Economic Growth and Energy Consumption for OECD Countries

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Abstract Following the nineteenth century, energy became an important and indispensable input to production and consumption activities in all over the world. In the meantime, energy has become a very determinant factor for growth for national economies. In this study, we aim to examine the relationship between energy consumption and economic growth for OECD countries. Panel data method and co-integration tests will be employed to analyze OECD member countries over the period 1960–2014. GDP per capita will be the proxy for the energy consumption and economic growth capita will be taken for energy consumption on an annual basis.

Keywords Economic growth • Energy consumption • Panel data analysis • Cointegration test

1 Introduction

Energy plays a vital role in the process of economic growth and development of a nation. In the absence of sufficient energy industry, transport and social life are subject to fail. Energy products constitute the largest cost item in the production processes in the modern economy. Being unable to meet the energy demand due to population growth, industrialization and rising living standards can cause social, political and military conflicts.

The increase in the world's primary energy consumption, respectively, is 2.0% in 2013 and 0.9% in 2014. The average primary energy consumption of the world in the last decade is 2.1%. In 2014, primary energy consumption growth is at least as low as during the past 10 years. OECD countries' primary energy consumption has shown a growth rate below historical growth.

Table 1 shows us the distribution of primary energy consumption in 2014. We can see the utilization of primary energy sources for the regions shows proportions

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Table 1 World primary energy consumption (2014)

Region	Oil (Mt)	Natural gas (Mtoe)	Coal (Mtoe)	Nuclear energy (Mtoe)	Hydro-Electricity (Mtoe)	Renew-ables (Mtoe)	Total	Percent (%)
Total North America	1024.40	866.30	488.90	216.10	153.50	73.60	2822.60	22
Total S. and Cent. America	326.50	153.10	31.60	4.70	155.40	21.50	692.80	5
Total Europe and Eurasia	858.90	908.70	476.50	266.10	195.70	124.40	2830.30	22
Total Middle East	393.00	418.60	9.70	1.00	5.20	0.30	827.90	6
Total Africa	179.40	108.10	98.60	3.60	27.50	2.90	420.10	3
Total Asia Pacific	1428.90	610.70	2776.60	82.50	341.60	94.20	5334.60	41
Total World	4211.10	3065.50	3881.80	574.00	879.00	316.90	12928.40	
Percent (%)	33	24	30	4	7	2		

Note: Mtoe is means "Million Tonnes of Oil Equivalent"
Source: BP (2015)

of 22% in North America, 5% in S. and Cent. America, 23% in Europe and Eurasia, 6%, in Middle East,%3 in Africa, 41% in Asia Pacific region. In 2014, oil which is the largest share of the world consumption of primary energy resources constituted 33% of whole consumption. Oil consumption is followed by coal, which is 30% of the world consumption. Natural gas is the third with 24% of primary energy consumption. 87% of world primary energy consumption is supplied by these three energy items, as a fossil source of energy.

The use of energy as a global trade goods in the ready of economic development and growth is not only requirement but highly important. Energy plays a vital part in advancing an economic system on supply and demand side. Where, on the supply side, energy is a fundamental component of production in as well as to labor, capital and materials and it appears also to play a prevailing part in the social and economic development of rural areas (Azam et al. 2015). While, on the demand side, energy being a significant merchandise of consumers, they determine to get it in order to maximize their benefits. The study further added that all these advise that there should be a causal linkage running from gross domestic product (GDP) to energy consumption as well as vice versa.

The significance of energy as an input in the development and growth process obtained more eminence following the oil price increases in 1973/1974 and 1978/1979 than at any other time. Afterwards, a notable volume of research-most of it in developed countries, mainly because of the large role energy and energy based inputs play in their production processes -has studied the relationship between economic growth and energy (Reddy 1998).

There are two contrast perspectives about the relationship between economic growth and energy consumption. First perspective proposes that energy consumption is affecting economic growth low-grade. Second perspective proposes that there is no relation between energy and economic growth. This is described as the 'neutrality hypotheses' in the literature. By the way energy consumption is thinkable key factor on economic growth. When the economy grows, it is likely to shift toward non-energy-intensive activities, which are the form of production (Mehrara 2007).

There have been many studies on energy consumption and economic growth so far. The relationship between energy consumption and economic growth is analyzed using data of a single country or of a group of countries. This study examines the relationship between GDP per capita and electricity consumption per capita for 20 OECD member countries (Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States and Italy) by using panel data methodology for the time period 1962–2012.

This study consists of five sections. The first part is about global energy outlook and the importance of relation between economic growth and energy consumption. The second part presents the literature review on the economic growth and energy consumption. Section 3 explains the data and methodology. In the fourth section of the study, empirical results are presented. Last section concludes the paper.

2 Literature Review

Relationship between economic growth and energy consumption has been widely studied in latest literature (Pablo-Romero and De Jesus 2016). There have been 51 economic studies about the relationship between of energy consumption and economic growth at least in the last 20 years (Menegaki 2014). This relationship has been analyzed for diverse countries. The literature offers inconsistent results on the relationship between economic growth and energy consumption after the pioneering work of Kraft and Kraft (1978). As pointed out by Toman and Jemelkova (2003), the lack of consensus may be due to the heterogeneity in climate conditions among countries, the changing energy consumption models, the structure and stages of economic development within a country and among countries, the variant econometric methodologies employed, the existence of omitted variable bias, and varying time horizons.

Joyeux and Ripple (2011) studied panel data technique to analyze the relations between income and three energy consumption series for 30 OECD and 26 - non-OECD countries. They found of causality flowing from income to energy consumption for developing and developed countries. Lee and Chang (2008) employed panel cointegration technique to examine the relationships among GDP, energy consumption and capital for 22 OECD and 16 Asian countries. They found a long-run causal relationship from energy consumption to GDP. Belke et al. (2011) indicated the presence of a bidirectional causal relationship between energy consumption and economic growth for 25 OECD countries. Costantini and Martini (2010) analyzed the causal relationship between economy and energy by adopting a Vector Error Correction Model cointegrated panel data for developing and developed countries. They found that real GDP growth drives energy consumption. Chontanawat et al. (2008) tested for causality between energy and GDP using a consistent data set and methodology for over 100 countries. They found that the causality from energy to GDP more prevalent in developed countries compared to the developing countries.

Recent studies of Chiou-Wei et al. (2008), Huang et al. (2008), and Fallahi (2011), among others, suggest that the relationship between economic variables and energy consumption might be innately non-linear. The irreconcilable findings of empirical studies make it troublesome to suggest a certain policy recommendation for OECD countries. Most previous studies did not consider the changing of causality direction, which may be due to such as business cycles, wage rates, energy crises, and structural reforms as stated by Fallahi (2011) and this creates room for a frequency-based rather than a conventional causality analysis between economic growth and energy consumption.

3 Data and Methodology

Data set covers the period from 1962 to 2012 for 20 OECD countries leading to 51 observations on annually basis. GDP per capita and electric power consumption (kWh per capita) data have been obtained from World Bank data base. Excel 2010 and E-Views 8.0 package programs have been used for processing the data and implementation of econometric analyses.

Panel data analyses embody information across both time and space. By using this approach we can bring to light the expected values and relationship between macroeconomic variables. Importantly, a panel keeps the same objects or entities and measures some quantity about them over time. Therefore we can put together observations for individuals, countries, firms and other entities for a specific period of time (Tatoğlu 2012).

Economic data are often non-stationary or have means, variances and covariances that change over time. A statistical analysis for a time series should be done whether it has a constant mean over time. The use of non-stationary data can lead to spurious regressions. If two variables are non-stationary, a regression of one on the other could have a high R2 even if the two are totally unrelated. So, if standard regression techniques are applied to non-stationary data, the end result could be a regression that looks good but fundamentally they are valueless. Such a model would be termed a spurious regression.

Recent literature recommends that panel-based unit root tests have superior power than unit root tests based on individual time series (DF, ADF, PP, KPSS)[1]. While these tests are widely termed "panel unit root" tests, theoretically, they are simply multiple-series unit root tests that have been analyzed to panel data structures. These tests can be done for multiple series.

In this study, Levin, Lin and Chu *unit root tests* and Fisher ADF and Fisher Philips and Perron *panel unit root tests* are employed. Levin et al. (2002) panel unit root test assumes that each unit has the same autoregressive parameter. In other words, they propose a test which has an alternative hypothesis that the $\boldsymbol{\rho_i}$ are identical. Because $\boldsymbol{\rho_i}$ is fixed across i, this is one of the most sophisticated of the tests because the data from the varied individuals need to be unified into a single final regression. Three models can be applied:

$$Model\ 1: \Delta Y_{it} = \rho Y_{it-1} + u_{it} \tag{1}$$

$$Model\ 2: \Delta Y_{it} = \alpha_{0i} + \rho Y_{it-1} + u_{it} \tag{2}$$

$$Model\ 3: \Delta Y_{it} = \alpha_{0i} + \alpha_{0i} t + \rho Y_{it-1} + u_{it} \tag{3}$$

The Fisher-ADF and PP panel unit root tests let for individual unit root processes so that $\boldsymbol{\rho_i}$ may vary across cross-sections. The tests are all characterized by the

[1] Levin et al. (2002), Breitung (2000), Im et al. (2003), Fisher-type tests using ADF and PP tests (Maddala and Wu (1999) and Choi (2001), and Hadri (2000).

assemblying of individual unit root tests to derive a panel-specific result. Panel unit root tests are similar, but not same, to unit root tests carried out on a single series. Fisher tests use unit root tests for each entity and then p-values obtained from these tests constitute the basis for executing the whole test.

Levin, Lin, and Chu tests assume that there is a usual unit root process so that $\boldsymbol{\rho_i}$ is similar across cross-sections. According to the null hypothesis, there is a unit root, while under the alternative, there is no unit root. The LLC method necessitates an identification of the number of lags used in each cross-section ADF regression. On top of it, the exogenous variables used in the test equations must be specified. There is an option to embody no exogenous regressors, or to embody individual constant terms (fixed effects), or to employ individual trends and constants.

An alternative solution near to panel unit root tests uses fisher's results to derive tests that relate the p-values from individual unit root tests. This idea has been offered by Maddala and Wu (1999) and by Choi (2001). The exogenous variables for the test equations and the number of lags employed in each cross-section ADF regression must be particularized for Fisher tests. Since Fisher tests allows us to use unbalanced panel data, they are more flexible.

Once you have been able to separate your variables as stationary, we are in position to classify long-run and short-run set up in your model, and to set up a model where statistical presumption will be significant.

The prevalent relevance in and the availability of panel data has led to an accenting on stretching several statistical tests to panel data. Ultimate literature has focused on tests of cointegration in a panel setting (Pedroni 1999, 2004; Kao 1999 and a Fisher-type test using an underlying Johansen methodology Maddala and Wu 1999).

Pedroni (1999) enlarged his panel cointegration testing steps for the models, where there are more than one independent variable in the regression equation. The Kao test follows the same basic approach as the Pedroni tests, but specifies cross-section specific intercepts and homogeneous coefficients on the first-stage regressors. Kao (1999) Panel Cointegration tests are based on DF (Dickey Fuller) and ADF (Augmented Dickey Fuller) tests. Under the null hypothesis, there is no cointegration ($H_0 : \rho = 1$).

$$y_{it} = X_{it}\beta + z_{it}\gamma + \varepsilon_{it} \tag{4}$$

Based on the results obtained from cointegration analyses for panel data, panel causality tests are employed. In order to perform a causality test a Vector Error Correction Model can be predicted by using VAR.

4 Empirical Results

In this analysis, GDP per capita and electric power consumption per capita data have been used for 20 OECD member countries and all data have been obtained from World Bank data base. Panel data analysis has been employed to investigate whether there is a relationship between GDP per capita and electric power consumption in the countries.

Levin et al. (2002) ADF, PP panel unit root tests have been conducted for the set of variables to see whether they are stationary or not.

In Table 2 above stationarity level results for two variables are shown. Under these hypotheses,

H_0: Variable is non-stationary. There is unit root.
H_1: Variable is stationary. There is not unit root.

The null hypothesis cannot be rejected for GDP per capita with intercept, with intercept and trend at 1% significance level. Moreover, for electric power consumption variable the null hypothesis cannot be rejected with constant and trend at 1% significance level. Since they are not stationary, stationarity process has to be employed.

When we take the first difference, both variables become stationary at 1% significance level as shown in Table 3. At this stage of the study, a cointegration test has been conducted to see the relationship between two variables. The results are shown in Table 4:

Under the null and alternative hypotheses,

H_0: There is no cointegration
H_1: There is cointegration

Table 2 Results of unit root test (level values)

Unit root test type	Include in test equation	GDP per capita (current US$)	Variables Electric power consumption (kWh per capita)
Levin, Lin and Chu	Individual intercept	4.786	−6.111
		(1.000)	(0.000)
	Individual intercept and trend	–1.143	7.047
		(0.126)	(1.000)
ADF-Fisher Chi-square	Individual intercept	3.318	75.671
		(1.000)	(0.006)
	Individual intercept and trend	40.945	14.802
		(0.428)	(0.999)
PP-Fisher Chi-square	Individual intercept	1.381	77.081
		(1.000)	(0.004)
	Individual intercept and trend	25.598	10.662
		(0.962)	(1.000)

Table 3 Results of unit root test (first difference)

Unit root test type	Include in test equation	GDP per capita (current US$)	Variables Electric power consumption (kWh per capita)
Levin, Lin and Chu	Individual intercept	−16.608	−9.152
		(0.000)	(0.000)
	Individual intercept and trend	−17.062	−12.340
		(0.000)	(0.000)
ADF-Fisher Chi-square	Individual intercept	341.99	191.89
		(0.000)	(0.000)
	Individual intercept and trend	297.87	240.15
		(0.000)	(0.000)
PP-Fisher Chi-square	Individual intercept	385.33	458.78
		(0.000)	(0.000)
	Individual intercept and trend	333.29	486.24
		(0.000)	(0.000)

Table 4 Panel cointegration test results

Test type	Test statistics	GDP per capita dependent variable		Electric power consumption per capita dependent variable	
		Statistic	Prob.	Statistic	Prob.
Pedroni (Engle-Granger Based)	Panel v-Statistic	−0.6666	0.7475	−2.0515	0.9799
	Panel rho-Statistic	−26.379	0.0000	−26.392	0.000
	Panel PP-Statistic	−18.218	0.0000	−18.293	0.000
	Panel ADF-Statistic	−16.949	0.0000	−17.696	0.000
	Grup rho-Statistic	−20.874	0.0000	−26.664	0.000
	Grup PP-Statistic	−18.438	0.0000	−21.488	0.000
	Grup ADF-Statistic	−16.438	0.0000	−16.395	0.000
Kao (Engle-Granger Based)	ADF	3.0050	0.0013	8.8417	0.000

Pedroni test statistics confirm with majority that the cointegration relationship exists. (six out of seven test statistics). Kao cointegration test statistics also confirm the same results at 5% significance level. In other words, the analysis affirms that GDP per capita in OECD countries and electric power consumption per capita are cointegrated in the long run and they move together. Granger causality test results are shown in Table 5.

When we examine the results, we conclude that two variables are affecting each other. GDP per capita causes Electric Power consumption and the vice versa is also valid. According to this result, if GDP "Granger-causes" electric power consumption, then past values of GDP should contain information that help spredict electric consumption above and beyond the information contained in past values of electric power consumption per capita alone.

Table 5 Granger causality-block exogeneity Wald test results

	Dependent	Independent	Chi-square	Prob.	Direction
Models	First difference of GDP per capita (current US$)	First difference of electric power consumption (kWh per capita)	52.9706	0.0000	Unidirection
	First difference of electric power consumption (kWh per capita)	First difference of GDP per capita (current US$)	80.3349	0.0000	Unidirection

5 Conclusion

There are many research papers on searching the relationship between economic growth and energy consumption with mixed findings. Some of them support and claim that energy consumption leads an economic growth, and many other analyses claim that economic growth leads energy consumption. In some research, we find a bilateral relationship between the set of variables. In this study, we investigate the relationship between energy consumption and economic growth for OECD countries. Panel data method and co-integration tests have been employed. At the first stage of the study, the stationarity transformation has been made by taking the first difference of the variables and then cointegration and Granger causality tests are applied to GDP and energy consumption data for 20 OECD countries over the period 1960–2014.

GDP and energy consumption per capita variables are cointegrated and Granger cause each other. First conclusion would be that energy consumption per capita affects GDP per capita. In other words, a growth or reduce in energy consumption will increase or decrease GDP. Energy consumption plays an important role on economic growth, directly on labor and capital component and indirectly on production process as well. Electric consumption is an incentive factor and indispensable insurance for a sustainable economic growth. Second conclusion would be that GDP per capita affects energy consumption per capita. That is, an increase or decrease GDP per capita will increase or decrease energy consumption per capita. Developing countries that are increasing their aggregate GDP and their production are subject to demand more and more energy sources. Countries that are in short providing the appropriate energy demand will be importing energy. This might eventually cause current and trade deficit.

Another result of the increase in energy consumption due to the economic growth is that it comes with environmental problems. The exploitation of fossil fuels as a source of energy consumption increases carbon emissions. The largest contribution to the provision of energy demand without increasing carbon emissions will be provided by renewable energy sources. While developing and developed countries are making economic progress, they should consider using renewable energy sources so that they will at least reduce most costly environmental problems.

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