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Abstract

The aim of the paper is twofold: First, to investigate the long-run economic relationship between electricity demand and income in Turkey for the period 1962-1996 using the concept of cointegration and error correction modelling. Second, to model the electricity consumption using univariate ARMA process and to make forecast for the years 1997-2010. The results indicate that electricity consumption and income are cointegrated, i.e., they tend to move together in the long run. Using error correction specification, the short- and long-run elasticities of income are estimated. The results show that income elasticity of electricity consumption is very high and electricity consumption in the future will continue to grow at higher rates.

1. Introduction

It might be claimed that the amount of electricity consumed is one of the main indicators of development. Similar to the experience of other developing countries, there has been a rapid increase in the growth rate of Turkish electricity consumption within the past few decades. This is mainly the result of the following factors: the rapid development of electrification since the 1950s; the increasing penetration of electricity-intensive technologies in the industrial sector; the rapid rise of electrical devices in households; the high growth of population and urbanization, and electrification in rural areas.

Today, when we look at the sectoral distribution of electricity consumption in Turkey, we see that 33% of total electricity is consumed in households, 4% in commercial and public services, and 50% in industry. Furthermore, the rapid increase in electricity consumption is likely to continue in the next few decades parallel to the industrialization process of the economy. Meeting this demand requires big investments to expand

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[1] The views expressed here are those of the authors and do not in any way represent those of the IEA and its members.

power supply capacity. However, the investment policies recently undertaken in Turkey are in contrast to the policies of the 1980s. Consequently there are, unfortunately, very few investments in energy in Turkey. Because of this reason the share of energy investments in gross fixed capital investments has currently sunk to 5% from its value of 11% in the 1980s. Therefore, analyses of the time series properties of electricity demand and of the statistical relationship between electricity demand and economic variables are of great importance.

In this context, we investigate the statistical properties of Turkish electricity demand using some recent econometric techniques. First the evidence of a long run relationship between electricity demand and income is analyzed within the framework of error correction mechanism using cointegration techniques. Second, possible causality between electricity demand and income is examined followed by a look at the time series properties of electricity demand using univariate ARMA methodology as an alternative approach. Finally, a forecast of electricity demand until the year 2010 is provided.

2. A cointegration analysis of electricity demand in Turkey

Most empirical time series exhibit variation that increases in both the mean and the dispersion in proportion to the absolute level of the series. Differentiation of the series frequently removes a time-dependent mean and if the standard deviation of a series is proportional to its level, then the data expressed in terms of natural logarithms will stabilize the variance. Given that most empirical time series require differencing to remove time dependence in the mean, a useful result emerges when the difference and the logarithmic transformations are combined (Loyd and Rayner, 1993). This form of transformation also leads to the loss of long-run properties and the inability to obtain a long-run solution (see Porkony, 1978).

It is well established that many trending economic variables can be described well by first-order integrated processes. A process is said to be first-order integrated (denoted $x_t \sim I(1)$) if its first differences are covariance stationary. Thus the changes in x_t, which are approximately growth rates, are stochastic variables with a constant mean. Typically, this concept gives a better fit to empirical phenomena than the alternative conception of trend stationarity.

Economic theory often suggests that certain pairs of economic variables should be linked by a long run equilibrium relationship. Although the variables may drift away from equilibrium for a while, economic forces may be expected to act so as to restore equilibrium. Granger (1981, 1991), Granger and Weiss (1983), and Engle and Granger (1987) have shown that, even though a given set of series may be nonstationary, there may exist various linear combinations of the individual series which are stationary. The desire to estimate models that combine both short-run and long-run properties and that, at the same time, maintain stationarity in all of the variables, has prompted a reconsideration of the problem of regression using variables measured in their levels (Charezma and Deadman, 1992).

It is well known that I(1) variables tend to diverge as T approaches infinity, because their unconditional variances are proportional to T. Thus it might seem that such variables could never be expected to obey any sort of long run equilibrium relationship. But in fact it is possible for variables that are I(1) to be I(0) for certain linear combinations of these variables. If that is the case, the variables are said to be cointegrated.

The fact that variables are cointegrated implies that there is some adjustment process which prevents the errors in the long run relationship from becoming larger and larger. Cointegrated series imply an error correction representation and cointegration is a necessary condition for error correction models to hold. In the error correction representation, both the economic theory relating to the long run relationship between variables and short run disequilibrium behavior are incorporated.

Two common procedures for testing cointegration are the two-step residual-based procedure for testing the null of 'no cointegration' due to Engle and Granger (1987), and the system-based reduced rank regression approach due to Johansen (1991).

The Engle and Granger (1987) procedure for testing cointegration includes estimation of the following equation by OLS

$$x_t = \alpha + \beta y_t + z_t \quad (1)$$

then applying the unit root tests to the time series of residuals by using the standard Augmented Dickey-Fuller regression:

$$\Delta Z = \alpha + \delta_t + \beta Z_{t-1} + \sum_{i=1}^{p} \Psi_i \Delta Z_{t-i} + U_t \quad (2)$$

z_t can be expressed as a linear combination of x_t and y_t, which are both I(1). If x_t and y_t are cointegrated, the test result should reject the null hypothesis that z_t is I(1), i.e., the null hypothesis is 'no cointegration'. The size of p is set so as to produce serially uncorrelated error terms.

If the variables are indeed cointegrated, then the specification must follow the error correction representation

$$\Theta(L)(I-L)Z_t = \delta C_t - \alpha' Z_{t-1} + \Theta(L)\varepsilon_t$$

(3)

where $\Phi(L)$ and $\Theta(L)$ are finite-order polynomials in the lag operator L. ε is the error term, where ε_t~IID(O,Λ). Thus, if Z_t is an nx1 vector, such that its components are cointegrated, then α is the cointegrating vector. C_t includes a constant term and any other independent variables, all of which are assumed to be either non-stochastic or stationary.

These recent developments in dynamic econometrics have enabled those modelling the energy sector to more effectively examine the existence of long run relationships between the demand for energy and its determinants. Over the past decade considerable attention has been paid in empirical economics literature to testing for the existence of long run relationships between economic variables using cointegration techniques. However, the use of these techniques in the field of energy is recent (see, Bentzen and Engsted (1993), Bentzen (1994), Fouquet (1995), Fouquet *et al.* (1997), among others). A major conclusion of these papers is that cointegration is an important statistical tool for investigating the relationship between energy and related economic variables.

Empirical results

In our analysis, we use time series covering the period 1962-1999. The series on GNP in 1987 prices, consumer price index, and population series are obtained from the State Planning Organisation. Electricity consumption and electricity prices are obtained from TEAŞ (1997). Electricity prices are deflated by the consumer price index. Both the electricity consumption and income variables are converted to per capita basis.

In order to test for the presence of stochastic stationarity in our data, we first investigate the integration of our individual time series, namely, natural logarithms of electricity consumption per capita (lncpc), income per capita (lnypc), and electricity price (lnpe), using the ADF test with trend.

Table 1

Unit Root Test for the Variables

Variable	t-statistic	Variable	t-statistic
lnpe	-1.617 (-3.531)	Δlnpe	-3.983 (-3.535)
lncpc	-1.958 (-3.531)	Δlncpc	-4.215 (-3.535)
lnypc	-2.564 (-3.531)	Δlnypc	-4.913 (-3.535)

Note: The values given in parentheses represent the McKinnon (1991) critical values.

The results reported in the above given table clearly show that the unit root test does not reject the null hypothesis for the variables in levels. We further investigated the unit root test in the first differences of the variables and the results reject the null hypothesis for the first differences of the variables, implying that the levels are non-stationary, and the first differences are stationary. Therefore we may conclude that the series are integrated of the first order. Note that the same analysis without trend and moreover the Phillips-Perron unit root tests also delivered the same conclusion.

The next step of the analysis is to investigate the potential cointegration properties of our data. Since we found the series to be non-stationary, the existence of a stationary linear combination would imply that these variables are cointegrated. We carried out the Engle-Granger two-step procedure for testing cointegration, which involves running a cointegration regression of income and price on consumption, and then carrying out the ADF test on the residuals.

Our cointegration regression has the standard demand function character. Thus, we regressed per capita electricity consumption on per capita real income and the real price of electricity. Our price variable turned out to be insignificant. This was not surprising since energy prices are subsidized in Turkey. That is also the reason why the price elasticities found in other studies such as Akdeniz and Demir (1994) and Erdoğan and Dahl (1997) were either insignificant or significant but lower than the average price elasticities found for developing countries by Dahl (1993). That is why we dropped the price variable from the cointegration regression. The results for this cointegration regression are given below:

$$\ln cpc_t = -37.818 + 3.134 \ln ypc_t$$
$$(-30.780) \quad (35.730)$$

$R^2 = 0.973$; $DW = 0.652$

When we apply the ADF test to the residual of the above regression, we obtain a t-value which is well above the 5 % critical value (a t-value of -2.3 compared to the critical value of -3.54). Therefore, the null hypothesis of ‘no cointegration’ cannot be accepted and we may conclude that electricity consumption and income are correlated.

In order to prove the robustness of the cointegration results between the variables, we carried out a more recent estimation procedure developed by Johansen (1988, 1991), which uses the full information maximum likelihood framework. The results obtained by using this procedure (based on the lag length of one) are given in Table 2.

Table 2

Test Results for Johansen’s Cointegration Procedure

List of Eigenvalues: 0.351 0.139

Null	max. Eigenvalues	CV	Trace	CV
$r \leq 1$	5.674	8.176	5.674	8.176
$r = 0$	16.397	14.900	24.072	17.953

The maximum eigenvalue statistic tests the restriction of no more than r cointegration vectors against the alternative of r+1 such vectors. The trace statistics test the restriction of no more than r cointegration vectors against the alternative of r = 0. As can be seen, the hypothesis of one cointegration vector cannot be rejected by both the maximum eigenvalue and the trace statistic values at the 95% level.

Based on the results obtained from the Johansen and the Engle-Granger approaches, we can now conclude that per capita electricity consumption and per capita real income are cointegrated. This implies that, under the hypothesis of cointegration, the series is tied together by some long run equilibrium relationship.

We used several alternative specifications throughout the study for real GNP (by using both the consumer price index and the wholesale price index). These include GNP at constant prices and purchasing power parities, GNP at constant prices and exchange rates (USD). In all cases, the results turned out to be very similar. Thus, we show in this paper only the results that use GNP in 1987 prices. Other variables such as the population growth rate, urbanization rate and exchange rates turned out to be insignificant.

Now, we are in a position to estimate long run relationships between income and electricity consumption by using the error correction model. To do that, we estimate Equation (3) by using our time series. The results of this error correction model are given below:

Table 3
Error Correction Specification

Dependent variable: Δ $lncpc_t$		
Sample Period : 1963-1999		
Variable	Coefficient	t-statistic
Int	0.054	-3.938
$\Delta lnypc_t$	0.692	7.323
e_{t-1}	-1.115	-3.938
Ra^2= 0.610; RSS=0.016; SE=0.021; DW= 1.932		
X^2_{SC} (1) = 0.046 ; X^2_{FF} (1) = 0.279 ; X^2_N (2) = 1.526;		
X_H^2 (1) = 3.148		

Note: R^2_a is adjusted R^2; RSS is residual sum of squares; SER is the standard error of regression; DW is the Durbin-Watson Statistic; X^2_{SC} is the Lagrange Multiplier test of residual serial correlation; X^2_{FF} is a functional form test (Ramsey's RESET test) using the square of the fitted values; X^2_N is the normality test based on skewness and kurtosis of residuals; X^2_H is a heteroscedasticity test based on the regression of squared residuals or squared fitted value; e_{t-1} is the lagged values of the residuals obtained from cointegration regression (Equation 3).

The diagnostic tests do not indicate any misspecification except for heteroscedasticity, which is mainly due to the year 1975. The results of our study suggest short run and long run income elasticies of 0.692 and 3.134 respectively. These elasticities are well above the international evidence. This shows that income plays a very important role in electric energy consumption. As is well known, parallel to the industrialization and development process in Turkey, electricity consumption has become very significant especially in households, communication and industry. However, the share of industry in electricity consumption fell to 45% in 1990s from its share of 60-65% in 1970s. The share of households in electricity consumption increased to 18%. The main reason for this picture is the increase in consumption of electricity in rural areas. The number of villages in Anatolia with electricity increased approximately 180 times between 1962 and 1999. As a matter of fact, sales of electrical household appliances increased tremendously in rural areas which constitute about 15% of the national income. Electricity consumption has increased more than proportionally to the increase in income and the rate of urbanization. For example, after the 1970s income increased on average 3.5% per year whereas electricity consumption increased about 10 % per year. This statistic supports very strongly the long run elasticity that is found in our model. This shows that electricity consumption does not only depend directly on income but indirectly on the degree of urbanization, changing life styles and quality of life as well.

If a dummy variable for the year 1975, representing the delayed effects of the oil price shock at the end of 1973 and the Cyprus war in 1974, is added into the regression, the explanatory power of the equation increases and seems to give a better representation of reality. The results of this estimation are given below:

Table 4

Error Correction Specification with Dummy

Dependent variable: $\Delta\ lncpc_t$
Sample Period : 1963-1999

Variable	Coefficient	t-statistic
Int	0.053	13.971
$\Delta lnypc_t$	0.667	7.668
e_{t-1}	-0.099	-3.605
Dummy	0.056	2.763

Ra^2= 0.67; RSS=0.013; SE= 0.02; DW= 2.08
X^2_{SC} (1) = 0.081; X^2_{FF} (1) = 0.259; X^2_N (2) = 0.986;
X_H^2 (1) = 0.483

The diagnostic tests indicate no misspecification. Although the equation given above appears to have a good fit it would be interesting to test its predictive power. Given that we have observations up to 1999 we may reestimate the model over the 1993-1996 period and use the remaining three years to test the predictive power. The results of this experiment are given below:

Table 5

Error Correction Specification with Dummy to Test the Predictive Power

Dependent variable: $\Delta\ lncpc_t$
Sample Period : 1963-1999

Variable	Coefficient	t-statistic
Int	0.054	13.251
$\Delta lnypc_t$	0.704	7.394
e_{t-1}	-0.112	-3.962
Dummy	0.053	2.592

Ra^2= 0.684; RSS=0.011; SE= 0.02; DW= 2.19
X^2_{SC} (1) = 0.407; X^2_{FF} (1) = 0.346; X^2_N (2) = 0.789;
X_H^2 (1) = 0.218; X_{PF}^2 (3) = 3.811

Note: X_{PF}^2 is Chow's second test for the adequacy of the predictions.

The difference between the forecasted and actual values made by using this model and the actual values is about 1 to 6 %.

actual	predicted	difference	summary statistics forecasts	
1320.506	1306.541	1%	Root Mean Squared Error	27.89086
1440.286	1396.125	3%	Mean Absolute Error	23.97620
1466.408	1378.338	6%	Mean Abs. Percent Error	1.795849

Although methodologically it is better to use the error correction mechanism, in practice it is usually the univariate time series analyses methods that are used to predict the future electricity demand. For this reason, we conducted another analysis to analyze the time series properties of electricity consumption and to make a forecast for a relatively long horizon using those kind of models.

3. Univariate time series analysis of electricity demand

Time series analysis provides another modeling approach that requires only data on the modelled variable. Univariate Box-Jenkins (1976) ARMA analysis has been widely used for modelling and forecasting in many fields. In practice, univariate ARMA models may outperform multiple-series regression models in terms of forecasting accuracy.

In the ARMA analysis, the time series to be modelled is based on observations generated by an underlying process that is to be identified. The goal is to find a good model that represents the data generating process adequately. The general model is a combination of autoregressive coefficients multiplied by past values of time series and moving average coefficients multiplied by past random shocks. The orders of the AR and MA parts are chosen such that the theoretical autocorrelation function (ACF) and partial autocorrelation function (PACF) of the combination approximately match the estimated ACF and PACF for the modeled time series.

The stages involved in ARMA modelling are - identification, estimation, diagnostic checking, and forecasting. In the identification stage, the ACF and PACF calculated for the available time-series data are considered as the estimated ACF and PACF for the unknown data generating process. In the estimation stage AR and MA parameters are estimated by fitting the below given model function to the time-series data and minimizing a criterion for the residual errors

$$(I-\Phi L)X_t=(I-\Theta L)\varepsilon_t+c \qquad (4)$$

where L is the lag operator, ε is a white noise innovation and c is a constant.

Tests at the diagnostic checking stage ensure that these residuals are statistically small, that their variance does not change over time, and that their ACF functions do not have significant autocorrelations, particularly at short lags.

An ARMA(1,1) model, given below, seems to give a satisfactory representation of Turkish per capita electricity consumption.

Table 6

ARMA Representation of Turkish Electricity Demand

Dependent variable: lecpc
Period : 1963-1996

Variable	Coefficient	t-statistic
Constant	9.755	5.126
AR(1)	0.981	91.225
MA(1)	0.396	2.501

Ra^2= 0.998 ; Ljung-Box Q(12)=10.522;
Jarque-Bera normality test stat = 1.342;
RCH test F-stat (4)= 2.079

Both the ACF and PACF of the residuals do not indicate any serial correlation. It should be noted here that if the model is estimated using the full period, the changes in the parameters are negligibly small. The AR coefficient is quite big and very close to a unit root. Indeed, from our ECM analysis we know that per capita electricity consumption level is not stationary and here we have a very close picture to that. Although the coefficient is not exactly one, the results and forecasts of this ARMA model should be interpreted with care.

Using this model we forecast the per capita electricity demand over the period 1997-2010 as given below.

These forecast results show that electricity consumption will increase about 60% in the following 11 years.

4. Conclusion

In this study, the long run relationship between electricity consumption and income in Turkey is investigated by using the concepts of error correction and cointegration. The time-series properties of electricity consumption are then analyzed by using a univariate ARMA process, which is an alternative procedure, and forecasts are made up to the year 2010.

Table 7

Predicted and Actual Electricity Demand (kWh per capita)

Year	Forecast	Actual
1997	1249.65	1284.57

1998	1312.90	1353.78
1999	1378.11	1385.95
2000	1445.26	
2001	1514.37	
2002	1585.41	
2003	1658.39	
2004	1733.30	
2005	1810.12	
2006	1888.85	
2007	1969.45	
2008	2051.92	
2009	2136.24	
2010	2222.38	

Root Mean Sq. Error = 31.36; Mean Absolute Error = 27.88; Mean Abs. Percent Error = 2.1

It is expected that electricity demand will continue to grow at a high rate as a natural consequence of industrialization. Therefore, substantial new investments are required in order to expand the power generation capacity of the country. Although there are some policy measures to slow down the rapidly increasing demand such as the increases in electricity prices to the level of their economic costs, it is unrealistic to believe that such policy initiatives alone would have a significant dampening effect on demand (considering the very low price elasticities observed in this study). This underlines the need for other policy instruments, like energy efficiency and conservation policies, to control the rapid increase of electricity demand.

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Özet

Türkiye’de elektrik talebinin ekonometrik analizi

Bu çalışma iki amaç içermektedir. Bunlardan birincisi 1962-1996 yılları arasında Türkiye’deki elektrik talebi ile gelir arasındaki uzun dönemli ilişkinin kointegrasyon ve hata düzeltme modelleri kullanılarak incelenmesidir. İkincisi ise tek değişkenli ARMA yöntemi kullanarak elektrik tüketimini modellemek ve 1997-2010 yılları için tahminde bulunmaktır. Çalışma sonuçlarına göre elektrik tüketimi ile gelir arasında kointegrasyon olduğu, yani uzun vadede bu iki değişkenin aynı yörüngeyi izlediği bulunmuştur. Hata düzeltme tanımlaması kullanılarak uzun ve kısa vadedeki gelir esneklikleri belirlenmiştir. Yine çalışma sonuçları göstermektedir ki elektrik tüketiminin gelir esnekliği oldukça yüksektir ve ilerideki elektrik tüketimi bu yüksek seviyelerde devam edecektir.