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The Relationship between Energy Consumption and Economic Growth: Evidence from Different Income Country Groups

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ABSTRACT

This study analyses the relationship between energy consumption and economic growth for 119 countries during the period of 1970-2015, classified into four groups regarding to the World Bank income ranking. The main motivation of this study is to analyze whether the causal relationship differs between different income groups of countries. For this purpose, panel auto regressive distributed lag boundary approach and Granger causality test were used. The results of the study indicate that the causal relationship between energy use and economic growth differs depending on which income group country belongs to. We conclude that the feedback hypothesis is supported for upper-middle income group in the long run and high-income group, while conservation hypothesis is supported for upper-middle income group in the short run and lower-middle income group in the long run. Finally, neutrality hypothesis is supported for low and lower middle-income groups in the short run.

Keywords: Energy Consumption, Economic Growth, Panel Unit Root, Auto Regressive Distributed Lag Boundary Approach, Panel Causality
JEL Classifications: Q44, Q48, O4

1. INTRODUCTION

As it is well-known, economic growth is one of the significant indicators of the level of economic welfare of society and the main macroeconomic purpose of any government. The conclusive determination of the empirical relationship between economic growth and other macroeconomic variables as consumption, investment or inflation rates has been always a crucial issue for policy-makers and an actual topic in empirical literature. The economic and political developments since the energy crises in 1970s, as well as the collapse of the Soviet Union and energy supply concerns are main motivating factors for the empirical estimation of the causal relationship between energy consumption and economic growth.

First of all, although the theoretical literature suggests different determinants of economic growth process, a fuel shortage in the 1970s stimulated a new dimension of the economic growth process of the countries, by adding energy consumption to the production function as an explanatory variable and bringing up conserving energy policies to governments' agenda for the first time. Secondly, increasing world population and concerns about environmental issues, as well as the negative political developments in the energy-supplying countries led to distinguish energy conserving policies with new acceleration after 1990's. As the third, detecting that a carbon dioxide emission, which is the major factor of global climate change in the word, is the direct result of the fossil energy sources consumption stimulates new investigations of the role of the energy as an input factor in the economic production process. Since restrictive policies on energy use imply various economic benefits and costs, determining the direction of the empirical relationship between total energy consumption and economic growth is an important issue for policy-makers as well as economists. Finally, with the collapse of the Soviet Union, "geopolitical superiority" conflicts in the energy-rich regions raised serious concerns about the security of energy supply as well as the worldwide energy demand as a cause of changes in the global population and income level. According to the BP Energy Outlook (2013), growth in population rate and per capita income are the key drivers behind the growing global energy demand. By 2035, the world's population is projected to reach 8.7 billion, which means an additional 1.6 billion people will need energy leading to growing concerns about the energy supply security concept.

The direction of the relationship between reel output level and the energy use plays a crucial role both in supply and demand sides of any economic system. Concerning the demand side of the economy, consumption of the energy resources such as crude oil, natural gas, coal or electricity maximizes households' utility by satisfying their different needs in the form of a final consumer good. However, there are two opposite views in the literature on the impact of energy sources within the context of supply. Neoclassical economic growth models such as Harrod – Domar or Solow - Swan, are fundamentally focused on the limited role of the energy resources in economic growth process[1], assuming capital, labor, and land as the ultimate factors of production, along with goods such as fuels and materials as the intermediate inputs, which lead to undermining the importance of energy resources in the economic activity (Stern, 2004; Ockwell, 2008). However, according to the ecological economists such as (Pokrovski, 2003), the role of energy resources in the production process is actualized in several ways: As a plain commodity, intermediate product and final product. Moreover, following Ghali and El-Sakka (2004) main inputs of the production process as a capital and labor force cannot transact in the absence of the energy. That is why according to the ecological economists, energy sources may be interpreted as the fundamental input of the value creation process and get all the features of a production factor, including the property to produce surplus value. As Pokrovski (2003) argues production of the value of output - Y- is specified by three production factors as Y = f (K, L, S), where S is a productive energy.

On the other hand, the features of the economic system and the phase of the economic growth process are the main underlying factors of the energy consumption influence on output growth indicators (Mehrara, 2007). Despite the conspicuous absence of evidence about the direction of causality between energy use and economic growth in the energy economics literature, there are four main hypotheses defining this possible relationship. First of all, according to the growth hypothesis energy consumption is a determinant of the economic growth process. In this situation, conserving policies on energy consumption may have destructive effects on economic growth and employment levels, whereas expansionary policies may stimulate economic growth and employment rates. In the context of Granger causality, it implies unidirectional causal relationship running from energy consumption to economic growth. If there is unidirectional causality running from gross domestic product (GDP) to energy consumption, implying that restrictive policies may be more applicable then conservation hypothesis will be supported in this situation. Parallel to the neoclassical economic growth theory, neutrality hypothesis implies the absence of causality between energy use and GDP, leading to implementing conservative or expansive energy policies without any concerns about destructive effects on the economic growth indicators. In this case feasible renewable energy policies, minimizing the environmental degradation may be applicable. Finally, feedback hypothesis requires bi-directional causality between energy consumption and income in the context of Granger causality. As expansive energy policies will not have negative impacts on the real GDP in this case, feasible renewable strategies which increase the energy consumption may be applicable in these countries. It is clear that to derive an appropriate energy policy implication for any economy, it is crucial to determine which of this hypothesis is supported for the observed country.

Unlike the previous studies, this study examines the causal relationship between energy consumption and economic growth for a sample of 119 countries belonging to different income level categories. The main motivation of this study is to find out whether the direction of causal relationship between energy consumption and reel output level changes across different income group of countries. For this purpose, we used panel unit root tests to investigate stationary properties of the observed series. Then we estimated auto regressive distributed lag (ARDL) model to study whether energy consumption and economic growth series are co-integrated or not. Finally, we used panel vector error-correction model (VECM) for investigating the significance of the short-run and long-run causal effects.

This study is organized in the following way. The second section requires the brief literature for the relationship between energy and electricity consumption and economic growth. The third section discusses the empirical model specification and estimation techniques. The fourth section presents empirical results and the final section provides concluding remarks.

2. LITERATURE REVIEW

The issue of the causal relationship between energy consumption and output growth rate took an important place in the energy economics literature since 1978, when the pioneering study in this field was realized by Kraft and Kraft for USA economy. The main base of initial studies in this field was, whether energy consumption promotes economic growth or economic growth process encourages energy use through aggregate demand and input (Masih and Masih, 1997). Berndt and Wood (1975) mentioned the energy consumption was substitutable with labor as well as complementary with the capital in the manufacturing process. However, following the results of the study, obtained by Griffin and Gregory (1976) for the same data, energy use was also substitutable with the capital. Thus, these studies led to conflicting results for the causal relationship between energy consumption and economic growth along with the role of energy in the production technology.

On the other hand, since the investigated time periods and conjectural features at these periods of the observed countries vary, the obtained results contradict for the same countries in different time periods as well as for countries with similar properties in same time periods. For instance, Oh and Lee (2004) analyzed the causal relationship between energy consumption and income for a data set of Korea, obtained for 1970-1999 and 1981-2000 periods. Although the same econometric approaches were used for both periods, contradictory results were obtained.

In spite of the fact that it is a well-studied topic within the scope of a large number of studies based on different countries, time periods,

1 This neutral role of the energy in the value creation process, leads production function to be transformed into Y = Y (K, L).

methods and variables, there is no single empirical evidence or consensus on a single feasible environmental or energy policies which can be achieved as a result of these studies. As pointed out by the Payne (2010), the variation in the results may be related to selected variables, model specifications, time periods of the studies and econometric approaches undertaken[2].

From historical perspective, depending on the econometric methods used in different studies, the related literature can be categorized in the following way; initially studies focused on vector autoregressive methodology, co-integration and standard Granger causality analyses (Kraft and Kraft, 1978; Masih and Masih, 1996; Masih and Masih, 1997; Glasure and Lee, 1998; Asafu-Adjaye, 2000; Soytas and Sari, 2003; Oh and Lee, 2004a; Oh and Lee, 2004b; Lee, 2005; Lee, 2006; Ghali and El-Sakka, 2004; Dinda and Coondoo, 2006; Yoo, 2006; Narayan and Singh, 2007; Mehrara, 2007; Ho and Siu, 2007; Chen et al., 2007; Lee and Chang, 2008; Wolde-Rufael, 2009; Akinlo, 2008; Apergis and Payne, 2009; Ghosh, 2009; Odhiambo, 2009a; Odhiambo, 2009b; Narayan and Smyth, 2009; Ozturk et al., 2010; Wang et al., 2011; Belke et al., 2011; Al-Mulali and Sab, 2012; Omri, 2013; Herrerias et al., 2013; Ouedraogo, 2013; Tan and Tang, 2013; Uddin et al., 2016, Ozturk and Acaravci, 2016), whereas with the developments in the applied methods more complicated techniques such as multivariate approach, variance decomposition, nonlinear co-integration (Omay et al., 2014), Pedroni (1999) and Westerlund (2006) co-integration (Narayan and Smyth, 2008; Basci et al., 2015), generalized method of moment (Al-Iriani, 2006; Huang et al., 2008b; Omri, 2013; Alaali et al., 2015), ARDL bound test (Ghali and El-Sakka, 2004; Lee, 2005; Dinda and Coondoo, 2006; Al-Mulali and Sab, 2012; Omri, 2013; Herrerias et al., 2013; Ouedraogo, 2013; Tan and Tang, 2013; Telatar, 2015; Farhani and Ozturk, 2015; Alam et al., 2016), Toda-Yamamoto (Fatai et al., 2004; Wolde-Rufael, 2006; Soytas and Sari, 2009; Squalli, 2007; Tang, 2008), Hsiao's versions of causality (Cheng and Lai, 1997; Jumbe, 2004; Yoo, 2006; Chontanawat et al., 2008) and bootstrapped causality (Narayan and Prasad, 2008) analyses were applied to examine the issue under consideration.

Since panel data estimation techniques may require more impressive results than time series approaches, panel co-integration and panel VECM are widely employed to analyze the causal relationship between energy consumption and economic growth for different country groups (Wolde-Rufael, 2006; Lee, 2006; Mehrara, 2007; Chen et al., 2007; Narayan and Prasad, 2008; Lee and Chang, 2008; Wolde-Rufael, 2009; Chiou-Wei et al., 2008; Chontanawat et al., 2008; Akinlo, 2008; Huang et al., 2008a; Huang et al., 2008b; Apergis and Payne 2009; Ozturk et al., 2010; Belke et al., 2011; Al-Mulali and Sab, 2012; Omri, 2013; Ouedraogo, 2013; Apergis and Payne, 2014; Omay et al., 2014; Basci et al., 2015; Alaali et al., 2015; Telatar, 2015). Although we employ panel data techniques used in previous studies, the originality of this paper is the investigation of the causality, for the panel of countries classified into four groups according to the World Bank income ranking.

2 Summary of the empirical studies in this field are presented in the appendix of this study, in Tables A1 and A2

3. ECONOMETRIC METHODOLOGY

As it is well known, the results obtained from the time series regression model which contains a unit root, may not represent the real relationship between variables and lead to the spurious regression problem. Therefore in this study, the Breitung (2000), Levin et al. (2002), Im et al. (2003), Maddala and Wu (1999), Choi (2001) methods are applied to analyze whether the energy consumption and GDP series contain a unit root or stationary. Breitung (2000) and LLC (2002) tests require the homogeneity across the series, whereas IPS (2003), Choi (2001), Maddala and Wu (1999) tests allow for the heterogeneity in the dynamics of autoregressive coefficients.

On the other hand, if the series in confederation are co-integrated, the findings obtained from the regression analysis may imply the real relationship between the variables. There are two types of co-integration tests which are commonly used in econometrics for this purpose; Engel and Granger (1987) and Johansen (1988) and Johansen and Juselius (1990). Both techniques are applicable if only related series are stable at the level or have the same order of integration. However, the panel ARDL proposed by Pesaran et al. (2001), can be applicable indifferent to the composition of the observed series, integrated order 0 or 1.

The ARDL modeling approach estimating as follows:

$$\Delta Y_t = \propto_{10} + \sum_{i=1}^{n} \beta_{1i}\, \Delta Y_{t-i} + \sum_{i=1}^{m} \gamma_{1i}\, \Delta X_{t-i} + \sigma_{1Y} Y_{t-1} + \sigma_{1X} X_{t-1} + \sigma_{1t} \quad (1)$$

$$\Delta X_t = \propto_{20} + \sum_{i=1}^{m} \gamma_{2i}\, \Delta X_{t-i} + \sum_{i=1}^{n} \beta_{2i}\, \Delta Y_{t-i} + \sigma_{2X} X_{t-1} + \sigma_{2Y} Y_{t-1} + \in_{2t} \quad (2)$$

Where, X is an energy consumption; Y is an economic growth.

After estimation of the above-mentioned ARDL model, the null hypothesis, which implies that series are not co-integrated i.e., H_0: $\sigma_{iX} = \sigma_{iY} = 0$ for i = 1, 2, should be tested. For this purpose rather using standard F-test, the upper (for I(1)) and lower (for I(0)) bounds statistics suggested by the Pesaran et al. (2001), are implemented. If calculated test statistics is over the critical value, then the null hypothesis is rejected. Additionally, if obtained test statistics is below the lower bound value, it will imply a co-integration relationship among the series, whereas if this statistic runs into the I(1) and I(0) bounds, indefinite results will be acquired.

According to the Engle and Granger (1987), if any observed series are co-integrated then, there is at least a unidirectional causal relationship between these series and VECM (3) and (4) should be estimated to examine the dynamics of this causality.

$$\Delta Y_t = \propto_{10} + \sum_{i=1}^{n} \beta_{1i} \Delta Y_{t-i} + \sum_{i=1}^{m} \gamma_{1i} \Delta X_{t-i} + \delta_Y EC_{t-1} + u_{1t} \quad (3)$$

$$\Delta X_t = \propto_{20} + \sum_{i=1}^{m} \gamma_{2i} \Delta X_{t-i} + \sum_{i=1}^{n} \beta_{2i} \Delta Y_{t-i} + \delta_X EC_{t-1} + u_{2t} \quad (4)$$

Where the u_{1t} and u_{2t} are normally distributed error terms. The error correction term (ECT), EC_{t-1}, implies the adjustment of the long-run equilibrium, at which a dependent variable returns to equilibrium after a change in other variables. The F-statistics on

Table 1: Overview of energy production, consumption and reserves (2013)

Some energy production, consumption and reserves indicators	High income group countries	Upper middle income group countries	Lower middle income group countries	Low income group countries
Fossil energy consumption (% of total)	82.99	86.61	66.07	19.67
Net energy import (% of energy use)	−4.26	−105.05	−2.00	−4.46
Total energy self-sufficiency (%)	142	176	106	95
Oil production (mtoe)*	67	55.4	17.13	0.35
Oil consumption (mtoe)*	59.5	48.9	33.08	1.37
Proved oil reserves (mtoe)**	1166	540	59	1.5
Natural gas production (mtoe)*	66.2	26.5	25.3	1.05
Natural gas consumption (mtoe)*	51.7	34.2	20.3	0.2
Proved natural gas reserves (trillion cubic meters)**	85.3	18,6	18	-
Coal production (thousand short tons)*	40	15	73	1,5
Coal consumption (thousand short tons)*	3.5	55	16	0,53
Proved coal reserves (million tonnes)**	530089	171841	122640	502

*Calculated as the approximate average value per country. **Represents the minimum total amount for the country group. Fossil energy consumption and energy import data were obtained from the World Bank Economic Indicators (www.wordbank.org) and the remaining data were obtained from the international energy agency (www.iea.org)

the lagged dependent variables indicate the significance of the short-run effects, whereas the t-statistics on the coefficients of the lagged ECTs indicate the significance of the long-run causal effect (Telatar, 2015).

4. ESTIMATION AND TEST RESULTS

This study analyses the relationship between energy consumption and economic growth for 119[3] countries during the period of 1970-2015, applying panel data research methodology. The data used in this study are categorized into four groups; high, upper middle, lower middle, and low income, based upon the World Bank income classification and obtained from the World Bank's World Development Indicators. The real GDP data is indicated in billions of constant 2001 U.S. dollars, whereas energy use is in kg of oil equivalent per capita.

4.1. Descriptive Statistics

Before continuing with the analysis, it may be useful to overview the energy positions of country groups in terms of energy production, consumption, reserves and imports.

For the reason that the world's biggest energy producers countries as Saudi Arabia and Russian Federation are in high income panel, this group is the richest in terms of proved petroleum, natural gas and coal reserves than other country groups. As it can be seen from Table 1, since the consumption of renewable energy resources is more unusual in developing countries, the level of fossil energy consumption is the highest in upper middle income country group. On the other hand, the fact that countries with lower income levels consume less energy resources compared to other groups, suggests that these countries employ more traditional production methods. Therefore energy sources are not used efficiently in the production process.

4.2. Panel Unit Root Analysis

After taking the natural logarithms of all series, panel unit root tests as Maddala and Wu (1999), Choi (2001), Breitung (2000), LLC (2002) and IPS (2003) were implemented to find out whether the series have a unit root or they are co-integrated. The obtained results are presented in Table 2.

As it can be seen from the Table 2, there is no single conclusion about the stationary features of the series. According to the results of some unit root tests, energy consumption and GDP series are integrated of order 0. However, some of the obtained results imply first-order stationary processes. Conflicting results obtained from the panel unit root tests, provide an inconclusive conclusion about the order of integration – I (0) and I (1) -, ARDL bounds testing is the convenient approach to analyze co-integration relationship.

4.3. Co-integration Analysis

For each country group; ARDL models was estimated in two ways, at first including GDP as an independent variable, then as an explained variable. The null hypothesis of no co-integration was tested by Chi-squared test. Obtained results for each model are summarized in Table 3. Appropriate lag length again was determined according to the Akaike information criterion.

As it can be seen from the results in the Table 3, there is not any co-integration relationship among the series for countries in low-income group, whereas the long-run relationship running from GDP to energy consumption was found for lower-middle income country panel. Furthermore, the evidence of bi-directional long run relationship among variables was found for both upper-middle income and high-income country groups.

Before estimating VECM to determine the causal relationship, Chow test was applied to analyze whether there is a structural break in the series or not. The null hypothesis of no structure break was tested again by F-test. The appropriate lag length was also determined according to the Akaike information criterion. Since F-statistics are not statistically significant at an alpha level of 0.05, we can conclude that there are not any structure breaks in these series.

4.4. Causality Analysis

Since there is no any evidence of co-integration relationship for low-income group countries, the VECM, obtained based on panel

3 The detailed list of the selected countries is given in Table A3, in the appendix of this study.

Table 2: Panel unit root tests

Variables	LLC		IPS		ADF-fisher		PP-fisher		Breitung
	Intercept	Intercept+Trend	Intercept	Intercept+Trend	Intercept	Intercept+Trend	Intercept	Intercept+Trend	Intercept+Trend
Low income country panel									
LGDP	2.14	−3.86*	3.04	−0.80	27.43	29.85	21.03	35.16*	5.32
LEC	−0.81	2.02	3.94	4.68	28.98	7.84	20.10	7.83	7.80
ΔLGDP	−8.04*	−8.64*	−8.54*	−7.79*	110.42*	93.07*	109.36*	109.53*	−6.53*
ΔLEC	−10.19*	−11.16*	−12.39*	−12.63*	180.28*	168.39*	182.30*	171.23*	−4.08*
Lower-middle income country panel									
LGDP	5.02	2.66	9.75	1.33	35.04	55.20	30.91	54.23	8.39
LET	1.59	2.02	2.91	3.74	54.98	31.44	47.29	48.80	5.96
ΔLGDP	−11.71*	−9.32*	−8.12*	−6.94*	170.89*	145.33*	203.18*	209.64*	−5.19*
ΔLEC	−11.46*	−11.46*	−16.22*	−16.34*	365.00*	345.40	667.56*	1033*	−6.98*
Upper-middle income country panel									
LGDP	−1.18	−3.09	5.12	−1.44	22.93	86.89*	29.18	99.32*	0.40*
LEC	−3.72*	−2.04*	−1.50	−0.38	92.81*	63.66	105.96*	55.63	0.63
ΔLGDP	−7.92*	−5.66*	−10.46*	−6.97*	224.35*	155.17*	392.55*	566.05*	−5.82*
ΔLEC	−14.24*	−13.00*	−15.58*	−14.16*	359.52*	310.13*	628.27*	809.72*	−12.04*
High income country panel									
LGDP	−6.12*	4.16	1.51	7.26	89.90	59.90	105.08	62.02	7.51
LEC	−7.34*	−0.15	−3.18*	2.62	170.08*	90.68	180.95*	115.56	6.17
ΔLGDP	−15.87*	−15.17	−14.58*	−12.2*	388.30*	314.99*	424.50*	433.8*	−8.44*
ΔLEC	−37.59*	−37.88*	−36.18	−36.9*	1154*	1226.5	1176*	2028*	−19.11*

*Indicates significance at the 5% level. LGDP: Log of GDP, LEC: Log of energy consumption, GDP: Gross domestic product, ADF: Augmented Dickey-Fuller, PP: Phillips and Perron

Table 3: Co-integration tests

ARDL model	F-statistic	Chow F-statistics		
		1997	1998	2008
Low income country panel				
$ARDL_{11}$	1.97	0.51	0.65	0.47
$ARDL_{12}$	0.21	0.08	0.16	0.09
Lower-middle income country panel				
$ARDL_{21}$	1.39	0.20	0.25	0.02
$ARDL_{22}$	5.60*	0.09	0.07	0.10
Upper-middle income country panel				
$ARDL_{31}$	16.15*	0.08	0.86	0.41
$ARDL_{32}$	4.38*	0.14	0.13	1.56
High income country panel				
$ARDL_{41}$	23.30*	0.03	0.05	0.16
$ARDL_{42}$	4.63*	0.03	0.03	0.09

*Indicates significance at the 5% level. ARDL: Auto regressive distributed lag

fixed effect regression method, was established for high, lower and upper-middle income country groups.

As it can be seen from the Table 4, ECT is statistically significant at an alpha level of 0.05, which implies that, the long-run causal relationship between energy consumption and economic growth has been proven to be valid for high-income, lower and upper-middle income country groups.

5. CONCLUSION

This study examined the causal relationship between energy consumption and economic growth for 119 country panel for the period of 1970-2015. For this purpose, firstly we investigated whether series have a unit root or not. Then a co-integration analysis is done. The results of the various panel stationary tests propose inconclusive results on the order of integration – I(0) and I(1). That is why we estimated an ARDL model, to investigate the co-integration relationship between the series. In order to examine long run dynamics of variables, VECM, and Granger causality analysis techniques was used. The obtained empirical result can be concluded as follows.

First of all, the causal relationship between energy consumption and economic growth for countries differs depending on which income group country belongs to. Secondly, in order that, there is not any evidence of co-integration relationship between energy consumption and economic growth for low income group countries as well as, causal relationship between the variable in the short run for the lower-middle income countries, the neutrality hypothesis is valid for these countries. This result may be explained by the fact that these countries are in the first stages of development, in which production process is still based on conventional technological methods (Telatar, 2014). In this case, implementation of renewable energy policies as well as innovation and research progress policies may be beneficial in terms of economic development. Thirdly, since positive causal relationship from economic growth to energy consumption was founded out for lower-middle income countries in the long run and for upper-middle income countries in the short run, conversation hypothesis is supported for these country groups. As restrictive energy policies do not have any destroying effect on economic growth parameters, in this case, applying of conservative energy policies consisting with sustainable economic targets, may be more advantageous. Finally, evidence of bi-directional causality

Table 4: Panel causality tests

Error correction model	Lower-middle income country panel		Upper-middle income country panel		High-income country panel	
	Long – run ECT t-statistics	Short – run F-statistics	Long – run ECT t-statistics	Short - run F-statistics	Long – run ECT t-statistics	Short - run F-statistics
LGDP→LEC	-	-	5.407*	2.316 (+)	−6.709*	3.708* (+)
LEC→LGDP	−4.370*	1.351 (+)	−2.445*	7.073* (+)	−2.356*	4.510* (+)

*Indicates significance at the 5% level. The parenthesis implies the sum of the coefficients. ECT: Error correction term, LGDP: Log of GDP, LEC: Log of energy consumption, GDP: Gross domestic product

was obtained for upper-middle income in long run and for high-income country groups, which implies that feedback hypothesis is supported for these countries. The adopting of tightening polices on consumer demand for energy resources and refinement the necessary technology to minimize environmental degradation may be beneficial for these countries.

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APPENDIX

Appendix Tables

Table A1: Summary of the empirical studies on the energy consumption – economic growth relationship

Author	Period	Country	Method	Result
Kraft and Kraft (1978)	1947-1974	USA	Granger causality	GD→EC
Masih and Masih (1996)	1955-1990	India, Pakistan, Indonesia, Malaysia, Singapore, Philippines	Co-integration, VECM, Granger causality	EC→GDP (India) GDP→EC (Indonesia) GDP↔EC (Pakistan) EC - - GDP (Malaysia, Singapore, Philippines)
Masih and Masih (1997)	1955-1991 1952-1992	Korea, Taiwan	Co-integration, VECM, variance decomposition	EC→GDP (Korea) GDP↔EC (Taiwan)
Glasure and Lee (1998)	1961-1990	South Korea, Singapore	Co-integration, Granger causality	EC - - GDP (South Korea) EC→GDP (Singapore)
Cheng and Lai (1997)	1955-1993	Taiwan	Co-integration, Hsiao's Granger causality	GDP→EC
Asafu-Adjaye (2000)	1973-1995 1971-1995	India, Indonesia, Thailand, Philippines	Co-integration, VECM, Granger causality	EC→GDP (India, Indonesia) GDP↔EC (Thailand, Philippines)
Fatai et al. (2004)	1960-1999	New Zealand, Australia	ARDL, Toda-Yamamoto (1995), Granger causality	EC - - GDP
Soytas and Sarı (2003)	1950-1992	16 emerging countries, G7	Co-integration, Granger causality	GDP→EC (Italy, Korea) EC→GDP (Turkey, France, Germany, Japan) EC↔GDP (Argentina)
Paul and Bhattacharya (2004)	1950-1996	India	Co-integration, Granger causality	GDP↔EC
Oh and Lee (2004a)	1981-2000	Korea	Co-integration, VECM, Granger causality	Short run: EC - - GDP Long run: GDP→EC
Oh and Lee (2004b)	1970-1999	Korea	Co-integration, VECM, Granger causality	Short run: EC→GDP Long run: EC↔GDP
Ghali and El-Sakka (2004)	1961-1997	Canada	Co-integration, VECM, Granger causality	GDP↔EC
Lee (2005)	1975-2001	18 emerging countries	Co-integration, VECM, Granger causality	EC→GDP (South Korea, Singapore, Argentina, Chile, Colombia, Mexico, Peru, Venezuela, Indonesia, Malaysia, Philippines, Thailand, India, Pakistan, Sri Lanka, Kenya)
Lee (2006)	1960-2001	11 developed country	Granger causality	EC→GDP (Canada, Belgium, Netherlands, Switzerland) GDP→EC (France, Italy, Japan) GDP↔EC (USA) EC - - GDP (Germany, England, Sweden)
Al-Iriani (2006)	1971-2002	6 Gulf Cooperation Council countries	Co-integration, GMM, Granger causality	GDP→EC (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, UAE)
Dinda and Coondoo (2006)	1960-1990	88 county panel	Co-integration, VECM, Granger causality	GDP↔EC (CO_2 emission)
Mehrara (2007)	1971-2002	11 oil exporting countries	Co-integration, VECM, Granger causality	GDP→EC (Iran, Kuwait, Saudi Arabia, UAE, Bahrain, Oman, Nigeria, Algeria, Mexico, Venezuela, The Republic of Ecuador)
Narayan and Smyth (2008)	1972-2002	G7	Pedroni (1999) and Westerlund (2006) co-integration, VECM, Granger causality	Long run: EC→GDP

(Contd...)

Table A1: ***(Continued)***

Author	Period	Country	Method	Result
Lee and Chang (2008)	1971-2002	16 Asian countries	Co-integration, VECM, Granger causality	EC→GDP (China, Hong Kong, India, Indonesia, Iran, Japan, Jordan, South Korea, Malaysia, Pakistan, Philippines, Singapore, Sri Lanka, Syria, Thailand, Turkey)
Wolde-Rufael (2009)	1971-2004	17 African countries	Variance decomposition, Toda-Yamamoto	GDP→EC (Egypt, Ivory Coast, Morocco, Nigeria, Senegal, Sudan, Tunisia, Zambia) EC→GDP (Algeria, Benin, South Africa) EC↔GDP (Gabon, Ghana, Togo, Zimbabwe) EC - - GDP (Cameroon, Kenya)
Chiou-Wei et al. (2008)	1954-2006	Emerging Asian countries, USA	Co-integration, VECM, VAR, linear Granger causality, BDS, Nonlinear Granger causality	Linear causality: GDP→EC (Taiwan, Philippines) EC→GDP (Hong Kong, Indonesia) EC↔GDP (Malaysia, Singapore) EC - - GDP (South Korea, Thailand, USA) Nonlinear Causality: EC→GDP (Taiwan, Hong Kong) GDP→EC (Philippines, Singapore) EC↔GDP (Indonesia) EC - - GDP (Thailand, USA)
Chontanawat et al. (2008)	1971-2000	30 OECD 78 non OECD	ARDL, VAR, Hsiao-Granger causality	EC→GDP (21 OECD countries out of 30 and 36 non-OECD countries from 78)
Akinlo (2008)	1980-2003	11 Sub-Sahara African countries	ARDL, Granger causality	GDP→EC (Sudan, Zimbabwe, Zambia, Ghana, Senegal, Congo) EC - - GDP (Cameroon, Ivory Coast, Nigeria, Kenya, Togo)
Huang et al. (2008a)	1971-2002	82 countries	Threshold regression approach	EC→GDP (48 countries)
Huang et al. (2008b)	1972-2002	82 countries	GMM-SYS	GDP→EC (middle and high income groups countries) EC - - GDP (low income groups countries)
Apergis and Payne (2009)	1980-2004	6 Central America	Co-integration, VECM, Granger causality	EC→GDP (Republic of Panama, Costa Rica, the Republic of El Salvador, Guatemala, Honduras Republic, the Republic of Nicaragua)
Odhiambo (2009a)	1971-2006	Tanzania	ARDL, Granger causality	EC→GDP
Ozturk et al. (2010)	1971-2005	51 countries	ARDL, Granger causality	Long run: GDP→EC (low income group countries) GDP↔EC (upper middle income and lower middle income groups countries)
Wang et al. (2011)	1995-2007	China	Co-integration, VECM, Granger causality	GDP↔EC
Belke et al. (2011)	1981-2007	25 OECD countries	Co-integration, VECM, Granger causality	EC↔GDP

(Contd...)

Table A1: ***(Continued)***

Author	Period	Country	Method	Result
Al-Mulali and Sab (2012)	1980-2008	33 Sub Saharan African	Co-integration, VECM, Granger causality	EC↔GDP (Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Ethiopia, Gabon, Gambia, Ghana, Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritius, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Swaziland, Togo, Zambia)
Omri (2013)	1990-2011	14MENA countries	GMM	EC↔GDP (Algeria, Bahrain, Egypt, Iran, Jordan, Kuwait, Lebanon, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, UAE)
Herrerias et al. (2013)	1995-2009	Chinese Regions	Co-integration, VECM, Granger causality	GDP→EC
Ouedraogo (2013)	1980-2008	ECOWAS countries	Co-integration, VECM, VAR, Granger causality	Short run: GDP→EC Long run: EC→GDP (Benin, Burkina Faso, Cape Verde, Zambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, Togo)
Apergis and Payne (2014)	1990-2013	MENA countries	Co-integration	EC→GDP
Omay et al. (2014)	1977-2007	G7	Nonlinear co-integration, Granger causality STR	EC↔GDP
Basci et al. (2015)	1990-2011	Central Asia and Azerbaijan	Westerlun (2007) co-integration	EC - - GDP
Alaali et al. (2015)	1981-2009	130 countries	GMM	EC→GDP

GDP: Gross domestic product, VECM: Vector error-correction model, ARDL: Auto regressive distributed lag, GMM: Generalized method of moment, OECD: Organization for economic co-operation and development, VAR: Vector autoregressive, EC: Energy consumption

Table A2: Summary of the empirical studies on the electric consumption – economic growth relationship

Author	Period	Country	Method	Result
Jumbe (2004)	1970-1999	Malawi	Co-integration, Standard Granger causality, Hsiao Granger causality	ELC↔GDP (standard Granger causality) GDP→ELC (VECM Granger causality)
Wolde-Rufael (2006)	1971-2001	17 African countries	ARDL, Toda-Yamamoto (1995), VAR, Granger causality	GDP→ELC (Cameroon Ghana, Nigeria, Senegal, Zambia, Zimbabwe) ELC→GDP (Tunisia, Benin, Republic of Congo) ELC↔GDP (Egypt, Gabon, Morocco) ELC - - GDP (Algeria, Kenya, Sudan, South Africa, Democratic Republic of Congo)
Altinay and Karagol (2005)	1950-2000	Turkey	Dolado-Lutkepohl, Granger causality	ELC→GDP
Squalli (2007)	1980-2003	OPEC	ARDL, Toda-Yamamoto (1995), Granger causality	GDP→ELC (Algeria, Iraq, Libya) ELC↔GDP (Iran, Qatar, Venezuela) There is not clear evidence about the direction of this relationship (Indonesia, Kuwait, UAE, Saudi Arabia, Nigeria)
Yoo (2006)	1971-2002	Southeast Asia countries	Co-integration, standard Granger causality, Hsiao Granger causality	ELC↔GDP (Malaysia, Singapore) GDP→ELC (Indonesia, Taiwan)
Narayan and Singh (2007)	1971-2002	Fiji Islands	Co-integration, Granger causality	ELC→GDP

(Contd...)

Table A2: ***(Continued)***

Author	Period	Country	Method	Result
Ho and Siu (2007)	1966-2002	Hong Kong	Co-integration, Granger causality	ELC→GDP
Chen et. al. (2007)	1971-2002	10 Asian countries	Pedroni panel co-integration, (1999, 2004), (HDM) Granger causality	GDP→ELC (India, Korea, Malaysia, Philippines, Singapore) ELC→GDP (Indonesia) ELC - - GDP (China, Taiwan, Thailand) ELC↔GDP (10 countries Panel)
Narayan and Prasad (2008)	1970-2002	30 OECD	Bootstrapped causality	GDP→ELC (Hungary, Netherlands, Finland) ELC→GDP (Australia, Italy, Slovakia, Czech Republic, Portugal) ELC↔GDP (England, Korea, Iceland) ELC - - GDP (remained 19 countries)
Tang (2008)	1972-2003	Malaysia	ARDL, Toda-Yamamoto (1995), (VAR) Granger causality	ELC→GDP
Ghosh (2009)	1970-2006	India	Co-integration, VAR, Granger causality	GDP→ES
Odhiambo (2009b)	1971-2006	South Africa	Co-integration, VECM	GDP↔ELC
Narayan and Smyth (2009)	1974-2002	Iran, Israel, Kuwait, Oman, Saudi Arabia and Syria	Co-integration, VECM, Granger causality	ELC→GDP
Tan and Tang (2013)	1970-2009	Malaysia	VAR, Granger causality	GDP↔ELC
Telatar (2015)	1960-2013	130 countries panel	ARDL, Granger causality	GDP→ES (high, upper middle income and lower middle income groups countries) ELC - - GDP (low income group countries)

GDP: Gross domestic product, VECM: Vector error-correction model, ARDL: Auto regressive distributed lag, OECD: Organization for economic co-operation and development, VAR: Vector autoregressive, ELC: Electricity consumption

Table A3: List of the analyzed countries

S. No.	Upper middle income	Lower middle income	High income	Low income
1	Albania	Bangladesh	Argentina	Benin
2	Algeria	Bolivia	Australia	Dem. People's Rep. of Korea
3	Azerbaijan	Cameroon	Austria	Dem. Rep. of the Congo
4	Brazil	Congo, Dem. Rep.	Bahrain	Eritrea
5	Bulgaria	Egypt	Belgium	Ethiopia
6	China	El Salvador	Britain	Haiti
7	Dominican Rep.	Ghana	Brunei Darussalam	Mali
8	Equator	Guatemala	Canada	Mozambique
9	Gabon	Georgia	Chile	Nepal
10	Jamaica	India	Croatia	Tanzania
11	Jordan	Indonesia	Cyprus	Togo
12	Iranian	Ivory Coast	Czech Rep.	Zimbabwe
13	Iraq	Honduras	Denmark	
14	Colombia	Kenya	Estonia	
15	Costa Rica	Morocco	Finland	
16	Cuba	Nicaragua	France	
17	Lebanon	Nigeria	Germany	
18	Libya	Pakistan	Greece	
19	Mauritius	Philippines	Hong Kong	
20	Malaysia	Senegal	Hungary	
21	Mexican	Sri Lanka	Iceland	
22	Namibia	Sudan	Ireland	
23	Panama	Syria	Israel	
24	Paraguay	Ukraine	Italy	
25	Peru	Vietnamese	Japan	
26	Romania	Yemen	Korea Rep.	
27	South Africa	Zambia	Kuwait	
28	Thailand		Latvia	
29	Tunisian		Lithuanian	

(Contd...)

Table A3: ***(Continued)***

S. No.	Upper middle income	Lower middle income	High income	Low income
30	Turkey		Luxembourg	
31			Netherlands	
32			Norway	
33			New Zealand	
34			Oman	
35			Poland	
36			Portugal	
37			Russia	
38			Singapore	
39			Slovak Rep.	
40			Slovenia	
41			Saudi Arabia	
42			Spain	
43			Swedish	
44			Swiss	
45			Train	
46			Trinidad and Tobago	
47			UAE	
48			Uruguay	
49			USA	
50			Venezuela	