ENERGY CONSUMPTION AND GDP REVISITED: A FRACTIONAL COINTEGRATION RELATIONSHIP FOR TURKEY

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ABSTRACT

This paper investigates the relationship between energy consumption and GDP for Turkey over the period from 1960 through 2009 by using a fractional cointegration approach, which allows residuals to be fractionally integrated rather than stationary, with the classical cointegration approach based on I(0) stationarity or I(1) cointegrating relationships. The findings obtained from the Engle and Granger cointegration test indicate that there is no evidence of cointegration between energy consumption and GDP. On the other hand, the results of the fractional cointegration test give evidence of fractional cointegration which implies that deviations from the long run relationship shared by energy consumption and GDP take a long time to dissipate before reaching their equilibrium level.

Keywords
Energy consumption, GDP, Fractional co-integration

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1. INTRODUCTION

Since the energy crisis of the 1970s, numerous studies have been conducted on the relationship between energy consumption and GDP to support the arguments which suggest that energy plays a crucial role in the economy on both demand and supply sides. On the demand side, energy is one of the products which a consumer decides to buy in order to maximise his or her utility. On the supply side, energy enhances the productivity of production factors and increases economic growth and living standards. This refers to a relationship running from energy consumption to GDP as well as vice versa (Chontanawat et al., 2006).

The direction of the relationship between energy consumption and GDP can help policymakers to make the most appropriate decisions. According to the possible outcomes of the relationship, four different hypotheses are referred in the literature. The growth hypothesis suggests that energy consumption is a crucial component in growth, directly or indirectly as a complement to capital and labour as input factors of production, because it can directly be used to produce a final product (Stern, 2000). Hence, a decrease in energy consumption causes a decrease in GDP. This denotes an "energy-dependent" economy. In contrast, the relationship from economic growth to energy consumption refers to the conservation hypothesis which suggests that reducing the energy consumption may be implemented with little or no adverse effect on GDP. This denotes a "less energy-dependent" economy (Oh and Lee, 2004). A bi-directional relationship, which means that energy consumption and GDP are jointly determined and affected at the same time, corresponds with the feedback hypothesis. In this case, policy makers should take into account the feedback effect of GDP on energy consumption by implementing regulations to reduce energy consumption. In addition, economic growth should be decoupled from energy consumption to avoid a negative impact on GDP (Belke et al., 2010). Finally, finding no relationship in any direction between energy consumption and GDP refers to the neutrality hypothesis which implies that reducing the energy consumption and energy conversation policies may not affect the GDP.

Previous studies on different countries, different time periods and methods investigate the relationship between energy consumption and economic growth based on mentioned hypotheses, and give mixed results as summarized in the Appendix. It is considered that these differences might be due to the different characteristics of the countries such as energy supply, political and economic history, political arrangement, culture and energy policy (Chen et al., 2007).

Different from previous studies, the aim of this paper is to extend the current literature by investigating the relationship between energy consumption and GDP in the context of the fractional cointegration approach versus the classical cointegration approach. It is important to note that cointegration methods which assume that all the variables are integrated of order one $I(1)$ and restrict error correction term to be $I(0)$, are too restrictive and have low power when the residuals are mean reverting but are not $I(0)$. The fractional cointegration approach allows residuals to be fractionally integrated rather than stationary. Following the classical cointegration test of Engle and Granger (1987) and the fractional cointegration concept of Gil-Alana (2003) and Caporale and Gil-Alana (2004), we examine the relationship between energy consumption and GDP in Turkey over the period from 1960 through 2009. As stated in Lise and Montfort (2007), the reasons for choosing Turkey in our analysis are as follows: Turkey is a candidate country for becoming a European Union (EU) member in the near future and preparation for membership can work as a stabilizer for Turkish economy. It is an emerging economy and it has various energy sources with its petrol, coal, natural gas reserves and alternative energy sources such as uranium, thorium and boron. Turkey has experienced a significant rise in energy consumption in recent decades. Considering its economic conditions, the increase in population and rapid economic developments are causing more energy consumption. This increase in energy consumption is approximately 5.5% for Turkey. While the primary energy consumption of the world for 2006 totaled about 10878 mtep (million tons petroleum equivalent), it was about 99.8 mtep for Turkey (Yazar and Erkaya, 2007). However, with energy production highly beneath the consumption, Turkey imports energy from other countries. While the gap between energy consumption and production was low in the early 1980s, it increased with the population increase and investments. This situation clearly indicates that Turkey is an energy importing country.

The remainder of the paper is organized as follows: Section 2 presents the methodology, and Section 3 describes the data and gives empirical results. Finally, the last section concludes.

2. METHODOLOGY

In studies relying on the standard Engle and Granger (1987) cointegration approach, two steps are involved: the first step is to check that the considered series share similar univariate integrational properties (the most popular outcome is to be $I(1)$ processes), then running an OLS regression of each series on each other, save the residuals obtained from cointegrating regressions and test to see if they are $I(0)$ processes or not. If the residuals are $I(0)$, there is evidence of cointegration. It is clear that the classical cointegration methods are too restrictive and have low power when the residuals are mean reverting but not $I(0)$. The fractional cointegration approach allows residuals to be fractionally integrated rather than stationary. Similar to the Engle and Granger (1987) cointegration approach, the fractional cointegration approach which is used in our paper involves two steps: first, the residuals are obtained from the cointegrating regressions. Secondly, the Robinson (1994) test is applied on the residuals following Gil-Alana (2003) and Caporale and Gil-Alana (2004). At this point, we show a brief description of the Robinson test which requires the estimation of the following regression model

$$y_t = \beta' z_t + x_t \qquad (2.1)$$

where y_t is the observed time series for $t = 1, 2, ...T$, $\beta = (\beta_1, ..., \beta_k)'$ is a $(k \times 1)$ vector of unknown parameters, z_t is a $(k \times 1)$ vector of deterministic regressors such as an intercept or a linear trend. The regression errors x_t can be explained as follows:

$$(1-L)^d x_t = u_t \quad , \quad t = 1, 2, ... \tag{2.2}$$

where L is the lag operator and u_t is an $I(0)$ process. Here, d can take any real value. Robinson suggests a Lagrange Multiplier (LM) test statistic for testing unit roots and other forms of nonstationary hypotheses, embedded in fractional alternatives. The main advantage of the procedure is that it tests unit and fractional roots with a standard null limit distribution, which is unaffected by inclusion or not of deterministic trends. Under the null hypothesis $H_0 : d = d_0$, the LM test statistic can be calculated as below:

$$\hat{r} = \frac{T^{1/2}}{\hat{\sigma}^2} \hat{A}^{-1/2} \hat{a} \tag{2.3}$$

where T is the sample size and

$$\hat{a} = \frac{-2\pi}{T} \sum_{j=1}^{T-1} \psi(\lambda_j) g(\lambda_j; \hat{\tau})^{-1} I(\lambda_j); \quad \hat{\sigma}^2 = \sigma^2(\hat{\tau}) = \frac{2\pi}{T} \sum_{j=1}^{T-1} g(\lambda_j; \hat{\tau})^{-1} I(\lambda_j);$$

$$\hat{A} = \frac{2}{T} \left(\sum_{j=1}^{T-1} \psi(\lambda_j)^2 - \sum_{j=1}^{T-1} \psi(\lambda_j) \hat{\varepsilon}(\lambda_j)' \times \left(\sum_{j=1}^{T-1} \hat{\varepsilon}(\lambda_j) \hat{\varepsilon}(\lambda_j)' \right)^{-1} \times \sum_{j=1}^{T-1} \hat{\varepsilon}(\lambda_j) \psi(\lambda_j) \right)$$

$$\psi(\lambda_j) = \log \left| 2 \sin \frac{\lambda_j}{2} \right|; \quad \hat{\varepsilon}(\lambda_j) = \frac{\partial}{\partial \tau} \log g(\lambda_j; \hat{\tau}_j); \quad \lambda_j = \frac{2\pi j}{T};$$

$$\hat{\tau} = \arg\min_{\tau \in T^*} \sigma^2(\tau) \ .$$

Here, $I(\lambda_j)$ is the periodogram of u_t and T^* is a compact subset or the Euclidean space. Robinson (1994) showed that the test statistic under certain regularity conditions is as below:

$$\hat{r} \rightarrow_d N(0,1) \text{ as } T \rightarrow \infty. \tag{2.4}$$

Thus, a one sided $100\alpha\%$ level test of the null hypothesis $H_0 : d = d_0$ against the alternative $H_1 : d > d_0$ is given by the rule "Reject H_0 if $\hat{r} > z_\alpha$". Conversely, a one sided $100\alpha\%$ level test of $H_0 : d = d_0$ against the alternative $H_1 : d < d_0$ is given by the rule "Reject H_0 if $\hat{r} < -z_\alpha$". Following these rules, Gil-Alana (2003) and Caporale and Gil-Alana(2004) suggest a fractional cointegration concept based on the following model:

$$(1-L)^{d+\theta} e_t = v_t \quad , \quad t = 1, 2, ... \qquad (2.5)$$

where e_t is the OLS residuals from the cointegrating regression and v_t is $I(0)$. The null $H_0 : \theta = 0$ hypothesis is tested against the one sided alternative $H_1 : \theta < 0$. If H_0 hypothesis on the estimated residuals is rejected, there is an evidence of fractional cointegration of a certain degree since the residuals are integrated of a smaller order than the individual series. If we cannot reject the null hypothesis, it can be concluded that there is no evidence of fractional cointegration since the integration order of the residuals are same as the univariate series.

In order to apply two step cointegration and fractional cointegration approaches in our paper, we estimate following cointegrating regression and obtain the residuals (e_{1t}):

$$LEC_t = \beta_0 + \beta_1 LGDP_t + e_{1t} \qquad (2.6)$$

Similarly, in order to examine the impact of LEC on LGDP, we also take LGDP as dependent variable and obtain the residuals (e_{2t}) by estimating the following cointegrating regression model:

$$LGDP_t = \alpha_0 + \alpha_1 LEC_t + e_{2t} \qquad (2.7)$$

In these models, *LEC* and *LGDP* refer to the logarithms of the energy consumption per capita and real GDP per capita series, respectively.

3. DATA AND EMPIRICAL RESULTS

This paper uses annual energy consumption per capita and real GDP per capita (constant 2000 prices) series over the period from 1960 to 2009. The source of the data is the World Development Indicators database of the World Bank. We convert the data into the natural logs before the analysis. The logarithms of the energy consumption per capita and real GDP per capita series are defined as **LEC** and **LGDP**, respectively, as reported in the previous section. Figure 1 illustrates the plots of the **LEC** and **LGDP** series.

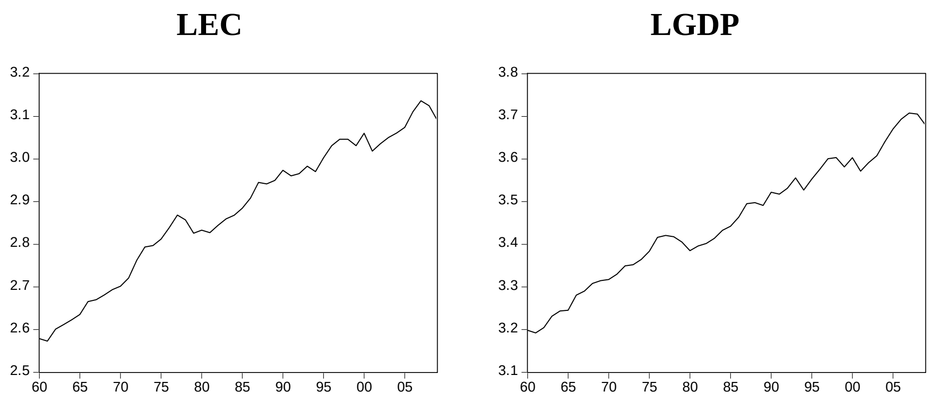

Figure 1: Plots of the LEC and LGDP series

The figure shows that the LEC and LGDP series have a nonstationary apperance with similar movements. Since the plots are only suggestive of the relationship between the series, we focus on this in the context of different techniques. As a first step, the unit root properties of the series are investigated by using Augmented Dickey Fuller (ADF) and Phillips and Perron (PP) unit root tests. The results are reported in Table 1.

Table 1: The results of ADF and PP unit root tests

Variables	ADF	PP
LEC	-1.960	-2.044
ΔLEC	-6.149[a]	-6.131[a]
LGDP	-2.935	-2.930
ΔLGDP	-6.599[a]	-6.600[a]

[a] denotes that the unit root null hypothesis is rejected at the 1% significance level. The sign "Δ" refers to the first differences of the series. The critical values for the model specification with an intercept and a linear trend are -4.156, -3.504 and -3.181 at the 1%, 5% and 10% significance levels, respectively.

As can be seen from the table, the unit root null hypothesis cannot be rejected for both LEC and LGDP series in level form. In other words, the series are non-stationary in level. However, both tests reject the unit root null hypothesis for the series when they are used in the first differences. Since the concept of traditional unit root tests are too restrictive, we also consider testing the unit root properties by performing the Robinson (1994) test on the individual series. The results for the specification with an intercept and a linear trend under the assumptions of white noise and AR(1) disturbances are tabulated in Table 2.

Table 2: The results of Robinson test for unit root

Variables	White noise disturbances	AR(1) disturbances
LEC	-0.503[b]	-0.939[b]
LGDP	-0.043[b]	0.303[b]

[b] indicates nonrejection values of the unit root null hypothesis ($d_0 = 1$) at the 5% significance level. We consider only the specification with an intercept and a linear trend for white noise and AR(1) disturbances.

According to the results, we cannot reject the unit root null hypothesis ($d_0 = 1$) for LEC and LGDP series in both disturbances. Having verified that the series have the same integration order (I(1)), our next step is to test whether there exists any long run relationship between LEC and LGDP. For this purpose, we first perform standard Engle and Granger (1987) cointegration approach by investigating the stationarity of the residuals (e_{1t} and e_{2t}). The results are in Table 3.

Table 3: The results of Engle and Granger cointegration test

	ADF
e_{1t}	-1.752
e_{2t}	-1.775

In ADF test for cointegration, MacKinnon (1990) critical values are used. These are -3.958, -3.410 and -3.127 for 1%, 5% and 10% significance levels, respectively.

The results in the table clearly show that residual series are not stationary ($I(0)$), implying no evidence of cointegration between LEC and LGDP series. Since this classical method has low power when the residuals are mean reverting but not $I(0)$, in our analysis, we also apply the fractional cointegration approach. It is particularly interesting as the error correction term in the cointegrating regressions may be fractionally integrated rather than stationary. Following Gil-Alana(2003) and Caporale and Gil-Alana(2004), the Robinson(1994) test is applied on the residuals (e_{1t} and e_{2t}). Table 4 gives the one sided $\hat{r}$ statistics for different values of d_0.

Table 4: The results of Robinson test on the residuals

Residuals	e_{1t}		e_{2t}	
d_0	**White noise disturbances**	**AR(1) disturbances**	**White noise disturbances**	**AR(1) disturbances**
0.00	5.875	22.571	5.829	22.261
0.05	5.529	20.574	5.483	20.273
0.10	5.162	18.499	5.116	18.215
0.15	4.773	16.410	4.727	16.151
0.20	4.362	14.375	4.317	14.146
0.25	3.932	12.450	3.888	12.253
0.30	3.485	10.671	3.442	10.503
0.35	3.027	9.051	2.986	8.908
0.40	2.563	7.582	2.524	7.461
0.45	2.099	6.246	2.062	6.142
0.50	1.643	5.017	1.607[b]	4.926
0.55	1.199[b]	3.867	1.166[b]	3.786
0.60	0.773[b]	2.775	0.742[b]	2.701
0.65	0.369[b]	1.726	0.340[b]	1.657
0.70	-0.010[b]	0.716[b]	-0.036[b]	0.652[b]
0.75	-0.361[b]	-0.246[b]	-0.385[b]	-0.306[b]
0.80	-0.684[b]	-1.148[b]	-0.707[b]	-1.204[b]
0.85	-0.979[b]	-1.976	-1.000[b]	-2.029
0.90	-1.247[b]	-2.723	-1.266[b]	-2.772
0.95	-1.488[b]	-3.383	-1.507[b]	-3.430
1.00	-1.706	-3.962	-1.723	-4.005

[b] indicates nonrejection values of the null hypothesis at the 5% significance level. We consider only the specification with an intercept and a linear trend for white noise and AR(1) disturbances.

The results in the table indicate that, when we apply the Robinson test on the residuals (e_{1t}) obtained from Equation (2.6), $H_0 : d = d_0$ cannot be rejected for $d_0 = 0.55, 0.60, 0.65, 0.70, 0.75, 0.80, 0.85, 0.90, 0.95$ in white noise disturbances and for $d_0 = 0.70, 0.75, 0.80$ in AR(1) disturbances. When we choose LGDP as the dependent variable and obtain the residuals (e_{2t}) from Equation (2.7), the Robinson test results applied on the residuals state that the nonrejection values take place at $d_0 = 0.50, 0.55, 0.60, 0.65, 0.70, 0.75, 0.80, 0.85, 0.90, 0.95$ in white noise disturbances and at $d_0 = 0.70, 0.75, 0.80$ in AR(1) disturbances. According to these results, it is clear that unit root null hypothesis $d_0 = 1$ is rejected for all cases - in other words, the integration order of the residuals are smaller than one. These findings support the existence of a fractional cointegration relationship between energy consumption and GDP in Turkey, implying that deviations from the long run relationship shared by energy consumption and GDP take a long time to dissipate before reaching their equilibrium level.

4. CONCLUSIONS

In this paper, the relationship between energy consumption and GDP in Turkey is investigated by using both cointegration and fractional cointegration approaches. As reported before, the classical cointegration methods are too restrictive and have low power when the residuals are mean reverting but not $I(0)$. The advantage of the fractional cointegration approach is that it allows residuals to be fractionally integrated rather than stationary. As a first step of the analysis, we examine the unit root properties of the energy consumption and GDP series by using ADF and PP unit root tests and find that both series are I(1). Since the concept of these unit root tests are too restrictive, we also apply the Robinson(1994) test on the series for unit root properties. After supporting that the series have the same integration order (I(1)), we apply standard the Engle and Granger (1987) cointegration approach. The findings show that there is no evidence of cointegration. To check these findings, the fractional cointegration method is also used. For this purpose, two main steps are followed: first, the residuals are obtained from the estimation of cointegrating regressions. Secondly, the Robinson(1994) test is applied on the residuals as mentioned by Gil-Alana(2003) and Caporale and Gil-Alana(2004). According to the results, it is found that energy consumption and GDP in Turkey are fractionally cointegrated, implying long memory and slow reversion to equilibrium. This suggests that deviations from the long run relationship shared by energy consumption and GDP take a long time to dissipate before reaching their equilibrium level.

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APPENDIX

Table: Summary of the previous studies on the relationship between energy consumption and GDP

Study	Countries (period)	Methodology	Direction of the relationship
Kraft and Kraft (1978)	US (1947-1974)	Sims' Technique	GDP → Energy Con.
Akarca and Long (1980)	US (1950-1970)	Sims' Technique	No Relationship
Yu and Hwang (1984)	US (1947-1979)	Sims' Technique	No Relationship
Yu and Choi (1985)	USA, UK, Poland, South Korea, Philippines (1950-1976)	Granger Causality, Sims' Technique	No Relationship (USA, UK, Poland) GDP → Energy Con. (South Korea) Energy Con. → GDP (Philippines)
Erol and Yu (1988)	West Germany, Italy, Canada, France, UK, Japan (1952-1982)	Granger Causality	GDP ↔ Energy Cons. (Japan), Energy Con. → GDP (Canada), GDP → Energy Con. (West Germany and Italy), No causality (France and UK)
Abosedra and Baghestani (1989)	US (1947-1987)	Cointegration, Granger Causality	GDP → Energy Con.
Stern (1993)	USA (1947-1990)	Multivariate Granger Causality	Energy Con. → GDP
Cheng (1995)	US (1947-1990)	Cointegration, Granger Causality	No Relationship
Yang (2000)	Taiwan (1954-1997)	Granger Causality	Energy Con. ↔ GDP
Soytaş et al. (2001)	Turkey (1960-1995)	Cointegration, Vector Error Correction Model	Energy Con. → GDP
Ghosh (2002)	India (1950-1997)	Granger Causality	GDP → Energy Con.

Note: → means uni-directional relationship and ↔ means bi-directional relationship.

Table: (Continued)

Study	Countries (period)	Methodology	Direction of the relationship
Soytaş and Sarı (2003)	Argentina (1950-1990) Italy (1950-1992) Korea (1953-1991) Turkey (1950-1992) France (1950-1992) Germany (1950-1992) Japan (1950-1992) Poland (1965-1994) Indonesia (1960-1992)	Cointegration, Vector Error Correction Model	GDP ↔ Energy Con. (Argentina) GDP → Energy Con. (Italy,Korea) Energy Con. → GDP (Turkey, France, Germany, Japan) No Relationship (Poland, Indonesia)
Altınay and Karagöl (2004)	Turkey (1950-2000)	Hsiao's Granger Test	No Relationship
Ghali and El-Sakka (2004)	Canada (1961-1977)	Cointegration, Granger Causality	GDP ↔ Energy Con.
Jumbe (2004)	Malawi (1970-1999)	Granger Causality, Error Correction Model	Energy Con. ↔ GDP
Shiu and Lam (2004)	China (1971-2000)	Error Correction Model	Energy Con. → GDP
Oh and Lee (2004)	Korea (1970-1990)	Cointegration, Vector Error Correction Model	Energy Con. → GDP (in the short run) GDP ↔ Energy Con. (in the long run)
Wolde-Rufael (2004)	Shanghai, China (1952-1999)	Toda-Yamamoto Granger Causality	Energy Con. ↔ GDP
Altınay and Karagöl (2005)	Turkey (1950-2000)	Granger Causality, Dolado Lütkepohl test	Energy Con. → GDP
Yoo (2005)	Korea (1970-2002)	Error Correction Model	Energy Con. ↔ GDP
Yoo (2006)	Indonesia, Malaysia, Singapure, Thailand (1971-2002)	Granger Causality, Hsiao's version of Granger Causality	GDP → Energy Con. (Indonesia) Energy Con. ↔ GDP (Malaysia, Singapore) GDP → Energy Con. (Thailand)

Note: → means uni-directional relationship and ↔ means bi-directional relationship.

Table: (Continued)

Study	Countries (period)	Methodology	Direction of the relationship
Halıcıoğlu (2007)	Turkey (1968-2005)	Granger Causality	GDP → Energy Con.
Lise and Montfort (2007)	Turkey (1970-2003)	Cointegration, Vector Error Correction Model	GDP → Energy Con.
Mozumder and Marathe (2007)	Bangladesh (1971-1999)	Cointegration, Vector Error Correction Model	Economic Growth → Electricity Con.
Kaplan et al. (2011)	Turkey (1971-2006)	Cointegration, Vector Error Correction Model, Granger Causality	Energy Con. ↔ GDP

Note: → means uni-directional relationship and ↔ means bi-directional relationship.