
Paraguay	2 (d=1, lags=1)	3.665	0.055	0.227	0.633	3.358	0.066
Peru	2 (d=1, lags=1)	32.060***	0.001	10.149***	0.001	19.041***	0.001
Philippines	2 (d=1, lags=1)	2.740	0.097	27.369***	0.001	27.363***	0.001
Portugal	2 (d=1, lags=1)	0.013	0.909	10.198***	0.001	21.953***	0.001
Saudi Arabia	2 (d=1, lags=1)	0.898	0.343	7.129***	0.007	11.462***	0.001
Senegal	2 (d=1, lags=1)	7.294***	0.006	0.326	0.568	3.207	0.073
Singapore	2 (d=1, lags=1)	6.999***	0.008	1.813	0.178	1.177	0.277
South Africa	2 (d=1, lags=1)	4.915**	0.026	0.678	0.410	3.425	0.064
Spain	2 (d=1, lags=1)	11.776***	0.001	0.344	0.557	0.006	0.938

Sudan	2 (d=1, lags=1)	0.847	0.357	21.761***	0.001	0.912	0.339
Sweden	2 (d=1, lags=1)	11.769***	0.001	9.297***	0.002	5.604**	0.017
Switzerland	2 (d=1, lags=1)	0.078	0,780	0.464	0.495	0.849	0.356
Thailand	2 (d=1, lags=1)	2.030	0.154	0.674	0.411	1.747	0.186
Togo	2 (d=1, lags=1)	1.669	0.196	14.840***	0.001	1.049	0.305
Trinidad & T.	3 (d=2, lags=1)	29.506***	0.001	15.300***	0.001	6.037**	0.048
Tunisia	2 (d=1, lags=1)	1.961	0.161	2.070	0.150	1.029	0.310
Turkey	2 (d=1, lags=1)	4.482**	0.034	2.088	0.148	0.673	0.412
UAE	2 (d=1, lags=1)	9.948***	0.001	1.806	0.178	15.602***	0.001
UK	2 (d=1, lags=1)	2.384	0.122	15.551***	0.001	10.289***	0.001
Uruguay	2 (d=1, lags=1)	10.255***	0.001	0.268	0.604	1.043	0.307
US	2 (d=1, lags=1)	2.697	0,100	0.753	0.385	4.049**	0.044
Venezuela	2 (d=1, lags=1)	2.060	0.151	8.854***	0.002	3.367	0.066
Zambia	2 (d=1, lags=1)	7.337***	0.006	0.112	0.737	0.183	0.668
Zimbabwe	2 (d=1, lags=1)	9.557***	0.001	0.214	0.643	0.526	0.468

*** Denotes significant at 1% level.
** Denotes significant at 5% level.

In Table 2 the test results show that there is a strong causality from energy consumption to economic growth in twenty-one economies. While energy-led growth hypothesis is valid in developed countries, such as Australia, Canada, Denmark, Italy, New Zealand and the USA; and in developing countries as Bolivia, Brazil, Brunei Darussalam, Cote d'Ivoire, Gabon, Guatemala, Honduras, India, Iran, Kenya, Nigeria, Oman, Peru, and Trinidad and Tobago. Mozambique is the only less developed country that occurs in this kind of causal relation. The results reflect that these countries can apply energy consumption policies to direct their significant energy-dependent economies. According to Table 2, these countries can have energy policies have significant influences on the economic growth of the country and also indicates that energy use became an important part of the production structure either direct or indirect effects. The results are in line with the findings of Chontanawat et al. (2008) on Kenya, Oman. According to the empirical results, economic globalization leads to growth in Australia, Canada, New Zealand, Bolivia, Brazil, Brunei Darussalam, Cote d'Ivoire, India, Nigeria, Oman, Peru, Trinidad and Tobago and Mozambique. Moreover, the causality from CO2 emission to GDP is statistically significant in Australia, Bolivia, Brazil, Brunei Darussalam, Honduras, Iran, Kenya, Nigeria, Oman, Peru and Trinidad and Tobago.

In Table 3, the results indicating that the feedback hypothesis is valid in 16 countries, including 9 developing countries, which are Bahrain, Congo Rep., Egypt, El Salvador, Mexico, Nicaragua, Pakistan, Philippines, United Arab Emirates and 5 developed countries, such as Belgium, Israel, Portugal, Sweden, UK. Angola and Bangladesh are the only significant cases among less developed economies. In addition, the results present that there are a cause and a feedback effect between energy policy and economic growth in these countries. The results confirm the findings of Asafu-Adjaye (2000) on Philippines, Chontanawat et al (2008) on Angola, and UAE.

Table 3. Summary of the Toda-Yamamoto augmented Granger non-causality test

GDP > Energy Cons.	Energy Cons. > GDP	Energy Cons. - GDP	Energy Cons. > < GDP
Albania***	Australia**	Argentina	Angola
Algeria***	Bolivia**	Benin	Bahrain
Austria**	Brazil***	Bolivia	Bangladesh
Botswana***	Brunei Darussalam***	Cameroon	Belgium
Bulgaria**	Canada***	Colombia	Congo Rep.
Chile**	Cote d'Ivoire**	Costa Rica	Egypt
China***	Denmark**	Cyprus	El Salvador
Dem. Congo***	Gabon***	Dominican Rep.	Israel
Ecuador***	Guatemala***	Finland	Mexico
Ghana***	Honduras****	France	Nicaragua
Greece***	India**	Iceland	Pakistan
Ireland**	Iran***	Indonesia	Philippines
Jamaica***	Italy**	Japan	Portugal
Korea***	Kenya***	Jordan	Sweden
Malaysia**	Mozambique***	Luxembourg	UAE
Malta**	New Zealand**	Mauritius	UK
Morocco***	Nigeria**	Paraguay	
Myanmar***	Oman***	Senegal	
Nepal**	Peru***	Singapore	
Netherlands***	Trinidad and T. **	South Africa	
Norway***	US**	Sudan	
Panama***		Thailand	
Saudi Arabia**		Zambia	
Spain***			
Switzerland**			
Togo***			
Tunisia***			
Turkey***			
Uruguay***			
Venezuela***			
Zimbabwe***			

*** Denotes significant at 1% level.
** Denotes significant at 5% level.

The findings in Table 3 also show that there is no statistically significant causal relationship between growth and energy in 23 countries, consisting of six developed countries, which are Cyprus, Finland, France, Iceland, Japan, Luxembourg and thirteen developing countries, such as Argentina, Bolivia, Cameroon, Colombia, Costa Rica, Dominican Republic, Indonesia, Jordan, Mauritius, Paraguay, Singapore, South Africa, Thailand. Benin, Senegal, Sudan, Zambia are the only less developed countries in which either the change in economic growth or energy policy does not affect other according to the empirical results. These results are consistent with the views of Chontanawat et al. (2008) on Cameroon, Indonesia, Zambia, with Akinlo (2008) on Nigeria and Wolde-Rufael (2009) on Cameroon, with Yildirim and Aslan

(2012) on Finland and France, Yildirim et al. (2014) on Indonesia, with Kivyiro and Arminen (2014) on South Africa.

5. Concluding Remarks

Energy consumption has a crucial role in achieving a high level of standard of living through economic outcomes of a country. To examine the causal relation between economic growth and energy use in an economy, CO2 emission and economic globalization levels of the country, which are the main determinants of this relation, are taken into account for 27 OECD and 64 non-OECD countries. Therefore, although every country has different causal relation in various development levels, both energy and economic policy makers in these economies should consider the causes of CO2 emission and the level of economic integration of a country to the world trade system on energy consumption and GDP while analyzing the balance between the environment and economic development under the climate change conditions in the future.

As a consequence, the empirical results present that growth strategies of the countries lead to energy policies much common than the energy dependency, which refers to the conservation hypothesis, particularly in high-income countries. The conservation hypothesis is empirically verifies that there is no influence of energy policies such as, managing demand or energy efficient policies on the economic growth in 37% of OECD countries. In other words, these countries have weak energy dependent economies. On the other hand, energy policies on productivity and consumption have crucial role on the economic performance, which presents the evidence for the validity of the growth hypothesis in these economies only in 22.2% of OECD countries. Energy dependency has profound impacts, that could lead these economies vulnerable to external energy shocks. The results also suggest that the neutrality hypothesis, which presents either energy policies or economic performance have no statistically significant impact on each other in 18.5% of OECD countries. Finally, the feedback hypothesis, which shows both energy policies on consumption or access and economic growth influence each other is valid for the 22.2% of OECD countries.

Since energy dependency could have seen a significant issue in the literature the findings show that growth hypothesis can be seen marginalized through the analyzed countries in this study. According to that, the results highlight the importance of the change of becoming less-energy-dependent countries at every income level for both policy makers in the governments and industries or energy firms. A future study could address the issue for the coefficients of the causal relation between growth and energy consumption.

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