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THE CAUSAL RELATIONSHIP BETWEEN ELECTRICITY CONSUMPTION AND GDP IN TURKEY: EVIDENCE FROM ARDL BOUNDS TESTING APPROACH

ABSTRACT

This paper investigates the long-run and causal relationship between electricity consumption and economic growth in Turkey by using the ARDL cointegration test and Granger causality models. It employs annual data covering the period of 1977–2006. The ARDL cointegration test yields evidence of a long-run relationship between electricity consumption per capita and real GDP per capita. The results from the Granger causality models indicate that there is an evidence of unidirectional causality running from the electricity consumption to economic growth in the long-run. The overall results confirm the "Growth hypothesis" for Turkey. This implies that, energy conservation policies, such as rationing electricity consumption, are likely to have an adverse effect on real GDP of Turkey.†

JEL classification: *C32, C52, Q43*
Keywords: *Electricity consumption, Economic growth, ARDL bounds testing*

I. INTRODUCTION

In Turkey, the higher demand for electricity is growing rapidly due to the technical, social and economic development. Its electricity demand tends to increase by a rapid average of %7.5 per year. In Turkey, electricity generation came from three main sources: natural gas by %48.17, coal by %28.98, and hydroelectric by %16.77 in 2008 (www.enerji.gov.tr). Both Figure 1 and differences between two growth rates in Table 1 also show that (i) both the electric power consumption per capita (kWh) and real GDP per capita (constant 2000 US$) are smoothly increasing, but (ii) electricity consumption per capita grows faster than GDP per capita.

On the other hand, energy prices have allegedly been a significant factor especially for the energy importing countries like Turkey. To make a well designing electricity policy, it is very important to ascertain empirically whether there is a long-run causal link between electricity consumption and economic growth and the way of causality.

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Figure 1

The log of electric power consumption per capita, kWh (LnELEC) and real GDP per capita, constant 2000 US$ (LnGDP).

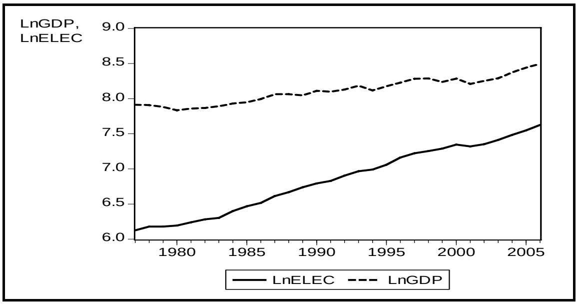

Table 1

The average growth rates of electricity consumption per capita and real GDP per capita

Variables	1977-1981	1982-1986	1987-1991	1992-1996	1997-2001	2002-2006
g_{ELEC}	2.28	4.68	4.29	5.16	1.95	5.49
g_{GDP}	-1.11	2.52	0.72	1.97	-1.45	4.82
$g_{ELEC} - g_{GDP}$	3.39	2.16	3.57	3.18	3.40	0.67

Notes: g_{ELEC} and g_{GDP} are the average growth rates of electricity consumption per capita (kWh) and real GDP per capita (constant 2000 US$), respectively.

Over the last three decades, the relationship between energy consumption and economic growth has been widely discussed in this literature. Since the seminal work of Kraft and Kraft (1978), different studies have focused on different countries, time periods, and have used different proxy variables for energy consumption and income, but the direction of the causality relationship has been mixed. The directions and its policy implications of causal relationship between electricity consumption and economic growth have been generally tested by using following four hypothesize within the literature (See Jumbe, 2004): (i) G*rowth hypothesis* (Causality running from electricity consumption to economic growth): This suggests that electricity consumption plays an important role in economic growth (Altinay and Karagol, 2005; Shiu and Lam, 2004). (ii) C*onservation hypothesis* (Causality running from economic growth to electricity consumption): This indicates that a country is not dependent on energy for growth and development and then electricity conservation policies will have little or no effect on economic growth. (Ghosh, 2002). (iii) *Feedback hypothesis* (two-way causality between electricity consumption and economic growth): This shows that electricity consumption and economic growth complement each other (Jumbe, 2004; Yoo, 2006). (iv) N*eutrality hypothesis* (No causal relationship between electricity consumption and real GDP): This means that neither conservative nor expansive policies in relation to electricity consumption have any effect on economic growth.

The empirical result for energy consumption - economic growth nexus is supported neutrality hypothesis, while there is an evidence of growth hypothesis for electricity consumption - economic growth nexus in the previous studies about Turkey (see Table 2 and Table 3). As it can be seen in these tables, almost all types of causality are found in these studies. In other words, the empirical results of energy-growth and electricity-growth nexus studies for Turkey are mixed and contradictory.

Table 2
Summary of empirical studies on energy consumption –growth xexus for Turkey

Authors	Period	Variables	Methodology	Conclusion
Soytas et al. (2001)	1960-1995	Energy consumption; GDP	Granger causality; VEC; JJ cointegration.	$EC \rightarrow GDP$
Soytas and Sari (2003)	1950-1992	Energy consumption; GDP	Granger causality; VEC; JJ cointegration.	$EC \rightarrow GDP$
Altinay and Karagol (2004)	1950-2000	Energy consumption; GDP	Hsiao causality; Zivot–Andrews structural break test	$EC \neq GDP$
Lise and Monfort (2007)	1970-2003	Energy consumption; GDP	Granger causality; VEC; JJ cointegration.	$GDP \rightarrow ELC$
Jobert and Karanfil (2007)	1960-2003	Energy consumption; GDP	Granger causality; VAR.	$EC \neq GDP$
Erdal *et al.* (2008)	1970-2006	Energy consumption; GDP	Granger causality; VEC; JJ cointegration.	$EC \leftrightarrow GDP$
Halicioglu (2009)	1960-2005	Carbon emissions; Energy consumption; GDP; Foreign Trade	Granger causality ARDL cointegration.	$EC \neq GDP$
Soytas and Sari (2009)	1960-2000	Energy consumption; carbon emissions; Labor; gross fixed capital investment; GDP	TY causality.	$EC \neq GDP$

Notes: $\rightarrow$, $\leftrightarrow$ and $\neq$ represent unidirectional causality, bidirectional causality, and no causality, respectively. Abbreviations are defined as follows: VAR= vector autoregressive model, VEC= vector error correction model, JJ= Johansen–Juselius, TY= Toda–Yamamoto, ARDL= autoregressive distributed lag, EC= energy consumption, ELC= electricity consumption, GDP= real gross domestic product.

Table 3
Summary of empirical studies on electricity consumption–growth nexus for Turkey

Authors	Period	Variables	Methodology	Conclusion
Murry and Nan (1996)	1950-1970	Electricity consumption; GDP	Granger-causality; VAR	$ELC \rightarrow GDP$
Altinay and Karagol (2005)	1950-2000	Electricity consumption; GDP	Granger-causality; Dolado–Lutkepohl causality.	$ELC \rightarrow GDP$
Halicioglu (2007)	1968-2005	Residential electricity consumption; GDP, residential electricity price; the urbanization rate	Granger causality ARDL cointegration.	$GDP \rightarrow ELC$
Narayan and Prasad (2008)	1960-2002	Electricity consumption; GDP	Bootstrapped Granger-causality	$ELC \neq GDP$
Soytas and Sari (2007)	1968-2002	Industry electricity consumption, value added-Manufacturing; Manufacturing employment; manufacturing real fixed investment	Granger-causality; VEC; JJ cointegration.	$IELC \rightarrow MVA$

Notes: → and ≠ represent unidirectional causality and no causality, respectively. Abbreviations are defined as follows: VAR= vector autoregressive model, VEC= vector error correction model, JJ= Johansen–Juselius, ARDL= autoregressive distributed lag, EC= energy consumption, ELC= electricity consumption, GDP= real gross domestic product, IELC= industrial electricity consumption, MVA= manufacturing value added.

These contractionary results are also confirmed in the study of Payne (2010) and Ozturk (2010). According to Payne (2010), the results for the specific countries surveyed show that 31.15% supported the neutrality hypothesis; 27.87% the conservation hypothesis; 22.95% the growth hypothesis; and 18.03% the feedback hypothesis. This survey also indicates that the empirical results have yielded mixed results in terms of the four hypotheses (neutrality, conservation, growth, and feedback) and electricity consumption - economic growth nexus is an unresolved issue. In empirical literature on energy consumption - economic growth or electricity consumption - economic growth, it can be seen that most of the studies are using only GDP and energy or electricity consumption variables in their models (See Payne, 2010; Table 1 for details). In other words, bivariate models were used in many of these empirical studies. Thus, we also prefer to apply bivariate model to compare and evaluate our results. To design an appropriate electricity policy, we investigate the long-run and causal relationships between the electricity consumption per capita and real GDP per capita by using recently developed autoregressive distributed lag (hereafter ARDL) bounds testing approach of cointegration by Pesaran and Shin (1999) and Pesaran *et al.* (2001), and error-correction based Granger causality models for Turkey. The rest of the paper is organized as follows. The next section presents the methodology and data. The third section reports the empirical results. The last section concludes the paper.

2. METHODOLOGY AND DATA

Following the empirical literature, the long-run relationship between the real GDP and the electricity consumption may be expressed as:

$$GDP_t = \alpha + \beta ELC_t + \varepsilon_t \tag{1}$$

where GDP and ELC are real GDP per capita (constant 2000 US$) and electric power consumption (kWh per capita), respectively and ε_t is the error term. The annual Turkish time series data are taken for 1977-2006 from the World Development Indicators (WDI) online database. All variables are employed with their natural logarithms. The long-run and causal relationships between real GDP per capita and the electricity consumption per capita in Turkey will be performed in two steps. Firstly, we will test the long run relationships among the variables by using the ARDL bounds testing approach of cointegration. Secondly, we test causal relationships by using the error-correction based causality models.

2.1. Autoregressive Distributed Lag (ARDL) Cointegration Analysis

The ARDL bounds testing approach of cointegration is developed by Pesaran and Shin (1999) and Pesaran *et al.* (2001). Due to the low power and other problems associated with other test methods, the ARDL approach to cointegration has become popular in recent years. The ARDL cointegration approach has numerous advantages in comparison with other cointegration methods such as Engle and Granger (1987), Johansen (1988), and Johansen and Juselius (1990) procedures: (i) The ARDL procedure can be applied whether the regressors are I(1) and/or I(0), while Johansen cointegration techniques require that all the variables in the system be of equal order of integration. This means that the ARDL can be applied irrespective of whether underlying regressors are purely I(0), purely I(1) or mutually co-integrated and thus no need for unit root pre-testing. (ii) While the Johansen cointegration techniques require large data samples for validity, the ARDL procedure is statistically more significant approach to determine the cointegration relation in small samples. (iii) The ARDL procedure allows that the variables may have different optimal lags, while it is impossible with conventional cointegration procedures. (iv) The ARDL technique generally provides unbiased estimates of the long-run model and valid t-statistics even when some of the regressors are endogenous (see Harris and Sollis, 2003). (v) The ARDL procedure employs only a single reduced form equation, while the conventional cointegration procedures estimate the long-run relationships within a context of system equations.

The ARDL model for the standard log-linear functional specification of long-run relationship between electricity consumption and real GDP may follows as:

$$\Delta GDP_t = \alpha_1 + \sum_{i=1}^{p1} \phi_{1i} \Delta GDP_{t-i} + \sum_{j=0}^{q1} \beta_{1j} \Delta ELC_{t-j} + \delta_1 GDP_{t-1} + \delta_2 ELC_{t-1} + \varepsilon_{1t} \quad (2)$$

where ε_{1t} and Δ are the white noise term and the first difference operator, respectively. An appropriate lag selection based on a criterion such as Akaike Information Criterion (AIC) and Schwarz Bayesian Criterion (SBC). The bounds testing procedure is based on the joint F-statistic or Wald statistic that is tested the null of no cointegration, $H_0 : \delta_r = 0$, against the alternative of $H_1 : \delta_r \neq 0$, $r = 1,2$. Two sets of critical values that are reported in Pesaran et al. (2001) provide critical value bounds for all classifications of the regressors into purely I(1), purely I(0) or mutually cointegrated. If the calculated *F*-statistics lies above the upper level of the band, the null is rejected, indicating cointegration. If the calculated *F*-statistics is below the upper critical value, we cannot reject the null hypothesis of no cointegration. Finally, if it lies between the bounds, a conclusive inference cannot be made without knowing the order of integration of the underlying regressors. Recently, Narayan (2005) argues that exiting critical values, because they are based on large sample sizes, cannot be used for small sample sizes. Narayan (2005) regenerated the set of critical values for the limited data ranging from 30–80 observations by using the Pesaran et al. (2001)'s GAUSS code. With the limited annual time series Turkish data on electricity consumption and income, this study employs the critical values of Narayan (2005) for the bounds F-test rather than Pesaran *et al.* (2001).

If there is evidence between long-run relationships (cointegration) of the variables, the following long-run and short-run models that are employed:

$$GDP_t = \alpha_2 + \sum_{i=1}^{p2} \phi_{2i} GDP_{t-i} + \sum_{j=0}^{q2} \beta_{2j} ELC_{t-j} + \varepsilon_{2t} \quad (3)$$

$$\Delta GDP_t = \alpha_3 + \sum_{i=1}^{p3} \phi_{3i} \Delta GDP_{t-i} + \sum_{j=0}^{q3} \beta_{3j} \Delta ELC_{t-j} + \psi ECT_{t-1} + \varepsilon_{3t} \quad (4)$$

where ψ is the coefficient of error correction term (hereafter *ECT*). It shows how quickly variables converge to equilibrium and it should have a statistically significant coefficient with a negative sign.

2.2. Causality Analysis

ARDL cointegration method tests whether the existence or absence of long-run relationships between the electricity consumption per capita and the real GDP per capita. It doesn't indicate the direction of causality. We use the two-step procedure from the Engle and Granger (1987) model to examine the causal relationship between the electricity consumption per capita and real GDP per capita. Once estimating the long-run model in Equation (3) in order to obtain the estimated residuals, the next step is to estimate error-correction based Granger causality models. As opposed to the conventional Granger causality method, the error-correction based causality test allows for the inclusion of the lagged error-correction term derived from the cointegration equation (See Narayan and Smyth, 2008; and Odhiambo, 2007, 2009):

$$\Delta GDP_t = \alpha_4 + \sum_{i=1}^{p4} \beta_{4j} \Delta GDP_{t-i} + \sum_{j=0}^{q4} \phi_{4i} \Delta ELC_{t-j} + \psi_1 ECT_{t-1} + \varepsilon_{4t} \quad (5.a)$$

$$\Delta ELC_t = \alpha_5 + \sum_{i=0}^{p5} \beta_{5j} \Delta GDP_{t-i} + \sum_{j=1}^{q5} \phi_{5i} \Delta ELC_{t-j} + \psi_2 ECT_{t-1} + \varepsilon_{5t} \quad (5.b)$$

Residual terms, ε_{4t} and ε_{5t}, are independently and normally distributed with zero mean and constant variance. An appropriate lag selection is based on a criterion such as AIC and SBC. Rejecting the null hypotheses indicate that ELC does Granger cause GDP and GDP does Granger cause ELC, respectively. Using Equations (5.a) and (5.b), Granger causality can be examined in three ways: i) Short-run or weak Granger causalities are detected by testing $H_0 : \phi_{4i} = 0$ and $H_0 : \beta_{5j} = 0$ for all *i* and *j* in equations (5.a) and (5.b), respectively. ii) Another possible source of causation is the *ECT* in equations. Thus, long-run causalities are examined by testing $H_0 : \psi_1 = 0$ and $H_0 : \psi_2 = 0$ for equations (5.a) and (5.b). iii) Strong Granger causalities are detected by testing $H_0 : \phi_{4i} = \psi_1 = 0$ and $H_0 : \beta_{5j} = \psi_2 = 0$ for all *i* and *j* in equations (5.a) and (5.b), respectively (Lee and Chang, 2008).

3. EMPIRICAL RESULTS

According to Pesaran and Shin (1999), the SBC is generally used in preference to other criteria because it tends to define more parsimonious specifications. With the limited observations, this study used the SIC to select an appropriate lag for the ARDL model. Table 4 presents the estimated ARDL (1,1) model that has passed several diagnostic tests that indicate no evidence of serial correlation and heteroscedasticity. Besides this, the ADF unit root test for the residuals revealed that they are stationary.

In addition, due to the structural changes in the Turkish economy it is likely that macroeconomic series may be subject to one or multiple structural breaks. In addition, . For this purpose, the stability of the short-run and long-run coefficients is checked through the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests proposed by Brown *et al.* (1975). Unlike Chow test, requires break point(s) to be specified, the CUSUM and CUSUMQ tests are quite general tests for structural change in that they do not require a prior determination of where the structural break takes place. Figure 2 presents the plot of CUSUM and CUSUMSQ test statistics that fall inside the critical bounds of 5% significance. This implies that the estimated parameters are stable over the period of 1977–2006.

The bounds *F*–test for cointegration test yields evidence of a long-run relationship between electricity consumption per capita and real GDP per capita at 5% significance level in Turkey. The estimated log-linear long-run coefficient of the electricity consumption per capita is about 0.40 and positive. This coefficient implies the elasticity of electricity consumption and an increase in electricity consumption per capita will raise the real GDP per capita at the 40%. The estimated *ECT* is also negative (-0.405) and statistically significant at 1% confidence level. *ECT* indicates that any deviation from the long-run equilibrium of between variables is corrected about 41% for each period and takes about 2.5 periods to return the long-run equilibrium level.

Figure 2

Plot of Cusum of Squares and Cusum test

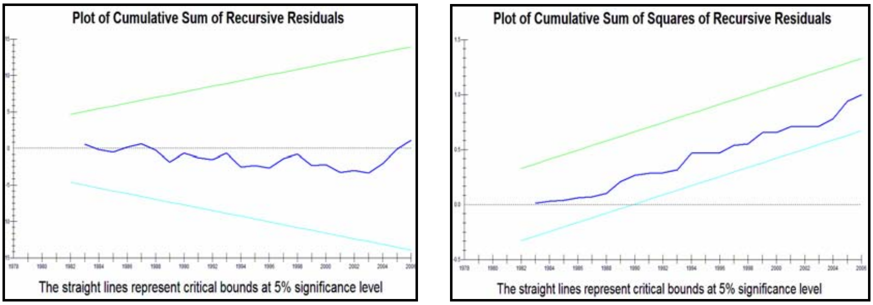

Table 4

Estimated coefficients

Variables	**Short-Run**	**Long-Run**
GDP(-1)	0.5946 [0.000]	
ELC	1.0181 [0.000]	0.4022 [0.000]
ELC(-1)	- 0.8550 [0.000]	
Constant	2.1386 [0.014]	5.2754 [0.000]

R^2	0.9810	NORM	1.464 [0.481]	*ECM*	-0.405 [0.009]
Adj. R^2	0.9787	LM	2.246 [0.134]	ADF	-6.391 (-4.513)
SEE	0.0267	HET	0.980 [0.322]	F	4.720

Notes:

SEE is the standard error of the regression.
NORM is a test for normality of residuals with a χ^2 distribution with two degrees of freedom.
LM is the Lagrange multiplier test for serial correlation with a χ^2 distribution with four degrees of freedom.
HET is test for heteroskedasticity with a χ^2 distribution with only one degree of freedom.
ECM is the estimated coefficient of error correction term.
p-values for the estimated coefficients and statistics are in [ ].
ADF is unit root test statistics for residuals and its 5% critical value is in ( ).
F is the ARDL cointegration test. The critical values for the lower *I*(0) and upper *I*(1) bounds are 4.090 and 4.663 for 5% significance level, respectively (Narayan, 2005, Appendix: Case II).

This study also explores causal relationship between the variables in terms of the three error-correction based Granger causality models. The overall results show that there is unidirectional causality running from the electricity consumption to economic growth in the long-run (see Table 5). This indicates that energy conservation policies, such as rationing electricity consumption, are likely to have an adverse effect on the real output growth of Turkey. Therefore, the energy growth policies regarding electricity consumption should be adapted in such a way that the development of this sector stimulates economic growth.

Table 5

Granger causality test results

The Null Hypotheses		Short-run (or Weak) Granger Causality
ΔELC $\rightarrow \Delta$GDP	$(H_0 : \phi_{4i} = 0)$	0.7737 (0.3791)
$\Delta GDP \rightarrow \Delta$ELC	$(H_0 : \beta_{5j} = 0)$	0.1540 (0.6948)
The Null Hypotheses		**Long-run Granger Causality**
ECT $\rightarrow \Delta GDP$	$(H_0 : \psi_1 = 0)$	3.4321 (0.0639)
$ECT \rightarrow \Delta$ELC	$(H_0 : \psi_2 = 0)$	0.0985 (0.7537)
The Null Hypotheses		**Strong Granger Causality**
ΔELC,ECT $\rightarrow \Delta$GDP	$H_0 : \phi_{4i} = \psi_1 = 0)$	3.8881 (0.1431)
$\Delta GDP, ECT \rightarrow \Delta$ELC	$H_0 : \beta_{5j} = \psi_2 = 0)$	0.1557 (0.9251)

Notes: The null hypothesis is that there is no causal relationship between variables.
Values in parentheses are p-values for Wald tests with a χ^2 distribution.
Δ is the first difference operator.

4. CONCLUDING REMARKS

The empirical result for energy-growth nexus is supported neutrality hypothesis, while there is an evidence of growth hypothesis for electricity consumption-growth nexus in the previous studies for Turkey. Since the question of whether electricity consumption causes economic growth or economic growth causes electricity consumption still is an unresolved issue, this paper may be considered as a complementary study to the previous studies for Turkey.

This paper explores the long-run and causal relationship issues between electricity consumption and economic growth in Turkey by using the ARDL cointegration test and Granger causality models. It employs annual data covering the period 1977–2006. The ARDL cointegration test yields evidence of a long-run relationship between electricity consumption per capita and real GDP per capita at 5% significance level. According to results from three kinds of Granger causality, the electricity consumption per capita causes real GDP per capita only in the long-run. But, there is no causal evidence from the real GDP per capita to electricity consumption per capita. In other words, “Growth hypothesis” is confirmed in Turkey. This suggests that electricity consumption plays an important role in economic growth and high electricity consumption tends to have high economic growth in the long-run, but not the reverse.

Therefore, energy conservation policies, such as rationing electricity consumption, may harm economic growth in Turkey in the long-run. In addition, any electricity consumption infrastructure shortage is likely to restrain the economic growth in Turkey. In order to avoid any adverse effect of electricity shortages on economy, the Ministry of Energy and Natural Resources of Turkey should continue to explore new resources and expand the electricity supply via hydroelectric power plants, thermal power plants and wind power plants to satisfy total demand for electricity. As a strategy toward higher long-run economic growth, Turkey should try to invest more on electricity supply infrastructure.

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KAUZALNI ODNOS POTROŠNJE ELEKTRIČNE ENERGIJE I BDP-a U TURSKOJ: DOKAZI DOBIVENI GRANIČNIM TESTIRANJEM ARDL

SAŽETAK

Rad proučava dugoročne i kauzalne veze između potrošnje električne energije i gospodarskog rasta u Turskoj koristeći ARDL (autoregresijski model s distribuiranim vremenskim pomakom) kointegracijski test i Grangerov kauzalni model. Koriste se godišnji podaci za period od 1977. do 2006. ARDL kointegracijski test dokazuje dugoročnu vezu između potrošnje električne energije i stvarnog BDP-a po glavi stanovnika. Rezultati dobiveni Grangerovim modelima kauzalnosti ukazuju na jednosmjernu kauzalnost koja dugoročno vodi od potrošnje električne energije do gospodarskog rasta. Ukupni rezultati potvrđuju «hipotezu rasta» za Tursku. To znači da bi politika uštede energije, kao što je ograničenje potrošnje električne energije, vjerojatno imala negativni učinak na stvarni BDP Turske.

Ključne riječi: *Potrošnja električne energije, gospodarski rast, ARDL granični test*