Unit Root Properties of Energy Consumption and Production in Turkey

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ABSTRACT

This study analyzes unit root properties of total and sectorial energy production and consumption series of Turkey. This study is the first to analyze unit root properties of Turkish energy production and consumption in detail. The unit root analysis of energy production and consumption are tested by using unit root tests based on LM considering without structural break and with one and two structural breaks. According to unit root test without structural break, the unit root hypothesis is rejected only for consumption of natural gas. The unit root hypothesis is rejected for 15 out of the 33 series by the LS test with one structural break. When unit root test with two structural breaks are conducted, 25 out of the 33 series are found to be stationary around a deterministic trend. The production of hydraulic and the consumption of lignite, electricity, petroleum, coal and electricity, total energy and petroleum consumption in Transportation sector are found to be non-stationary, which indicates that the impacts of innovations on these variables will be permanent. The policy implication of the results suggests that the impacts of shocks on energy consumption and production will be temporary and not have a long memory for most of variables.

KEYWORDS

Energy Consumption, Energy Production, Unit Root Analysis, Turkey

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Introduction

The impact of unit root properties of energy variables for the formulation and consequences of economic policies are crucial in several aspects, especially on structural transitions from shocks in energy markets towards key macroeconomic variables (Mishra, Sharma, & Smyth, 2009; Narayan & Smyth, 2007). Impact of shocks on energy variable can be permanent or transitory according to its unit root properties. If the energy variable is stationary, impact of shocks will be transitory and long short term. On the other hand, if the energy variable is not stationary, the impacts of shocks will be permanent and have a long memory. Hendry and Juselius (2000) indicate that economic variables can inherit unit root properties from related economic variables and can in turn transmit this property to other related variables. They argued that relationship between economic variables can spread unit root properties throughout the economy. In this context, knowledge of unit root properties of an energy variable is of importance, since this property can be inherited by related macroeconomic variables. The impact of energy demand on economic activity can be serious. The literature has shown that energy price shocks, via their substantial impact on energy consumption, have significant impacts on output (Chang & Wong, 2003; Du, Yanan, & Wei, 2010; Hamilton, 1996, 2007; Huang, Hwang, & Peng, 2005; Jayaraman & Choong, 2009; Jiménez-Rodríguez, 2008; Lardic & Mignon, 2008; B. R. Lee, Lee, & Ratti, 2001; Lorde, Jackman, & Thomas, 2009; Zhang, 2011), inflation (Chang & Wong, 2003; Cologni & Manera, 2008; Cuñado & Pérez de Gracia, 2003; Ewing & Thompson, 2007), unemployment (Carruth, Hooker, & Oswald, 1998; Chang & Wong, 2003; Rafiq, Salim, & Bloch, 2009), employment (Papapetrou, 2001), stock market (Arouri, Lahiani, & Nguyen, 2011; Basher, Haug, & Sadorsky, 2012; Evangelia, 2001; Filis, Degiannakis, & Floros, 2011; Park & Ratti, 2008; Sadorsky, 1999), investment (Rafiq et al., 2009), the budget deficit (Rafiq et al., 2009), exchange rate (Ayadi, 2005; Basher et al., 2012; S. S. Chen & Chen, 2007; Narayan, Narayan, & Prasad, 2008; Özturk, Feridun, & Kalyoncu, 2008), interest rate (Lowinger, Wihlborg, & Willman, 1985; Park & Ratti, 2008), exports (Chiou Wei & Zhu, 2002; Faria, Mollick, Albuquerque, & León-Ledesma, 2009; Zhang, 2011), fluctuations in business cycle (Kim & Loungani, 1992) and money supply (Zhang, 2011).

Besides shocks on energy demand, Hamilton (2007) showed that disruptions on energy supply can also have significant impact on economic activity by presenting a model based on Cobb-Douglas production function as below:

$$Y = F(L, K, E) \qquad (1)$$

where output (Y) is production, (L) is labour, (K) is capital and (E) is energy use of a firm. The profits (π) of a firm can be estimated as:

$$\pi = PY - WL - rK - QE \qquad (2)$$

where P is the price of output per unit, W is the nominal wage paid for labour, Q is the nominal cost of energy used in the production process and r is the nominal rate of rented capital. The equilibrium energy price for rational firm will be at a level where marginal product of energy is equal to unit price of energy:

$$F_E(L, K, E) = Q / P \qquad (3)$$

where $F_E(L,K,E)$ is the partial derivative of *F(.)* regarding *E*. The following equation will be obtained in case both sides of the equation (3) are multiplied by E and divided by Y:

$$\partial \ln F / \partial \ln E = QE / PY \qquad (4)$$

Eq (4) indicates that the elasticity of output regarding change in energy consumption used in the production process can be derived from the cost of the energy used to produce the total output. Disruptions in energy production will affect energy prices and a change in energy prices used in production process will also have a significant impact on output of an economy as shown in Eq (4). Therefore, shocks on non-stationary energy production series will be permanent and affect economic activity perpetually , while shocks on stationary energy production series will be transitory and affect economic activity temporarily, via transmission mechanism (Narayan, Narayan, & Smyth, 2008).

The unit root properties of energy variables are of importance for forecasting these variables. Accurate forecasts are crucial for energy planning and policy formulation. Future values of a stationary energy variable can be forecasted based on its past behavior (P. F. Chen & Lee, 2007), while past data about a nonstationary energy variable are useless in forecasting (Mishra et al., 2009).

Stationarity of energy consumption can be due to a multitude of factors. Hsu, Lee, and Lee (2008) suggested that abundance of energy resources, less energy consumption, new environmental regulations and laws introduced by governments and middle income level may lead to stationarity of energy consumption.

The goal of this study is to analyze the unit root properties of energy consumption and production in Turkey by employing a Lagrange Multiplier based unit root test without structural break proposed by Schmidt and Phillips (1992) (SP) and a unit root test considering one structural break proposed by J. Lee and Strazicich (2004) (LS) and two structural breaks developed by J. Lee and Strazicich (2003) (LS). If the time series of the variable to be tested for the unit root properties has structural breaks, the unit root hypothesis cannot be rejected by conventional unit root tests (Perron, 1989). Monte Carlo simulations point that statistical performance of LS is better than other alternatives (Narayan, Narayan, & Popp, 2010). This study is the first to investigate unit root properties of Turkish energy production and consumption in detail. The next section briefly summarizes the literature on studies analyzing the unit root properties of energy consumption and production. Section 3 describes data used in the analysis. Section 4 summarizes the unit root tests used in this study. Section 5 presents results of the unit root test. Section 6 discusses main findings and implications of the results for policy formulation and implementation.

Brief Overview of the Literature

Although there have been numerous studies analyzing the unit root properties of energy consumption series, only a handful of studies have investigated energy production. Barros, Gil-Alana, and Payne (2011) examine the time series behavior of oil production for 13 OPEC member countries for the period of January 1973 and October 2008. They found that oil production series have mean reverting persistence with breaks identified in 10 out of the 13 countries. The results of the study indicate that the impact of shocks on oil production in these countries will be persistent in the long run for all countries.

Narayan, Narayan, and Smyth (2008) analyze the unit root properties of crude oil production for 60 countries by conducting panel data unit root tests with and without structural breaks between 1971 and 2003. The results of tests without a structural break are inconclusive, while the results of test with a structural break are conclusive and indicate the stationary structure of production series of crude oil and natural gas liquids.

Maslyuk and Smyth (2009) test for non-linarities and unit roots in crude oil production. They used monthly crude oil production for 17 OPEC and non-OPEC countries between January 1973 and December 2007. The results of their study show the presence of threshold effects on the crude oil production and unit root for 11 of the countries in both regimes and a partial unit root for the others.

In contrast to the dearth of studies investigating unit root properties of energy production series, there are numerous studies on unit root properties of energy consumption. Narayan and Smyth (2007) analyze the stationarity properties of per capita energy consumption of 182 countries for the period of 1979 to 2000 by using annual data. The results of univariate unit root test indicate that the series of 56 countries are nonstationary at the 10% level or better. The panel data unit root test indicate that there is overwhelming evidence about stationary of energy consumption.

P. F. Chen and Lee (2007) investigate energy consumption per capita series of 7 regional panel sets for the period of 1971 to 2002 by employing panel unit root testing procedure, and find stationary structure in all series. A substantial literature review about the unit root properties of energy consumption can be found in P. F. Chen and Lee (2007), Hsu et al. (2008) and Aslan and Kum (2011).

Data

The unit root properties of primary total production, total and sectorial consumption of various energy variables of Turkey covering different periods are explored in this study as shown in Table 1. The data are obtained from Ministry of Energy and Natural Resources (MENR) of Turkey. The periods of analysis are determined by data availability. All data used in this study are transformed to natural logarithmic form prior to unit root tests. Descriptive statistics of the variables subject to analysis are presented in Table 1.

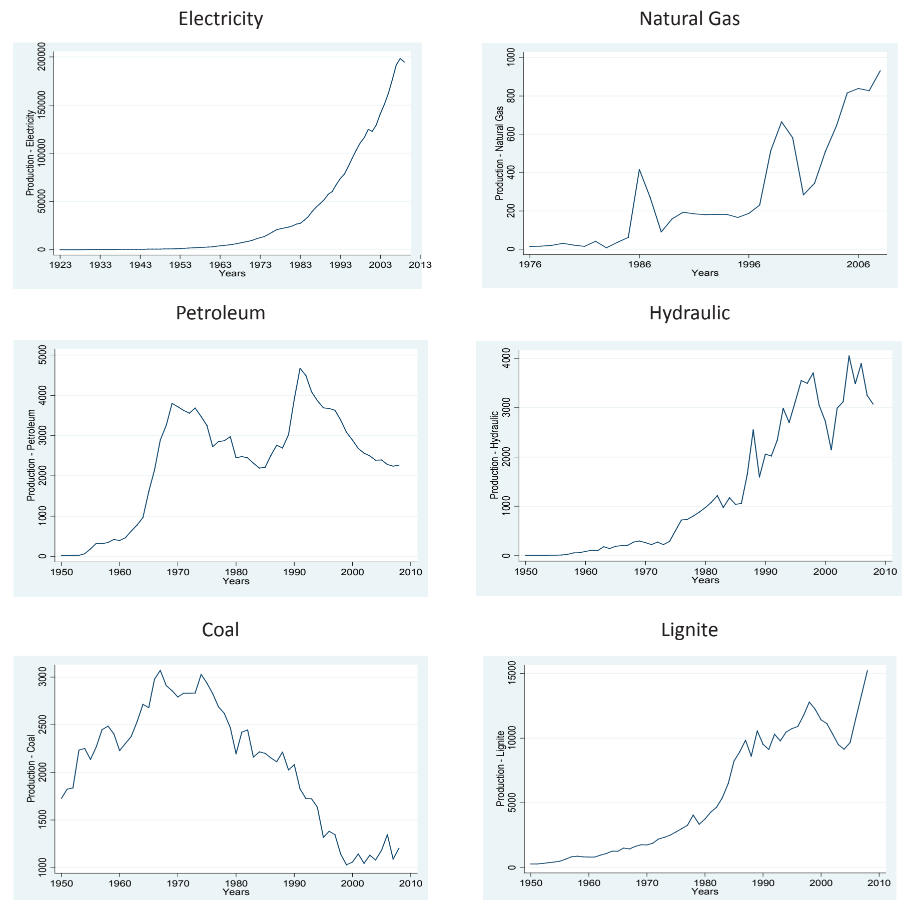
Table 1. Descriptive Statistics

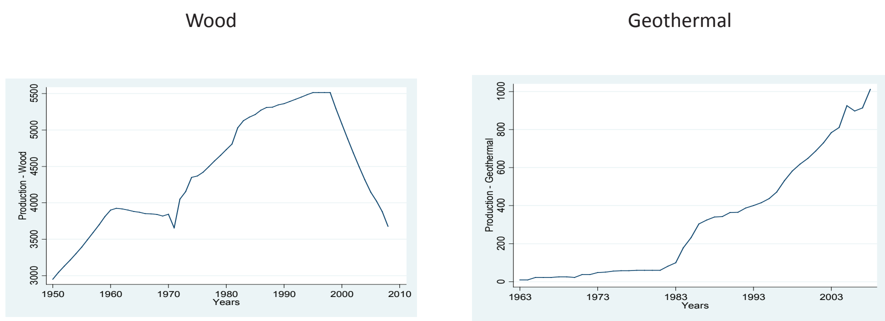
Series Code	Series Name	Period	Unit	Mean	Std. Dev.
		Production			
PCL	Coal	1950 - 2008	TEP	2097	623
PLT	Lignite	1950 - 2008	TEP	5498	4569
PPM	Petroleum	1950 - 2008	TEP	2325	1325
PNG	Natural Gas	1976 - 2008	TEP	293	284
PHC	Hydraulic	1950 - 2008	TEP	1322	1329
PGL	Geothermal	1963 - 2008	TEP	318	309
PWD	Wood	1950 - 2008	TEP	4405	764
PEY	Electricity	1923 - 2009	10^6 kWh	34695	53778
		Consumption			
CCL	Coal	1970 - 2009	TEP	6411	3942
CLT	Lignite	1970 - 2009	TEP	8084	4061
CPM	Petroleum	1970 - 2009	TEP	23066	7786
CNG	Natural Gas	1976 - 2009	TEP	9089	10980
CHC	Hydraulic	1970 - 2009	TEP	1971	1215
CGL	Geothermal	1970 - 2009	TEP	354	296
CWD	Wood	1970 - 2009	TEP	4776	615
CEY	Electricity	1923 - 2009	10^6 kWh	28122	43089
		Sectorial Consumption			
IND	Industrial	1970 - 2009	TEP	15218	8461
IND_PET	Industrial (Petroleum)	1970 - 2009	TEP	4699	1810
IND_ECT	Industrial (Electricity)	1970 - 2009	TEP	2630	1773
IND_NGS	Industrial (Natural gas)	1976 - 2009	TEP	2508	2680
TPT	Transportation	1970 - 2009	TEP	8869	3826
TPT_PET	Transportation (Petroleum)	1970 - 2009	TEP	8637	3976
TPT_ECT	Transportation (Electricity)	1970 - 2009	TEP	36	22
RES	Residential	1970 - 2009	TEP	16368	4926
RES_PET	Residential (Petroleum)	1970 - 2009	TEP	3346	2428
RES_ECT	Residential (Electricity)	1970 - 2009	TEP	2252	2079
ACL	Agricultural	1970 - 2009	TEP	2083	1208
ACL_PET	Agricultural (Petroleum)	1970 - 2009	TEP	1927	1058
ACL_ECT	Agricultural (Electricity)	1970 - 2009	TEP	129	149
OSC	Other sectors	1970 - 2009	TEP	18450	6117
OSC_PET	Other sectors (Petroleum)	1970 - 2009	TEP	4700	1670
OSC_ECT	Other sectors (Electricity)	1970 - 2009	TEP	2381	2227
NEY	Non-energy	1970 - 2009	TEP	1471	1152

Note: TEP indicates Ton Equivalent Petroleum

Time series plot for the production of energy variables of Turkey are shown in Figure 1. Decrease in petroleum, coal and wood production series are remarkable in comparison to other series in recent years. The decrease in wood production for energy usage indicates substitution for this resource with other energy resources such as natural gas. Trends for other series increase with some fluctuations over the periods analyzed and display steep increase thereafter. However, electricity and geothermal production series have no serious fluctuation indicating successful production policies on these energy variables and these production process variables' structural strength towards disruptive shocks.

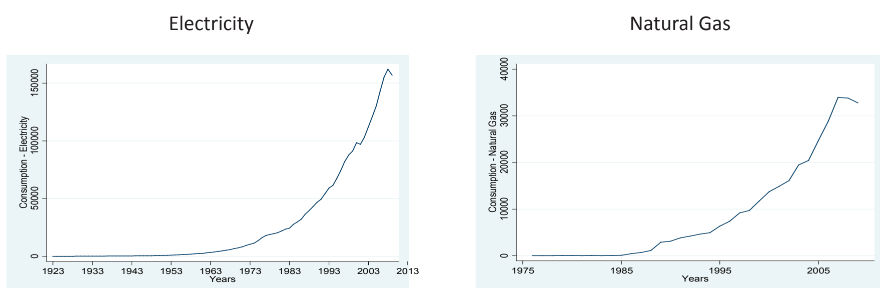
Figure 1. Energy Production (Source: MENR)

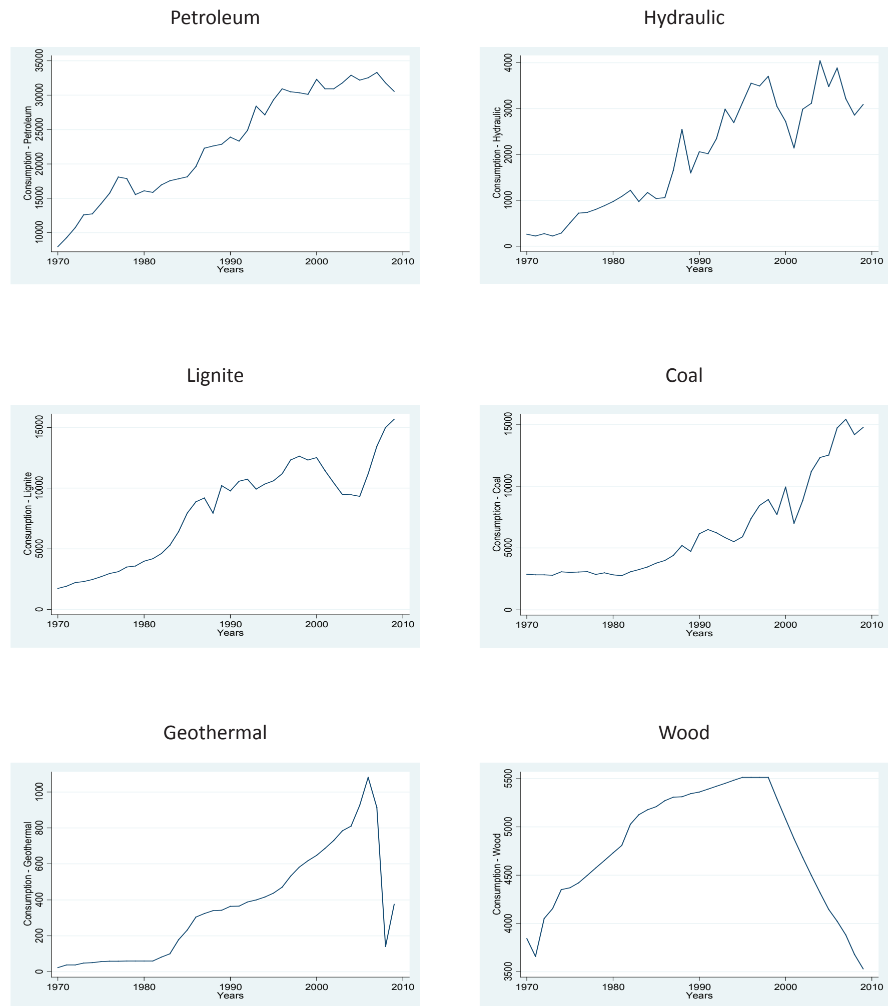




Time series plot for consumption of energy variables of Turkey are shown in Figure 2. Only consumption of geothermal and wood series for energy usage significantly decrease among all energy variables. The decrease in wood consumption is consistent with its decrease in production, owing to alternative energy resources such as natural gas production. The increase in consumption of electricity, natural gas and petroleum are remarkable compared to other variables, and indicate the importance of these energy resources for economy in Turkey. Although the price of natural gas in Turkey is the highest in the world (Altunsoy, 2008), the remarkable increase in its consumption indicates it is still cheaper than other energy resources in Turkey.

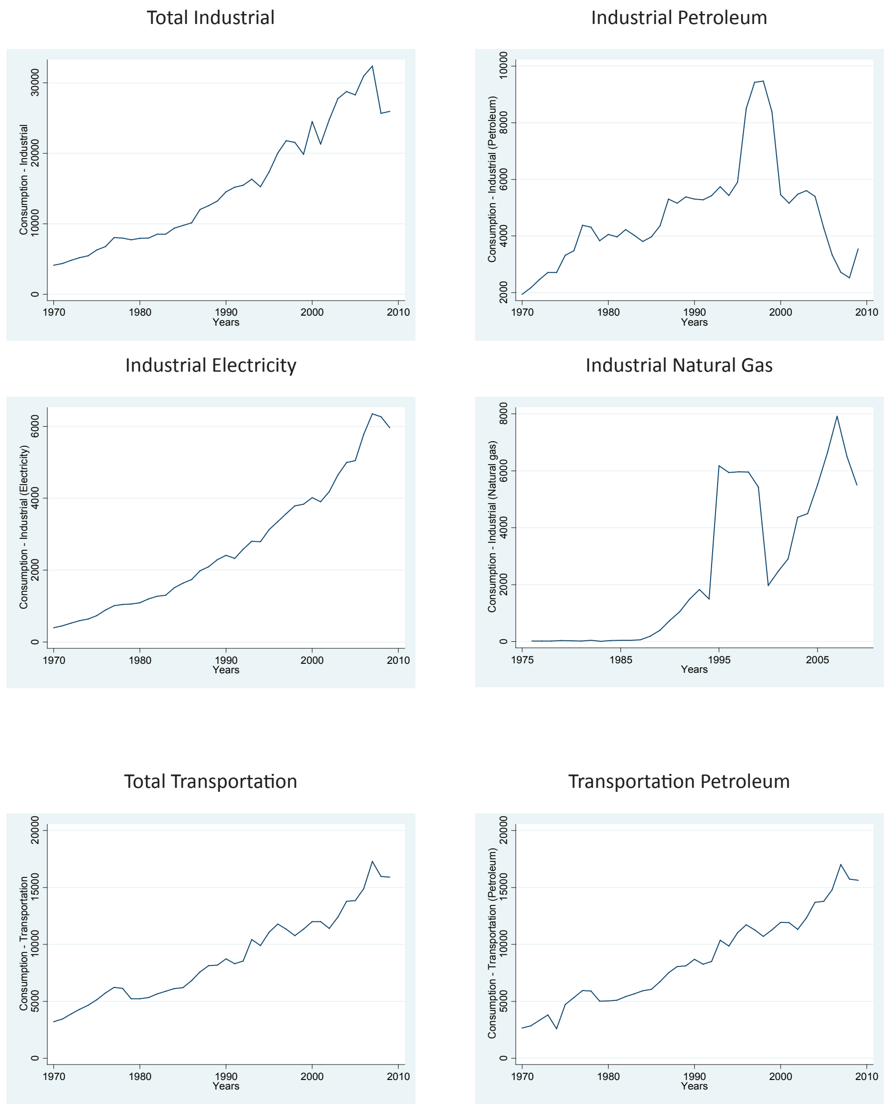
Figure 2. Energy Consumption (Source: MENR)

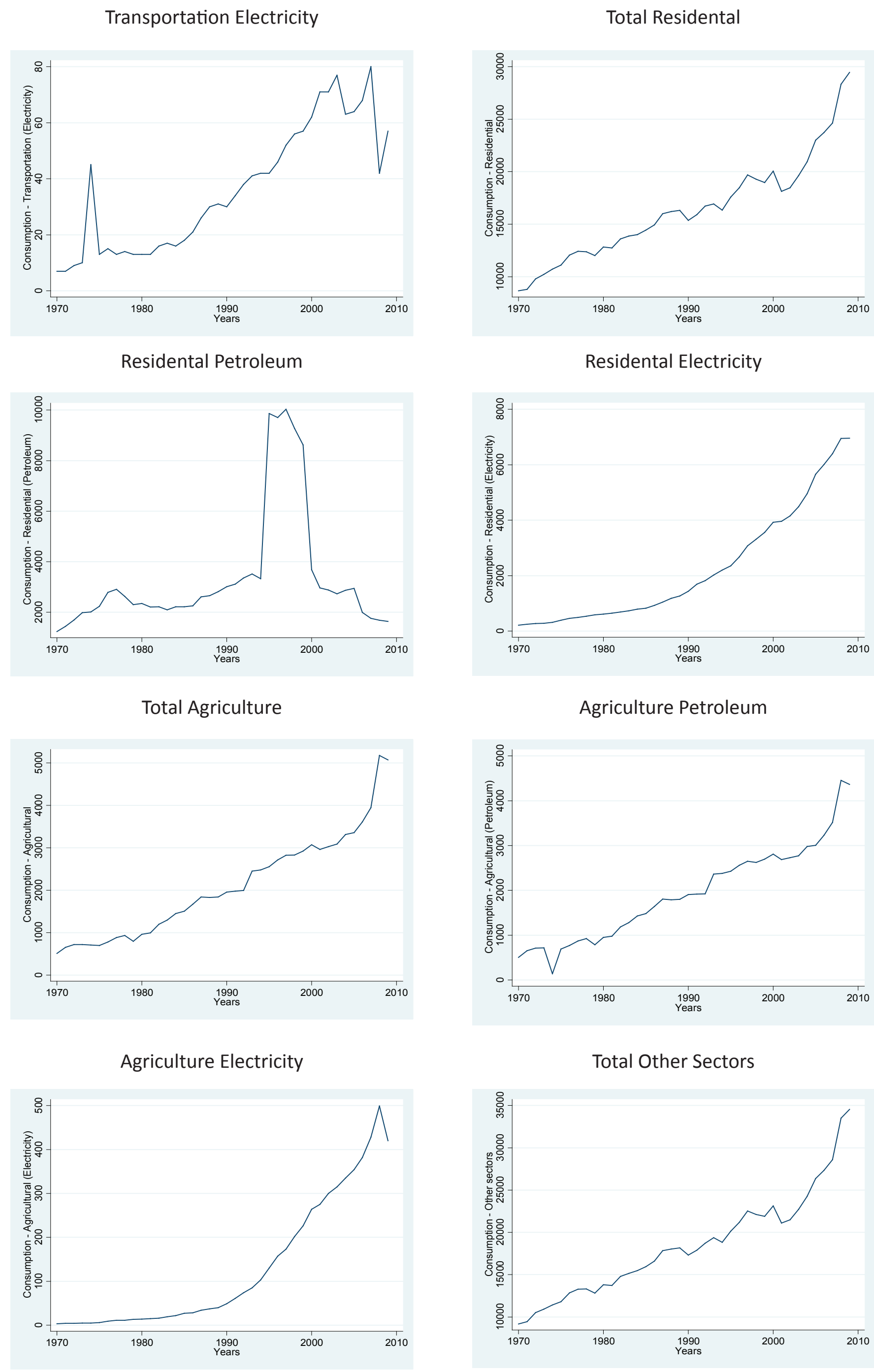




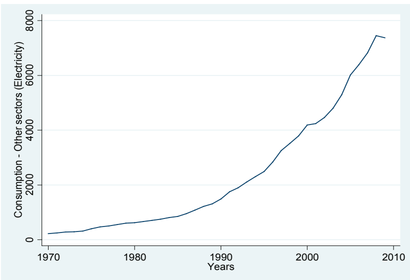
Time series plot for sectorial consumption of energy variables of Turkey are shown in Figure 3. The increase in energy consumption in industry indicates how the importance of industry has increased in the economy. At the end of 1990s, use of petroleum decrease significantly in industry. When compared to other energy resources, the significant increase in natural gas consumption in industry indicates a substitution between energy resources because of increasing oil prices and energy policies promoting natural gas consumption. Total energy consumption in every sector increased with a positive trend indicating the rapid growth in the Turkish economy in the last decade. Structural breaks are clear in 1994, 1999, 2001 and 2008 when economic crises occurred.

Figure 3. Sectorial Energy Consumption (Source: MENR)

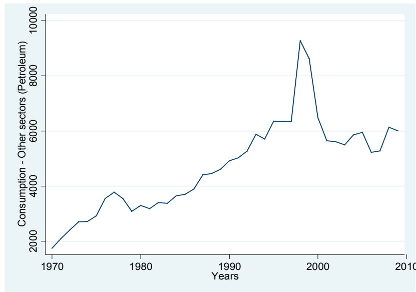




Other Sectors Electricity



Other Sectors Petroleum



Econometric Methodology

The LS unit root test is based on Lagrangian Multiplier (LM) for trending data. J. Lee and Strazicich (2003, 2004) extended Schmidt and Phillips (1992) methodology by considering structural breaks. The form of the test allows endogenous determination of two structural breaks under both the null and alternative hypotheses for a change in both the level and trend.

$$\Delta Y_t = \delta' \Delta Z_t + \varphi \tilde{S}_{t-1} + \varepsilon_t, \quad (5)$$

where $Z_t = [1, t, D_{1t}, D_{2t}, DT_{1t}, DT_{2t}]$ is a vector of exogenous variables, $\delta = [\mu, \gamma, d_1, d_2, d_3, d_4]$ is a parameter vector of Z_t and the subsequent dummies, which allow two time changes in the level and trend, are as follows:

$$D_{jt} = \begin{cases} 1 & t \geq T_{Bj}+1 \\ 0 & t < T_{Bj}+1 \end{cases} \quad and \quad DT_{jt} = \begin{cases} t - T_{Bj} & t \geq T_{Bj}+1 \\ 0 & t < T_{Bj}+1 \end{cases}, \quad j = 1,2. \quad (6)$$

$\tilde{\psi}_x = Y_1 - Z_1\tilde{\delta}$ and $\tilde{S}_t = Y_t - \tilde{\psi}_x - Z_t\tilde{\delta}$ where $\tilde{\delta}$ are coefficients in the regression of ΔY_t on ΔZ_t. The null and alternative hypotheses are:

$$H_0 : \beta - 1 = \varphi = 0 \;\; vs \;\; H_1 : \beta - 1 = \varphi < 0 \quad (7)$$

To determine the location of the breaks ($\lambda = (\lambda_1 = T_{B1}/T,\ \lambda_2 = T_{B2}/T)$) LS procedure utilizes a grid search as follows:

$$LM_{\tau} = \inf \tilde{\tau}_{\lambda}(\lambda) \quad (8)$$

Break points are where the corresponding test statistic is minimal.

Results

The results of the unit root tests with one and two structural breaks and without structural break are presented in Table 2. Three distinct unit root tests are used in this study to distinguish the impacts of structural break(s) on the energy series. We considered breaks at level and trend of the series. The number of lags is determined according to the general to specific method up to specific number of maximum lag[1] running by t-statistics significance at the 10% significance level.

The unit root hypothesis is rejected only for consumption of natural gas by conventional unit root tests without structural break. The LS unit root test with one structural break rejected the unit root hypothesis for 15 out of the 33 series. When two structural breaks are taken into account, 25 out of the 33 series are found stationary. This series is stationary around deterministic trend with breaks. The production of hydraulic and the consumption of lignite, electricity, petroleum, and coal, total energy consumption in the transportation sector and consumption of petroleum in the transportation sector are found to be non-stationary. According to the results, structural breaks in energy variables of Turkey should be taken into consideration when the unit root properties are examined. If the time series of the variable with structural breaks are tested by conventional unit root tests, the unit root hypothesis may be not cannot rejected (Perron, 1989). Our results verify the theory that the number of rejection of unit root null hypothesis declines when the number of structural breaks is increased.

1 The number of maximum lag depends on number of observation of the series.

Table 2. Results of unit root tests

Series	SP		LS - one break			LS - two breaks			
	k	t statistics	k	t statistics	TB	k	t statistics	TB1	TB2
PHC	0	-1.52	6	-3.87	1999	6	-5.04	1983	1993
PGL	0	-2.12	3	-3.58	2006	9	-8.71a	1987	2006
PLT	2	-1.45	2	-3.44	1991	3	-6.35a	1987	2001
PWD	8	-0.73	9	-4.20c	1990	6	-5.79b	1984	1996
PPM	8	1.83	7	-3.37	1988	7	-5.40c	1988	1994
PCL	0	-1.99	9	-4.73b	1994	8	-6.46a	1988	1994
PNG	8	-2.16	8	-6.65a	1994	2	-16.39a	1988	2003
PEY	9	-0.45	9	-3.68	1987	9	-4.51	1944	1973
CHC	0	0.14	0	-2.33	1966	7	-5.39b	1968	1993
CGL	3	-1.94	2	-5.74a	1989	2	-6.88a	1975	1987
CLT	9	-1.93	9	-3.87	1998	9	-4.62	1979	1999
CWD	2	-0.53	5	-4.26c	1989	10	-6.18b	1972	1990
CPM	6	-0.93	10	-4.30c	1991	6	-4.65	1965	2002
CCL	9	-1.80	10	-2.94	1989	5	-5.06	1975	1993
CNG	8	-3.13c	5	-5.76a	1987	2	-9.17a	1988	1990
CEY	11	-0.08	11	-4.68b	1981	11	-4.87	1981	1989
IND	0	-2.22	5	-5.03b	2000	5	-5.69b	1991	2000
IND_PET	5	-1.72	9	-4.14	2003	9	-6.41a	1989	1994
IND_ECT	6	1.45	0	-3.98	1985	5	-5.97b	1984	2000
IND_NGS	0	-1.53	4	-3.19	1993	6	-8.61a	1994	1999
TPT	0	-1.68	0	-4.11	1997	8	-4.68	1987	1991
TPT_PET	0	-2.56	3	-4.25c	1997	8	-5.15	1987	1991
TPT_ECT	5	-2.07	9	-3.95	2002	6	-6.99a	1986	2002
OSC	0	-1.40	0	-2.53	2001	6	-8.54a	1982	1999
OSC_PET	0	-1.15	1	-4.78b	2000	2	-7.47a	1996	2000
OSC_ECT	0	-0.98	9	-3.94	1985	9	-6.40a	1982	1995
RES	0	-1.46	0	-2.42	2001	6	-8.44a	1982	1999
RES_PET	0	-1.07	9	-4.97b	1993	9	-11.48a	1987	1993
RES_ECT	0	-1.11	9	-3.95	1985	9	-7.02a	1982	1995
ACL	0	-1.64	4	-3.61	1995	7	-6.82a	1993	2006
ACL_PET	7	-2.73	7	-4.48c	1994	7	-5.39c	1993	1999
ACL_ECT	8	-1.94	8	-4.95b	1992	9	-5.64b	1994	2006
NEY	1	-3.74a	2	-5.01b	2003	3	-6.60a	1997	2003

Notes: k indicates the number of lags. a, b and c denote significance at the 1% 5% and 10% level, respectively. TB denotes time breaks.

Conclusion

Specification of unit root properties of energy consumption and production is crucial for energy policy formulations and implementations. The impact of shocks on energy variables with a stationary process will be temporary and long short term, while impact of shocks on energy variables with a nonstationary process will be permanent and have a long memory.

In this study, the unit root properties of total and sectorial energy production and consumption series of Turkey are investigated. This study is the first to investigate unit root properties of Turkish energy production and consumption in detail. The unit root structure for energy variables are tested by using the unit root tests based on LM without structural break and with one and two structural breaks. The results of unit root test without structural break show that the unit root hypothesis is rejected only for consumption of natural gas. In the case of one structural break, the unit root hypothesis is rejected for 15 out of the 33 series by LS test. When two structural breaks are taken into account, 25 out of the 33 series are found to be stationary around a deterministic trend with breaks. The production of hydraulic, the consumption of lignite, electricity, petroleum, coal, electricity, total energy consumption and petroleum consumption in the transportation sector are found to be non-stationary, which indicates that the impact of innovations on these variables will be permanent.

The policy implication of these results suggests that the impacts of shocks on energy consumption and production will be temporary and not have a long memory for most of the variables. Therefore, the economic impact of energy stabilization and conservation policies will be temporary in Turkey. The results of this study, which found that most of the variables are stationary, are consistent the consensus about stationarity of energy variables found in numerous other studies (Narayan et al., 2010). In addition, the historical data on these stationary variables can be taken into account to forecast the future values of these variables.

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