Business and Economics Research Journal
Volume 7 Number 4 2016
pp. 1-15
ISSN: 1309-2448
DOI Number: 10.20409/berj.2016422335

The Relationship between Aggregated–Disaggregated Energy Consumption and Economic Growth in Turkey[1]

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Abstract: *Energy is recognized as an important factor in the production process by capital and labor. Energy consumption has increased substantially in the world, especially since the Industrial Revolution and the 1973 oil crisis. In this study, the causality relationship between energy consumption (petroleum, electricity, per capita and total primary energy consumption, carbon dioxide emissions) and economic growth is estimated by using the JJ cointegration test, DLVAR, generalized impulse-response, and variance decomposition analyses for the Turkish economy for the 1972–2011 period. According to the results of the JJ cointegration test, there is no co-movement between energy consumption and economic growth in the long run, but the DLVAR analysis indicates that energy is an important input for the Turkish economy's steady growth in the short run. The findings lead to the conclusion that a positive unidirectional causality runs from petroleum, electricity, primary energy consumption, and carbon dioxide emissions to economic growth in the short run. The results of generalized impulse-response and variance decomposition analyses also support the results of the DLVAR analysis.*

Keywords: Energy Consumption, Economic Growth, Dolado-Lütkepohl VAR, Causality, Turkey

JEL Classification: C22, Q40, Q43

1. Introduction

Energy has become a vital resource for generating mechanical power in the economic development process since the Industrial Revolution in the late 18th century. The Industrial Revolution initiated technological innovations and mass production techniques as well as contributing a great increase in the demand for labor, capital, and energy resources. Although the Industrial Revolution greatly increased energy demand in the production process, an extensive debate remains as to the role of energy in economic development. In the second half of the 18th century, physiocrats were the first to see energy as a source of power in agriculture, asserting that all energy came from the land, rain, and sun (Ayres, Van den Bergh, Linderberger & Warr, 2013: 81). The neoclassical dominant view contends that energy is an endogen factor in the production process and its role is unimportant in growth. The most of the empirical studies based on the neoclassical model mainly analyzed how economic growth affected energy consumption rather than vice versa. Most neoclassical economists, with the notable exceptions of Jevons and Hotelling, persistently either ignored or lessened the role of energy in such growth and assumed that energy was not a production factor (Yapraklı & Yurttancıkmaz, 2012: 197). Following the oil crises in the 1970s, some economic theories

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considered energy to be a factor in the production of economic resources that contributed to the production of goods and services. Regarding the potential association between energy and growth, many different views have been put forth in the literature. However, today the broadly accepted view is that that energy is an essential resource in the production process. Georgescu-Roegen (1975), in his fund-flow model, pointed out that energy plays a key role in transforming inputs into outputs in the production process. Many economists considered Georgescu-Roegen's fund-flow model to be more advanced than the neoclassical models. Wrigley (1988), Allen (2009), and some economic historians also pointed out that energy has played a key role in economic development and in explaining the different growth pattern after the Industrial Revolution. Stern (2004) developed a modified version of Solow's (1956) neoclassical growth model by adding energy as an input and considered energy as an essential and complementary factor, but not a substitute, for capital and labor factors. In Stern's (2004) general production function: $(Q_1,.....,Q_u)' = f(A, X_1,.....,X_u, E_1,.....,E_u)$ Q_i are different outputs such as goods and services: A is the state of technology; X_i are various inputs such as capital and labor; and E_i are various energy inputs such as oil, electricity, and coal. Except in micro-economic activities in the service sector, all kinds of production methods using labor and capital in macro-economic activities require energy. Energy is not only an exogenous but also an essential factor in the production and growth process, particularly in the service and production sectors, because not only labor and capital, but also energy is a factor in the production function, as indicated in some biophysical production models. In some biophysical models, energy is the most important and primary factor affecting growth, and labor-capital factors are the secondary factors processing energy. According to ecological economists, technological developments and innovations have little effect on efforts to increase productivity, but energy and energy-related resources play a major role in the growth and production process (Stern, 2011: 30).

Since initiating trade liberalization reforms after 1980, Turkey has shifted to a free market economy and accomplished rapid socioeconomic development. According to World Development Indicators (WDI) averages, GDP growth reached nearly 4.2% (5.4%) a year for the 1980–2014 (2010–2014) period. With a population of 78.7 million, Turkey as a newly industrialized developing country was recently ranked as the 17th largest GDP by PPP in the global economy. Turkey's aim is to become one of the top 10 largest economies in the world. In parallel to the rapid economic growth, Turkey has faced fast energy demand growth in all sectors. However, Turkey has limited energy sources, and it is expected to become an energy-dependent country, especially in gas and oil. Today, almost 74% of total energy demand is being met by imports. Energy is not only an important input in the industry, but also relatively important in both agriculture and service sectors in Turkey. Turkey imports approximately 83% of its energy consumption from other countries, and the 70% of its current account deficit (54.1 billion dollars) was driven mostly by energy imports in 2011.

According to BP, Turkey's oil consumption was 724 thousand barrels per day in 2014, accounting for 33.6% of the total primary energy consumption. Total primary energy consumption is 125.3 million tons, equivalent to the consumption of 207 billion gWh of oil and electricity in the same year. Turkey's share of the world's oil consumption, the primary source of energy and electricity, is 1%. Turkey's economy is expanding steadily, and its total final/primary energy demand is the fastest growing one among the developing countries over the last decade. Turkey's oil consumption has increased each year, reaching from 360 (1985) to 720 (2014) kbd/day, while oil production increased from 41 (1985) to 45 (2014) kbd/day. As the world's 27th-largest oil consumer, Turkey increased its oil (natural gas) dependency by nearly 93% (99%), and its shares of oil and natural gas imports are expected to increase in the coming years (BP, 2015: 11-23). Due to its limited domestic energy production, it is evident that Turkey has to increase its level of investment in energy resources in all sectors.

This study analyzes the causality link between energy consumption and economic growth in Turkey. The rest of this study is organized as follows: The second section outlines empirical findings concerning the link between energy and economic development in the previous literature. The third section explains the data set and its statistical characteristics. The fourth section explains the methodology and empirical results. Econometric methods in this study are explained shortly to save space because the details are available in most textbooks. Finally, the fifth part presents a short summary, conclusions, and suggestions for policymakers.

2. Literature Summary

The interrelation between both energy consumption (energy use) (EU) and economic growth (Y) is an important topic in the literature and has been studied in both developed and developing countries. The probable causality relationships in a Granger sense between energy and economic growth in the previous studies can be classified in a four-way relationship: 1) energy causes growth (E→Y), so the energy-led growth (called growth) hypothesis is valid; 2) growth causes energy (Y→E), so the growth-led energy (conservative) hypothesis is valid; 3) growth (energy) causes energy (growth) (Y↔E), so the two-way/feedback hypothesis is valid; and 4) growth (energy) does not cause energy (growth) (Y≠E), so the neutrality (no-way causality) hypothesis is valid. The general view in the literature is that energy consumption and economic activities have a permanent and stable relationship over time. Therefore, the energy conservation policy is harmful and adversely affects economic activities.

Table 1. Energy Consumption and Economic Growth Studies in Literature

Author (Year)	Country	Period	Method	Causality
Kraft & Kraft (1978)	USA	1947-1974	Sims causality	Y→EU
Terzi (1998)	***Turkey***	***1950-1991***	***EG-cointegration, ECM***	***EC↔Y***
Asafu-Adjaye (2000)	India Indonesia, Thailand, Philippines	1973-1995 1971-1995	JJ cointegration, VECM	EU→Y EU↔Y
Aqeel & Butt (2001)	Pakistan	1955-1996	Hsiao causality	EU→EM; EC↔Y Y→OC
Chang, Fang & Wen (2001)	Taiwan	1982M1-1997M11	JJ cointegration, VECM, Hsiao causality, UVAR	EU→Y
Ghali & El-Sakka (2004)	Canada	1961-1997	JJ cointegration, VECM	EU→Y
Oh & Lee (2004)	Korea	1981Q1-2000Q4	JJ cointegration, VECM	Y→EU
Sari & Soytas (2004)	***Turkey***	***1969-1999***	***GEVD***	***EU→Y***
Altinay & Karagol (2005)	***Turkey***	***1950-2000***	***DLVAR Granger causality***	***EC→Y***
Narayan & Smyth (2005)	Australia	1966-1999	Bounds test, ECM	YP→EC YP→EU
Yoo (2006)	Korea	1968-2002	JJ cointegraton, ECM	OC↔Y
Zou & Chau (2006)	China	1953-2002	JJ cointegration, ECM, UVAR	OC→Y
Erbaykal (2007)	***Turkey***	***1970-2003***	***Bounds test, UECM***	***EU→Y***
Lise & Montfort (2007)	***Turkey***	***1970-2003***	***EG cointegration, ECM***	***Y→EU***
Soytas & Sari (2007)	***Turkey***	***1968-2002***	***JJ cointegration, VECM***	***EC→Y***
Aktas & Yilmaz (2008)	***Turkey***	***1970-2004***	***JJ cointegration, ECM***	***OC↔Y***
Yuan, Kang, Zhao & Hu (2008)	China	1963-2005	JJ cointegration, VECM	EC, OC→Y; Y→EU Y→CC; Y→OC
Mucuk & Uysal (2009)	***Turkey***	***1960-2006***	***JJ cointegration, Granger causality***	***EU→Y***
Aytac (2010)	***Turkey***	***1975-2006***	***UVAR***	***Y≠EC***
Fuinhas & Marques (2011)	Portugal	1965-2008	Bounds test, VECM	EU↔Y
Karagol, Erbaykal & Ertugrul (2011)	***Turkey***	***1974-2004***	***Bounds test, ECM***	***EC→Y***
Korkmaz & Yılgör (2011)	***26 countries***	***1980-2004***	***Pedroni Cointegration***	***EC→Y***
Polat, Uslu & San (2011)	***Turkey***	***1950-2006***	***Bounds test, VECM***	***EC→Y***
Yanar & Kerimoglu (2011)	***Turkey***	***1975-2009***	***JJ cointegration, ECM***	***EU→Y***

Aktas & Yilmaz (2012)	***Turkey***	***1970-2004***	***JJ cointegration, ECM***	***EC↔Y***
Fuinhas & Marques (2012)	Portugal	1965-2009	Bounds test, UECM	OC↔Y
Yapraklı & Yurttançıkmaz (2012)	***Turkey***	***1970-2010***	***JJ cointegration, VECM***	***EC↔Y***
Yazdan & Hossein (2012)	Iran	1980-2010	JJ cointegration, ECM	OC↔Y
Akpolat & Altıntas (2013)	***Turkey***	***1961-2010***	***JJ cointegration, VECM***	***Y↔EU***
Altıntas (2013)	***Turkey***	***1970-2008***	***Bounds test, VECM, TY VAR causality***	***I, PEC, YP→CO_2 CO_2↔EU PEC→YP, I***
Baranzini, Weber, Bareit & Mathys (2013)	Switzerland	1970-2010	Bounds test, UECM	Y→OC; Y↔OCH Y→EC; Y→EU
Khan (2013)	Bangladesh	1965-2007	JJ cointegration, TYVAR causality (SUR)	Y↔EU CO_2→Y
Salahuddin & Khan (2013)	Australia	1965-2007	JJ cointegration, UVAR causality	EU↔Y
Vidyarthi (2013)	India	1971-2009	JJ cointegration, VECM	EU→Y CO_2→Y; Y→EU
Aslan (2014)	***Turkey***	***1968-2008***	***Bounds test, ECM***	***Y↔EC***
Bhattacharya & Bhattacharya (2014)	India, China	1980-2010	JJ cointegration, VECM	OC→Y Y↔CC
Linh & Lin (2014)	Vietnam	1980-2010	JJ cointegration, VECM	CO_2↔Y; EU→Y
Mbarek, Ali & Feki (2014)	Tunisia	1980-2010	UVAR causality	Y→CO_2; Y→EU CO_2↔EU
Nasiru, Usman & Saidu (2014)	Nigeria	1980-2011	JJ cointegration, Granger causality	OC→Y
Nonejad & Fathi (2014)	Iran	1971-2009	JJ cointegration, VECM	EU↔Y
Park & Yoo (2014)	Malaysia	1965-2011	JJ cointegration, ECM	OC↔Y
Satti, Hassan, Mahmood & Shahbaz (2014)	Pakistan	1974-2010	Bounds test, VECM	Y↔CC
Shaari, Hussain & Rashid (2014)	Malaysia	1975-2008	JJ cointegration, VECM	EU→Y
Stambuli (2014)	Tanzania	1972-2010	JJ cointegration ECM	Y→OC
Topallı & Alagöz (2014)	***Turkey***	***1970-2009***	***JJ cointegration VECM, TYVAR causality***	***Y→EC***
Vlahinic & Jakovac (2014)	Croatia	1952-2011	Bounds test, JJ cointegration, VECM	EU↔Y EU→Y
Alshehry & Belloumi (2015)	Saudi Arabia	1971-2010	JJ cointegration, VECM	EU→Y, CO_2 CO_2↔Y
Lyke (2015)	Nigeria	1971-2011	JJ cointegration, VECM	EC→Y
Terzi & Pata (2016)	**Turkey**	**1974-2014**	**Hsiao, UVAR, TYVAR causality**	**OC→Y**

Note: CC: Coal consumption, CO_2: Carbon dioxide emission, EC: Electricity consumption, ECM: Error correction model, EG: Engle-Granger, EM: Employment, EP: Energy price, EU: Energy use, GEVD: Generalized variance decomposition, I: Investment, JJ: Johansen-Juselius, OC: Oil consumption, OCH: Oil consumption for heating purposes, OP: Oil price, PEC: Primary energy consumption, TY: Toda-Yamamoto, UECM: Unrestricted error correction model, UVAR: Unrestricted VAR, VECM: Vector error correction model, Y: Gross domestic product, YP: Gross domestic product per capita. → denotes one-way and ↔ denotes two-way causality.

To the best of our knowledge, in their pioneering study, Kraft and Kraft (1978) showed that the causality relationship was only running from economic growth to energy. In the last three decades, many studies have analyzed the causality relationship between Y and EU by using alternative data and estimation procedures. In this section, the findings from a total of 49 studies are listed in Table 1, including 20 studies related to the Turkish economy. The 22 empirical findings from the 20 studies covering the Turkish data examining the causality relationship between growth-related variables (Y, YP, I) and energy-related variables (EU, EC, OC, PEC, CO_2) have been fairly mixed and inconclusive. Ultimately, 15% (45%) of the findings concluded that a one-way causality runs from growth (energy)-related variables to energy (growth)-related variables. In addition, 35% of the findings concluded that a two-way causality exists between the variables. Only 1 out of 20 studies found no causality in either direction between economic growth and total primary energy consumption. The 45 empirical findings from the 29 studies covering 21 countries' data, analyzing the causality relationship between growth-related variables and energy-related variables, were also fairly mixed and inconclusive due to different periods of time, different variables, and different econometric methods used. Furthermore, 33% (31%) of the findings concluded that a one-way causality runs from growth (energy)-related variables to energy (growth)-related variables and 36% of the findings found a two-way causality between the variables. Overall, the studies showed mixed results and demonstrated no consensus on the direction of causality. However, the previous studies have a consensus on the existence of a one-way causality.

3. Data Set and Descriptive Statistics

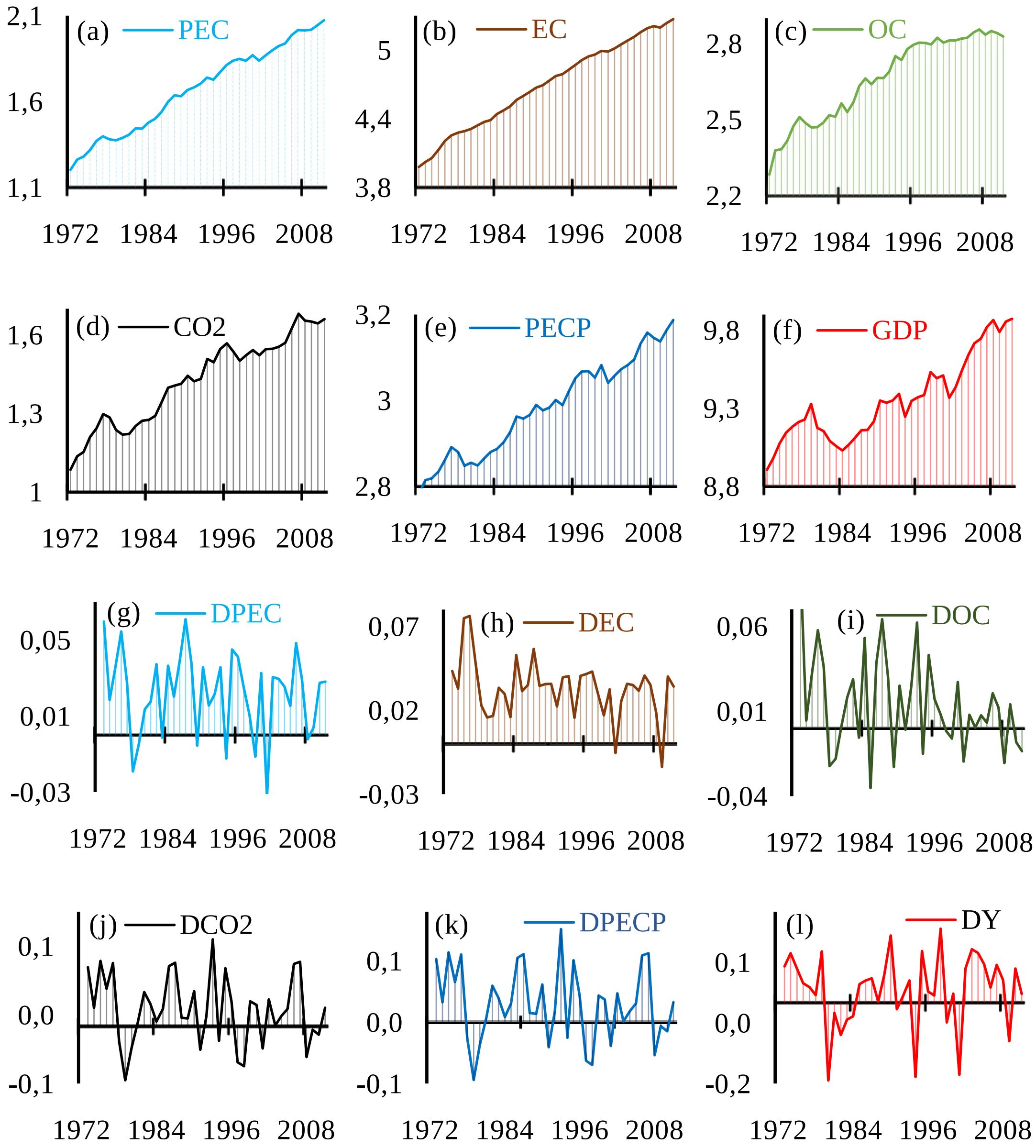
The data set covers the annual time series from 1972 to 2011 for Turkey. Currently, the annual data set is available up to the end of 2011 in the WDI, and all variables are expressed in logarithmic form. The nominal GDP series in millions of current US dollars were deflated by the GDP deflator (using 2009 as the base year). The nominal GDP and GDP deflator, carbon emissions (CO_2) from all transport activity except international marine bunkers and international aviation, in million metric tons; per capita primary energy consumption (PECP), a kilogram of oil equivalent were obtained online from the WDI. The following variables were selected: primary energy consumption (PEC), a million ton equivalent petroleum; oil consumption (OC), in thousand barrels per day, from BP's 2015 statistical workbook and electricity consumption (EC), in GWh, from the TEDAS and Turkstat website.

Table 2. Pearson Correlation Matrix and Descriptive Statistics

Variables	PEC	PECP	EC	OC	CO_2	Y
PEC	1	0.99[a]	0.99[a]	0.98[a]	0.99[a]	0.91[a]
PECP	0.99[a]	1	0.99[a]	0.97[a]	0.97[a]	0.93[a]
EC	0.99[a]	0.99[a]	1	0.98[a]	0.98[a]	0.90[a]
OC	0.98[a]	0.97[a]	0.98[a]	1	0.98[a]	0.84[a]
CO_2	0.99[a]	0.99[a]	0.98[a]	0.98[a]	1	0.89[a]
Y	0.91[a]	0.93[a]	0.90[a]	0.84[a]	0.89[a]	1
Mean	1.66	2.98	4.68	2.66	1.42	9.35
Median	1.69	2.99	4.71	2.67	1.43	9.34
Kurtosis	-0.12	0.02	-0.18	-0.47	-0.24	0.52
Skewness	1.75	1.83	1.83	1.91	1.87	2.28
Jarque-Bera	2.70	2.26	2.47	3.44	2.52	2.67

The Pearson correlation coefficients and a summary of the descriptive statistics are listed in Table 2. The high and positive Pearson's coefficients suggest a definite positive relationship between the variables. There is also a strong linear relationship/correlation (greater than 0.84) between the variables, and the variables move in the same direction. Since the p-values of the JB statistics are higher than 0.10, the null hypothesis is valid, and all variables have a normal distribution. Figure 1 presents how the twelve series behave over time on a logarithmic scale. The time plots of the first differenced variables show that the series are approximately horizontal with constant variance and do not exhibit a unit root in the g, h, i, j, k, and l panels. Increasing variances, means, and covariances of the level variables in the time series plot clearly exhibit a trend and show that the series are nonstationary in the a, b, c, d, e, and f panels.

Figure 1. Level and First Differenced Data Plots of Variables (PEC, EC, OC, CO_2, PECP, GDP)



4. Methodology and Empirical Results

4.1. ADF, PP and ADF-GLS Unit Root Tests

A number of unit root tests based on different assumptions are available in the literature. The Augmented Dickey-Fuller (ADF) (1979), Phillips-Perron (PP) (1988), and ADF-GLS (1996) unit root tests are some of the commonly used tests in the applied studies. The PP test is the most commonly utilized non-parametric alternative test to the ADF test, especially in large samples.

The ADF and PP tests are based on the same OLS regression, but the ADF-GLS test uses GLS regression to detrend the time series before testing whether the time series contains a unit root. Many studies point out that the ADF-GLS test, called the modified DF t-test, has significantly greater power than the ADF and PP tests, especially for small sample sizes. All three unit root tests utilize Davidson-MacKinnon (1996) critical table values. The unit root tests were based on equations (1) and (2) to test the null (alternative) hypothesis H_0: $\psi=0$ (H_1: $\psi\neq0$). The H_0 (H_1) hypothesis is that Y is a random walk (white noise). In equations (1) and (2), there are two alternative H_0 hypotheses: Y is stationary with a constant but no linear time trend and Y is stationary with a constant and a linear time trend, respectively.

$$\Delta Y_t = \alpha_0 + \psi Y_{t-1} + \sum_{i=1}^{k} \sigma_i \Delta Y_{t-i} + \varepsilon_t \quad (1)$$

$$\Delta Y_t = \alpha_0 + \beta t + \psi Y_{t-1} + \sum_{i=1}^{k} \sigma_i \Delta Y_{t-i} + \varepsilon_t \quad (2)$$

where α is a constant term; σ and ψ are the coefficients; t is a linear time trend; Δ is the first difference operator; k is the optimal lag length determined by the Akaike's information criterion (AIC); y_t is the variable of interest, and ε_t is the error term.

Table 3. The Results of ADF, PP and ADF-GLS Unit Root Tests

Tests	ADF		PP		ADF-GLS	
Variables	C	C+T	C	C+T	C	C+T
PEC	-1.10 (0)	-2.72 (0)	-1.12 (2)	-2.80 (1)	1.57 (0)	-2.47 (0)
PECP	-0.47 (0)	-3.07 (0)	-0.42 (3)	-3.07 (0)	1.05 (0)	-3.07 (0)
EC	-2.42 (0)	-2.11 (0)	-2.34 (3)	-2.20 (2)	0.71 (3)	-1.49 (0)
OC	-2.04 (1)	-0.92 (1)	-2.76 (0)	-2.21 (2)	-0.12 (0)	-1.68 (0)
CO_2	-1.56 (0)	-2.70 (0)	-1.54 (2)	-2.70 (0)	0.34 (0)	-2.40 (0)
Y	-0.55 (0)	-1.91 (0)	-0.57 (2)	-2.15 (3)	0.41 (0)	-1.99 (0)
ΔPEC	-6.39 (0)[a]	-6.29 (0)[a]	-6.58 (5)[a]	-6.46 (5)[a]	-2.77 (1)[a]	-5.83 (0)[a]
ΔPECP	-6.36 (0)[a]	-6.27 (0)[a]	-6.48 (4)[a]	-6.39 (4)[a]	-5.15 (0)[a]	-6.06 (0)[a]
ΔEC	-4.55 (0)[a]	-4.91 (0)[a]	-4.53 (2)[a]	-4.79 (4)[a]	-4.40 (0)[a]	-5.04 (0)[a]
ΔOC	-7.38 (0)[a]	-7.83 (0)[a]	-7.42 (2)[a]	-8.52 (6)[a]	-0.82 (2)	-5.85 (0)[a]
ΔCO_2	-5.31 (0)[a]	-5.27 (0)[a]	-5.33 (5)[a]	-5.25 (5)[a]	-4.47 (0)[a]	-5.20 (0)[a]
ΔY	-6.41 (0)[a]	-6.36 (0)[a]	-6.42 (1)[a]	-6.36 (0)[a]	-6.10 (0)[a]	-6.35 (0)[a]

Note: ( ) optimal lag length is selected by the AIC, maximum lag length is 8, n=40, [a] denotes significant at 1% level. MacKinnon (1996) critical table values for the ADF and PP tests: (T) [C+T] 1% (-3.61) [-4.21], 5% (-2.93) [-3.52], 10% (-2.60) [-3,19]. Elliott-Rothenberg-Stock (1996, Table 1) critical table values for the ADF-GLS test: (T) [C+T] 1% (-2.63) [-3.77], 5% (-1.95) [-3.19], 10 % (-1.61) [-2.89].

Table 3 summarizes the unit root test results for the ADF, PP, and ADF-GLS test. Three alternative unit root tests clearly indicate that all variables are nonstationary at the levels. In the first differenced data, the calculated statistics are greater than the critical values. Thus, the null of a unit root hypothesis is rejected at the 1% level, and variables are stationary around a mean and around a linear time. Therefore, variables are stationary and integrated of the same order d(I(1)).

4.2. Johansen-Juselius (JJ) Cointegration Test

In the first step, unit root tests indicate that all variables are stationarity at the first/same order of integration I(1). Since all variables are integrated I(1), this justifies the use of the JJ approach to cointegration. In the second step, this study applies the JJ cointegration method (1990) called as max eigenvalue and trace tests. The JJ cointegration tests based on the VAR model and have more advantages than the EG cointegration test (Sevüktekin & Çınar, 2014: 581). The JJ cointegration test is based on two kinds of tests: the trace test and the max eigenvalue test as shown in equation 3. T is the sample size, $\dot{\lambda}_i$ is the ith largest canonical correlation of Δy_t with y_{t-1}.

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{u} \ln(1-\dot{\lambda}_i); \quad \lambda_{max}(r, r+1) = -T \ln(1-\dot{\lambda}_{r+1}) \quad (3)$$

The null hypothesis (H_0: r=0, no cointegration) is tested against the alternative hypothesis (H_1: r>0, cointegration). If trace or max-eigen statistics are greater than the critical value, for rank k, then the H_0 hypothesis that the cointegration rank is equal to k is rejected.

The details of the tests and critical values can be found in Johansen and Juselius (1990). First, the model requires selecting an optimal lag of the VAR model before performing the JJ cointegration test. The optimal lag lengths under the usual criteria (LR, FPE, SIC, and HQ) for the cointegration test covering the four variables (EC-OC-CO_2-Y) are selected 1, as shown in Table 4. Except for AIC, all other criteria indicate the same optimal lag length.

Table 4. Optimal Lag Length for JJ Cointegration Test (EC-OC-CO_2-Y)

Lag	LR	FPE	AIC	SIC	HQ
0	NA	7.58e-10	-9.64	-9.47	-9.58
1	**273.50***	**2.09e-13***	-17.85	**-16.97***	**-17.54***
2	18.63	2.65e-13	-17.65	-16.05	-17.10

Note: * Denotes optimum lag order selected by the criterion

Table 5. The Results of JJ Cointegration Test (Two Variable Models)

Model	H_0	Lag	Trace Statistics	Critical Value 5%	λ-Max Statistics	Critical Value 5%
Y	r=0	1	13.90	25.90	10.20	19.40
CO_2	r≤1		3.75	12.50	3.75	12.50
Y	r=0	1	7.27	15.50	5.07	14.30
OC	r≤1		2.20	3.84	2.20	3.84
Y	r=0	1	8.12	15.50	6.00	14.30
EC	r≤1		2.12	3.84	2.12	3.84
Y	r=0	1	4.74	15.50	3.79	14.30
PEC	r≤1		0.95	3.84	0.95	3.84
Y	r=0	1	16.27	25.90	12.30	19.40
PECP	r≤1		3.93	12.50	3.93	12.50

The results of the trace and max eigenvalue tests in the JJ cointegration test based on two variable models indicate that both the test statistics are statistically insignificant for rejecting the H_0 hypothesis of r=0 at 5% significance level (see Table 5).

Table 6. The Results of JJ Cointegration Test (EC-OC-CO_2-Y)

H_0	H_1	Trace Statistics	Critical Value 5%	H_0	H_1	λ-Max Statistics	Critical Value 5%
r=0	r≥1	30.40	47.9	r=0	r≥1	15.17	27.58
r≤1	r≥2	15.20	29.8	r≤1	r≥2	8.02	21.13
r≤2	r≥3	7.15	15.4	r≤2	r≥3	7.02	14.26
r≤3	r≥4	0.13	3.84	r≤3	r≥4	0.12	3.84
r=0	r≥1	53.00	63.9	r=0	r≥1	24.70	32.10
r≤1	r≥2	28.30	42.9	r≤1	r≥2	14.80	25.80
r≤2	r≥3	13.50	25.9	r≤2	r≥3	7.14	19.40
r≤3	r≥4	6.40	12.6	r≤3	r≥4	6.35	12.50

It can be concluded that no cointegration vector exists among the variables. A four-variable JJ cointegration model covering EC, OC, CO_2, and Y was also applied. The results of the trace and max eigenvalue tests in the JJ cointegration test based on four variable models also indicate that the trace and max-eigen statistics are less than its critical value at the 5% level (see Table 6). Thus, no cointegration vector exists among the variables.

4.3. Dolado-Lütkepohl (DL) VAR Granger Causality Analysis

The DLVAR methodology, developed by Dolado and Lütkepohl (1996), has been applied by many empirical studies. The DLVAR approach first involves finding the maximum order of integration dmax of the series to be incorporated into the model. To this end, a unit root test is applied in each series to find the maximal order of integration. The variables are found to be I(1); therefore, the maximal order of integration is 1. Second, the DLVAR approach specifies a well-behaved m^{th} optimal lag order vector autoregressive model.

Since the variables in the UVAR model are integrated of order one I(1) and the optimal lag length (m) in the five UVAR model was 3, the DLVAR model bases on the estimation of UVAR(m(3)+dmax(1))=4 in equations (4) and (5). Finally, the DLVAR method employs the MWALD test having chi-sq distribution for restrictions on the coefficients of the first m lags only because the MWALD test is more efficient than the Wald test in the TYVAR model (Dolado & Lütkepohl, 1996: 371).

$$Y_t = \alpha_{10} + \sum_{i=1}^{m+1} \alpha_{1(i+1)} Y_{t-(i+1)} + \sum_{i=1}^{m+1} \alpha_{1(i+1)} X_{t-(i+1)} + \varepsilon_{1t} \quad (4)$$

$$X_t = \alpha_{20} + \sum_{i=1}^{m+1} \alpha_{2(i+1)} X_{t-(i+1)} + \sum_{i=1}^{m+1} \alpha_{2(i+1)} Y_{t-(i+1)} + \varepsilon_{2t} \quad (5)$$

A two variable (Y, PEC) the DLVAR model can be expressed in the following equation (6) built into a seemingly unrelated regression (SUR) form.

$$\begin{bmatrix} Y_t \\ PEC_t \end{bmatrix} = \begin{bmatrix} \alpha_{10} \\ \alpha_{20} \end{bmatrix} + \begin{bmatrix} a_{11}^1 & a_{12}^1 \\ a_{21}^1 & a_{22}^1 \end{bmatrix} \begin{bmatrix} Y_{t-1} \\ PEC_{t-1} \end{bmatrix} + \begin{bmatrix} a_{11}^2 & a_{12}^2 \\ a_{21}^2 & a_{22}^2 \end{bmatrix} \begin{bmatrix} Y_{t-2} \\ PEC_{t-2} \end{bmatrix} + \begin{bmatrix} a_{11}^3 & a_{12}^3 \\ a_{21}^3 & a_{22}^3 \end{bmatrix} \begin{bmatrix} Y_{t-3} \\ PEC_{t-3} \end{bmatrix} + \begin{bmatrix} a_{11}^4 & a_{12}^4 \\ a_{21}^4 & a_{22}^4 \end{bmatrix} \begin{bmatrix} Y_{t-4} \\ PEC_{t-4} \end{bmatrix} + \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix} \quad (6)$$

Equation (6) allows for testing the causality relationship between any two variables (PEC and Y). The null hypothesis with the MWALD chi-sq statistics is H_0: $a_{12}^1 = a_{12}^2 = a_{12}^3 = 0$, where a_{12} is the coefficients of PEC. If the H_0 is rejected, then a one-way causality can be confirmed from PEC to Y. Then, the alternative null hypothesis tests reverse the way of causality (H_0: $a_{21}^1 = a_{21}^2 = a_{21}^3 = 0$, where a_{21} is the coefficients of Y). If both H_0 hypotheses are rejected, one can conclude that Y and PEC have a two-way (feedback) causality relationship.

The DLVAR models passed the following diagnostic tests. The JB tests confirm the normality behavior of the estimated residuals. The White tests confirm that the residuals are homoscedastic. All AR roots are less than one and fell within the unit circle, so the DLVAR models are stable. The Cusum tests suggest that the coefficients remain stable over the sample period. The BG serial correlation LM test does not reject the null hypothesis of no autocorrelation. The chi-square test statistics for models (1) through (5) shown in Table 7 have values of 10.17, 6.81, 11.80, 7.52, and 8.33, respectively. The data indicate that the variables (CO_2, EC, OC, PEC, and PECP) are statistically significant, so a one-way positive causality exist, running from energy-related variables (CO_2, EC, OC, PEC, and PECP) to economic growth (Y). The signs of the sum of the lagged values of the explanatory variables [1.09, 1.98, 1,23, 1.15, and 1.59] are also positive and statistically significant, suggesting a definitely strong relationship from energy-related variables to Y. Thus, high energy consumption causes high economic growth, and energy is also an important input in the production process.

Table 7. The Results of DLVAR Causality Test Estimated by SUR Method

Model	Chi-sq Test	P-value	Way of Causality	Wald Test P-value	m+1
Y=*f*(CO_2) CO_2=*f*(Y)	10.17 1.54	(0.01)[a] (0.67)	CO_2→Y[+1.09][a] no	8.17 (0.004)[a]	3+1
Y=*f*(EC) EC=*f*(Y)	6.81 3.19	(0.07)[c] (0.36)	EC→Y[+1.98][b] no	5.02 (0.03)[b]	3+1
Y=*f*(OC) OC=*f*(Y)	11.80 1.26	(0.008)[a] (0.73)	OC→Y[+1.23][a] no	8.74 (0.003)[a]	3+1
Y=*f*(PEC) PEC=*f*(Y)	7.52 0.97	(0.05)[b] (0.80)	PEC→Y[+1.15][b] no	4.11 (0.04)[b]	3+1
Y=*f*(PECP) PECP=*f*(Y)	8.33 1.56	(0.03)[b] (0.66)	PECP→Y[+1.59][b] no	5.84 (0.02)[b]	3+1
Diagnostic Tests	**Jarque-Bera**	**White Test**	**AR Roots (max; min)**	**Cusum Test**	**BG-LM Test**
Model 1	2.27 (0.68)	46.01 (0.55)	0.93; 0.60	0.84 (0.11)	4.26>(0.37)
Model 2	2.20 (0.69)	41.72 (0.72)	0.98; 0.50	0.76 (0.18)	3.20 >(0.52)
Model 3	5.15 (0.27)	51.57 (0.33)	0.93; 0.60	0.55 (0.52)	3.66 >(0.45)
Model 4	3.30 (0.50)	48.85 (0.43)	0.97; 0.47	0.60 (0.41)	2.47 >(0.65)
Model 5	5.95 (0.20)	46.23 (0.54)	0.99; 0.55	0.78 (0.16)	3.21 >(0.52)

Note: [ ] The sum of the lagged coefficients represents the summation of the lags(m) in the DLVAR; () p-values are in parentheses. [a,b,c] denote significant at 1% , 5% and 10% level, respectively.

4.4. Generalized Impulse-Response Function (GIRF) and Generalized Forecast Error Variance Decompositions (GFEVD) Analyses

The GIRF and GFEVD analyses developed by Pesaran and Shin (1998) are considered to be outstanding approaches in interpreting an estimated linear time series model. Compared to traditional impulse-response and variance decomposition analyses utilizing the standard procedure of the Cholesky decomposition method, the GIRF and GFEVD approaches do not require the orthogonalization of shocks and sum to unity. The ordering of variables is also not important in the VAR model. The GIRF analysis not only shows the effect of a unit change of one variable to another variable in the VAR model, but also shows whether a shock in a variable has a positive/persistent or negative/transitory effect on endogenous variables. The GFEVD analysis shows how much of a change in a variable is due to its own shock and how much is due to shocks to other variables (as a percent). The generalized cumulative impulse response functions (GCIRF) results in Figure 2 and the GFEVD results in Table 8 are obtained from the bivariate DLVAR models in Table 7. In the GCIRF analysis, the x-axis shows the annual time period and the y-axis shows the accumulated response to the impulse. The black line shows the accumulated impulse function for 12 years and the blue dotted lines show the 95% confidence bands. The cumulative sum of the impulse response functions do not approach zero. The GCIRF values for the 12th year are positive for the Y and predicted a positive effect on Y. An increasing positive cumulative response of Y to a change in PECP (0.32), PEC (0.24), EC (0.23) CO_2 (0.28) and OC (0.18) occur, with a time horizon of 12 years, and energy consumption positively stimulates economic growth.

Figure 2. The Results of GCIRF Analysis ±2 Standard Error Bands

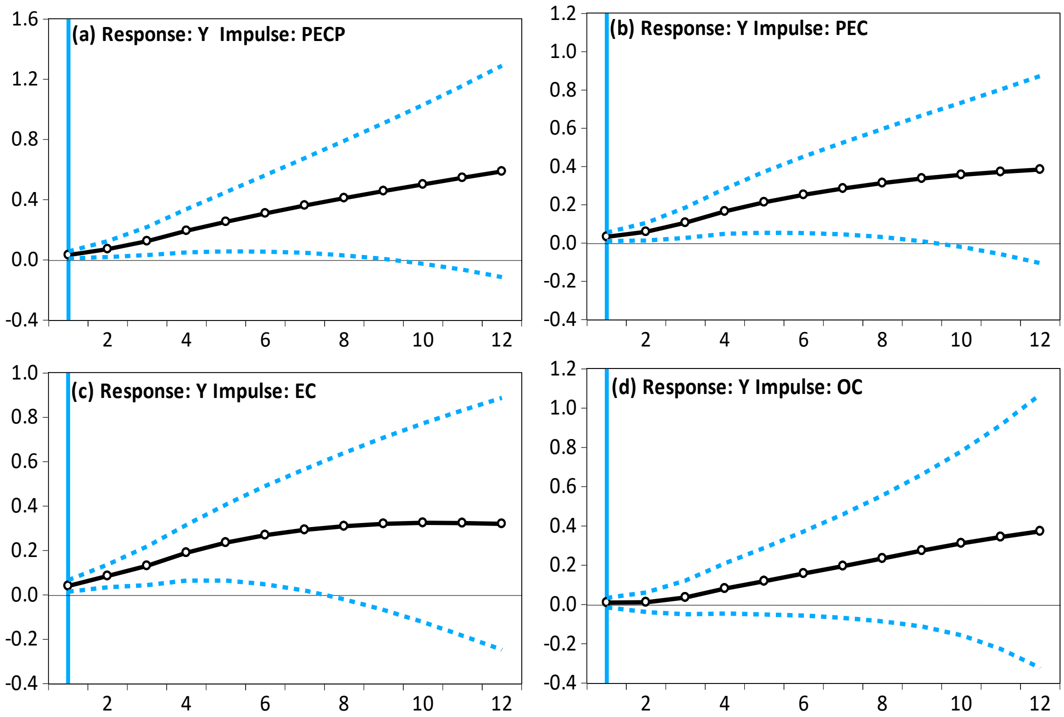


Table 8. The Results of GFEVD Analysis for Y

Period	Y	PEC	Y	CO_2	Y	EC	Y	OC	Y	PECP
0	100	22	100	8	100	33	100	2	100	21
3	87	48	83	36	86	62	89	17	79	58
6	79	58	63	58	81	68	79	30	64	71
9	74	61	51	68	79	68	68	40	55	77
12	71	61	43	73	79	68	63	44	49	80
Avg.	82	**50**	68	**49**	85	**60**	80	**27**	69	**61**

The GFEVD analysis in Table 8 shows that PECP, EC, PEC, CO_2, and OC explain 61%, 60%, 50%, 49%, and 27% of variations in Y, and the variations of Y are explained 68% to 85% of their own variation for the 12-year averages. The GFEVD analysis in Table 9 shows that Y explains 25%, 14%, 13%, 12%, and 5% of the variation in EC, PEC, PECP, OC, and CO_2, and the variations of PEC, CO_2, EC, OC, and PECP are explained 84% to 97% of their own variation for the 12-year average.

Table 9. The Results of GFEVD Analysis for PEC, CO_2, EC, OC, PECP

Period	PEC	Y	CO_2	Y	EC	Y	OC	Y	PECP	Y
0	100	22	100	8	100	33	100	2	100	21
3	98	13	99	5	99	26	99	1	98	14
6	89	10	99	4	92	20	90	6	97	11
9	78	12	97	3	82	21	74	19	96	9
12	68	15	95	3	72	25	58	34	95	9
Avg.	87	**14**	98	**5**	89	**25**	84	**12**	97	**13**

5. Summary and Conclusions

The main aim of this study is to examine the causality relationship between economic growth and energy consumption for Turkey from 1972 to 2011. This study utilized unit root-cointegration tests and the DLVAR causality methods. To the best of our knowledge, this study is the first to analyze the causality relationship between energy consumption and economic growth by the DLVAR causality test using the SUR method. According to the ADF, PP, and ADF-GLS unit root tests used to specify the order of integration, all variables were nonstationary in levels but become stationary after taking first differences. Thus, all the series were I(1). The JJ cointegration test adopted both bivariate and multivariate approaches to determine co-movements in the long run. Both the trace and max eigenvalue test statistics failed to reject the null hypothesis of no cointegrating/long-run relationship between/among the variables. The DLVAR causality test was utilized in a bivariate approach.

The GCIRF and GFEVD analyses indicated that a one standard deviation shock to the PECP, PEC, EC, CO_2, and OC would cause Y to rise over a 12-year period and the shocks from the PECP, PEC, EC, CO_2, and OC have a large and positive significant impact on Y. Energy consumption explained 27% to 61% of the variation in Y, and Y explained 5% to 25% of the variation on energy consumption over an average 12-year period. This study reached the following conclusions: 1) a positive one-way causality runs from OC to Y, supporting the findings of Zou and Chau (2006), Bhattacharya and Bhattacharya (2014), Nasiru, Usman, and Saidu (2014), and Terzi and Pata (2016); 2) a positive one-way causality runs from EC to Y, supporting the findings of Altinay and Karagol (2005), Soytas and Sari (2007), Karagol, Erbaykal, and Ertugrul (2011), Polat, Uslu, and San (2011), Yuan, Kang, Zhao, and Hu (2008), and Lyke (2015); 3) a positive one-way causality runs from CO_2 to Y, supporting the findings of Khan (2013) and Vidyarthi (2013); and 4) a positive one-way causality runs from PEC to Y, supporting the findings of Sari and Soytas (2004), Erbaykal (2007), Mucuk and Uysal (2009), Korkmaz and Yılgör (2011), Yanar and Kerimoglu (2011), Lihn and Lin (2014), Shaari, Hussain, and Rashid (2014), and Alshehry and Belloumi (2015).

The findings of this study conclude that aggregated and disaggregated energy consumption/sources are an important determinant of economic growth. The energy-led growth hypothesis (the growth hypothesis) is valid such that an increase in the level of energy consumption positively stimulates Turkey's economic growth. Thus, energy consumption/production can help boost economic development while energy is a limiting factor to economic growth; a negative shock to energy consumption would have a negative effect on economic growth. Therefore, Turkey should increase the production/consumption of the energy-related variables to sustain economic growth.

End Notes

[1] *This article is derived from the unpublished master's thesis in economics titled as "Energy Consumption and Economic Growth Relationship in Turkey" submitted by Uğur Korkut PATA in 2016 under the supervision of Prof. Dr. Harun Terzi to the graduate master's program in the Institute of Social Sciences of Karadeniz Technical University, Trabzon.*

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