ANALYSING THE INDUSTRIAL ELECTRICITY DEMAND FOR TURKEY

Türkiye İçin Sanayi Sektörü Elektrik Talebinin Analizi

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Abstract

This study analyses the effects of some selected parameters on Turkey's industrial electricity demand by using annual data between 1978 and 2018. In this regard, the Autoregressive Distributed Lag (ARDL) Bounds Testing method is utilized for establishing the models. The variables that used in the models of this study are electricity consumption, industrial value added, price of electricity, urbanization rate and average air temperature. According to the empirical findings, the price elasticities are estimated negative as expected which are -0.14 and -0.18 for the short and long term, respectively. On the other hand, the income elasticities have positive signs and computed as statistically significant. The short and long run income elasticities of industrial electricity demand are found as 0,15 and 0,35, respectively. Additionally, the urbanization rate and air temperature positively affect the industrial electricity demand of Turkey. These results indicate that the estimated price and income elasticities for the Turkish industrial electricity demand are very low and smaller than 1 in absolute terms. Therefore, it can be said that an increase and/or decrease in price and income as percentage is more than increase in electricity consumption for the industrial sector. In addition, these results imply that since the electricity usage in Turkey's industrial sector is a necessity, consumers are not changing their consumption behaviour easily with respect to the price and income movements.

Keywords: Elasticity estimates, industrial electricity demand, ARDL bounds testing, Turkey

Jel Codes: B23; Q41

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Öz

Bu çalışma 1978 ile 2018 arasındaki yıllık verileri kullanarak Türkiye'nin sanayi sektörü elektrik talebine etki eden bazı parametreleri analiz etmektedir. Bu bağlamda, modelleri oluşturmak için ARDL Sınır Testi yaklaşımı kullanılmıştır. Çalışmanın modellerinde kullanılan değişkenler elektrik tüketimi, sanayi katma değeri, elektriğin fiyatı, şehirleşme oranı ve ortalama hava sıcaklığıdır. Ampirik bulgulara göre kısa ve uzun dönem fiyat esneklikleri beklendiği üzere negatif ve kısa dönem için -0.14, uzun dönem için ise -0.18 olarak hesaplanmıştır. Diğer taraftan, gelir esneklikleri pozitif işarete sahip ve anlamlı olarak tahmin edilmiştir. Sanayi sektörü elektrik talebinin kısa ve uzun dönem gelir esneklikleri sırasıyla 0,15 ve 0,35 olarak bulunmuşlardır. Buna ek olarak, şehirleşme oranı ve hava sıcaklığı değişkenleri Türkiye'nin sanayi sektörü elektrik talebini pozitif bir şekilde etkilemektedir. Bu sonuçlar, Türkiye için hesaplanan sanayi sektörü elektrik talebi fiyat ve gelir esnekliklerinin oldukça küçük ve mutlak değerce 1'den az olduğuna işaret etmektedir. Dolayısıyla, sanayi sektörü için fiyat ve gelirde yaşanan artışın ve/veya azalışın yüzdesel olarak elektrik tüketiminde yaşanandan daha fazla olduğu söylenebilir. Ayrıca, bu sonuçlar Türkiye'nin sanayi sektöründeki elektrik kullanımı zorunlu olduğu için tüketicilerin tüketim alışkanlıklarını fiyat ve gelirde meydana gelen hareketler karşısında kolayca değiştirmedikleri anlamına gelmektedir.

Anahtar Kelimeler: Esneklik hesaplamaları, sanayi sektörü elektrik talebi, ARDL sınır testi, Türkiye

Jel Kodları: B23; Q41

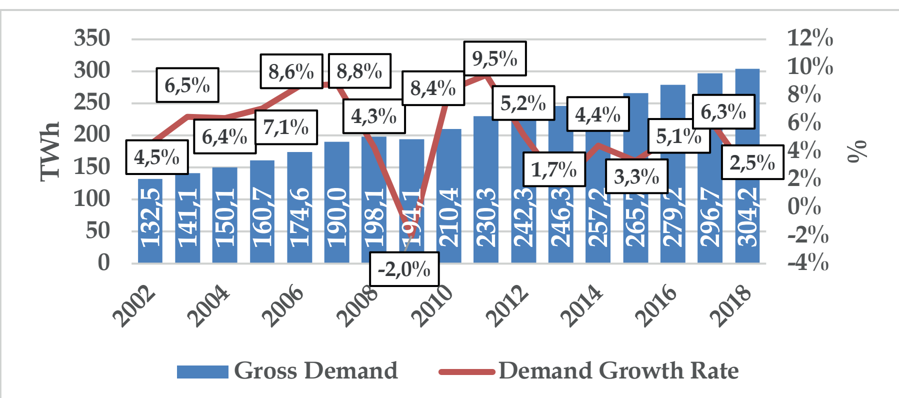
1. Introduction

Energy is a necessity in modern world. Especially in the industrialized economies, energy and growth move together. Developing countries primarily aim to provide sustainable, reliable, efficient, cost-effective and clean energy supply. In addition, for ensuring sustainable economic growth, energy policies are tried to be rearranged as effective as possible to provide sufficient energy supply to the sectors, such as industry, residential, public and private (Ediger and Tatlidil, 2002). In Turkey, as a developing country, the energy policies have been developed within the context of providing sufficient and reliable energy supply to support the economic and social development (MENR, 2014). In this regard, Turkey's domestic primary energy production has been shown dramatic changes since in the middle of the 1980s. Before the 1980s, the energy portfolio of Turkey mainly consists of coal, oil, and biofuels, whereas with the beginning of the 1990s, natural gas has started to use. Furthermore, the share of hydropower and oil products have increased in the primary energy production. On the other hand, the usage of biofuels and waste have been lowered gradually. Starting from the 2000s, energy production from renewable sources have shown an increasing trend in Turkey.

Electricity is one of the commonly used energy types in Turkey. It is utilised in industry, residences, commercial, manufacturing, and transportation sectors. In other words, electricity, as an energy type, is used in almost all fields of life in Turkey as well as in the world. Therefore, the production, consumption and demand trends of electricity should be analysed very carefully.

Turkey's electricity sector has been developing especially since 2002. While the gross electricity demand was 132.5 TWh in 2002, it increased more than two times and reached the level of 304.2 TWh in 2018 (Figure 1). Although the demand growth rate has fluctuated in this period, the amount of gross demand has increased consistently except in the year 2009.

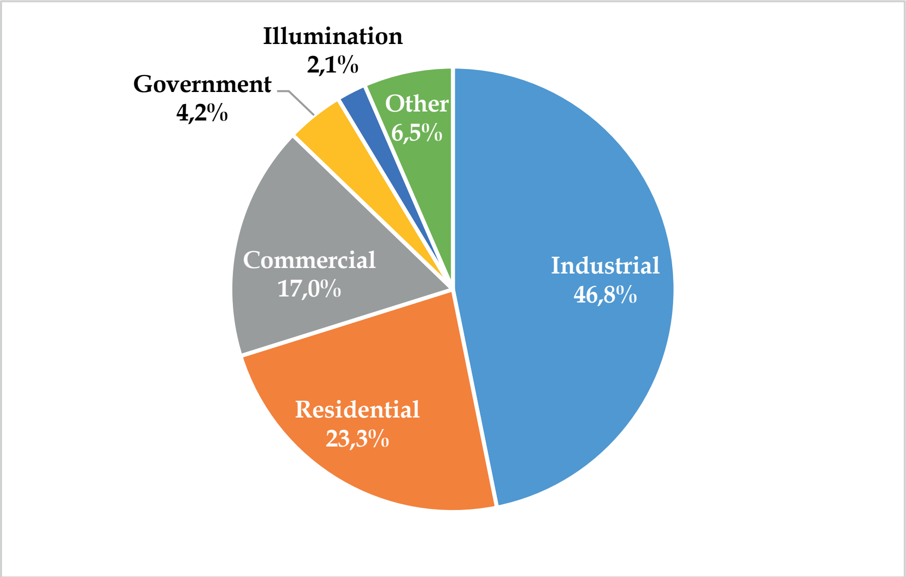
Figure 1: Turkey's Electricity Gross Demand Growth Changes (2002–2018, TWh, %)



Source: TEİAŞ, 2020

In terms of sectoral demand, industrial net electricity consumption consists 46.8% of total consumption with regard to ten years average (Figure 2). Furthermore, while on average 23.3% of the total electricity was consumed by the residential, that of 17% was used by the commercial sector. The rest of the ten years average net electricity consumption is made by the government (4.2%), illumination (2.1%) and others (6.5%). From this point of view, it can be said that industry is the most electricity consuming sector in Turkey and then residential, commercial sector, government, and illumination follow the industrial sector, respectively.

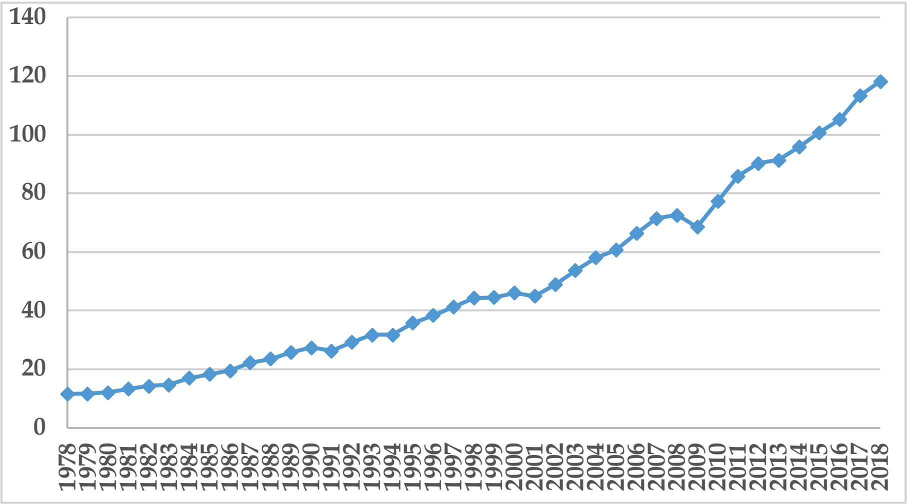
Figure 2: Ten Years Average Distribution of Net Electricity Consumption by Sectors (2009-2018, %)



Source: TURKSTAT

The general overview of Turkey in terms of industrial electricity demand will be presented in detail since this sector is analysed in this study. The export-led growth policies were applied in Turkey after the 1980s and, thereby, the industrial sector in Turkey has had a significant change (Taban and Aktar, 2008). In parallel with this development, the industrial electricity demand increased continuously over the period 1978 to 2018 except in 2001 and 2009 (Figure 3). These two years were economic crisis periods in Turkey. Thus, the industrial electricity demand was affected negatively and decreased.

Figure 3: Turkey's Industrial Electricity Demand (1978-2018, TWh)



Source: IEA, 2019a

Turkey's total industrial electricity consumption was 118.25 TWh in 2018 which was increased almost ten times since 1980 (IEA, 2019a). On the other hand, while the share of industrial electricity demand on total electricity consumption was approximately 60% up to 1990, this share decreased to 45% level in 2018. This shows that instead of electricity, the usage of other energy sources, such as natural gas and coal was increased in the industrial sector over time.

In this paper, after giving general information about the electricity consumption trend in Turkey, a brief literature review is summarized related to the industrial electricity demand. The methodology and data are introduced in Part 3. In part 4, the empirical findings are presented. The final part concludes the study.

2. Literature Review

The first official attempts to determine energy demand for Turkey were started after 1984 by the authorized institutions such as State Planning Organization (SPO) and Ministry of Energy and Natural Resources (MENR). Initially, mathematical modelling approaches were used by SPO and MENR in the 1960s and 1970s. They used various best fit curves method for the period of 1966 to 1978, and as a result of their estimation, the predicted energy demand was found much higher than the actual consumption (Ediger and Tatlidil, 2002). After the mid of the 1980s, the models that described below were officially started to be used by the Ministry to forecast the energy demand in Turkey.

In 1984, the World Bank offered MENR two models developed by the International Atomic Energy Agency (IAEA), namely MAED (Model for Analysis of Energy Demand) and WASP III (Wien Automatic System Planning). These models were constituted for determination of the general energy demand. This has been the beginning point for energy planning and forecasting of future energy demand in Turkey. In this period, Kouris' correlation and Balance-Impact models were also used by MENR for the short- and long-term energy projections. In addition, for the period between 1981 and 1985, the energy demand model called EFOM-12 C Mark I (Energy Flow Optimization Model) developed by the commission of the European Union was applied in Turkey (Ercan et al., 1988). Furthermore, the SPO and the SIS (State Institute of Statistics) employed their own models. On the one hand, the SPO statistically estimated sectoral energy demands for different consumer groups. On the other hand, the SIS modelled the relationship between demographic indicators and economic parameters with primary energy demand by using the Durbin-Watson statistical test. Both two methods found a strong correlation between GDP and energy demand, and they reached similar results with MAED (Ediger and Tatlidil, 2002).

In the case of energy demand projection, there are several methods different from stated above. As an individual or institutional, the main aim is to forecast more reliable and consistent energy demand for the future. However, the estimation by MAED, WASP III, and EFOM-12 C Mark gave much higher results than the actual energy demand (Ediger and Tatlidil, 2002). Recently, remarkable methods, such as fuzzy logic, artificial neural network, grey prediction, input-output models, end-use models and some econometric techniques have been developed by the scientists in the fields of engineering, economy and other disciplines to obtain more reliable results.

In this section of the paper, after presenting some selected previous industrial electricity demand studies, the literature about Turkey's industrial sector is reviewed. At the end of this part, a detailed summary of these studies is presented in Table 1.

Fisher and Kaysen (1962) was one of the oldest studies in the field of industrial electricity demand. They utilised multiple regression and covariance analysis to estimate the price and income effects on industrial electricity demand of the United States between 1946 and 1957. They concluded that not only the economic factors but also the non-economic ones are important in estimating the industrial electricity demand trend. In addition, the price effect on electricity demand decreased for the observed period in the US.

Beenstock et al., (1999) examined the period between 1962 and 1994 by using quarterly time series data. They utilized a dynamic regression model and cointegration analysis to estimate the electricity demand for the industrial sector in India. By employing different techniques, Beenstock et al., (1999) found long-run income and price elasticities of 0.99 to 1.12 and -0.31 to -0.44, respectively.

El-Shazly (2006) analysed the six different sectors electricity demand for Egypt from a different perspective. He used a panel cointegration approach to estimate the elasticities and the long run relationships in a dynamic model between 1982 and 2010. The sectors that he investigate are industry, agriculture, public utilities, commercial, residential and government. According to the results of this study, the price, exchange rate and income elasticities for Egyptian industrial electricity demand are found as 0.05, 0.17 and 1.33, respectively. One interesting and unexpected outcome of this study is the positive price elasticity. The author explained this result with the regularity distortions in the form of subsidized energy prices for the examined period.

In 2018, two important studies related to the industrial electricity demand are stood out. Campbell (2018) used ARDL Bounds Testing approach to estimate the long run price and income elasticities of

Jamaica's industrial electricity demand between the period of 1970-2014. The results of this paper indicate that the price and income elasticities of industrial electricity demand are -0.25 and 1.22, respectively. These findings indicate that the industrial consumers are very sensitive to the income changes in Jamaica. On the other hand, Cialani and Mortazavi (2018) examined the determinants of electricity demand in 29 European countries for the years 1995-2015. They used two different approaches namely, Generalized Method of Moments (GMM) and Maximum Likelihood (ML) to estimate the effects of the variables on industrial and residential electricity demand. The results indicate that while the price and income elasticities are found as -0.02 and 0.18 by the GMM method, the same variables estimated as -0.05 and 0.16 by the ML approach. In addition, they analysed the effects of heating and cooling degree days on electricity consumption. According to the results, they concluded that the electricity consumption is more sensitive to the cold weather than that of the hot in Europe zone.

Along with the world, one of the most investigated subjects in the field of energy demand modelling and forecasting is electricity demand in Turkey. The electricity demand studies for Turkey have first begun in the 1990s, and they have increased significantly until today. The sectoral electricity demand studies, on the other hand, have gained the popularity after the 2000s. Some of these empirical studies related to the industrial electricity demand are mentioned below.

In 2007, Akay and Atak (2007) proposed a Grey Prediction Model with Rolling Mechanism to estimate Turkish industrial and aggregate electricity demand. They used the annual data between 1970 and 2004 to forecast Turkey's industrial and total electricity consumption for the period of 2006-2015. Akay and Atak (2007) calculated the industrial and total electricity consumption as 140.37 TWh and 265.7 TWh for 2015, respectively. In addition, they argued that Grey Prediction Model performs better results than official studies carried out by the Turkish Ministry of Energy and Natural Resources for both total and industrial sector's electricity demand estimation.

Dilaver and Hunt (2011a, 2011b, 2011c) analysed Turkish industrial, residential and aggregate electricity demand elasticities, respectively in 2011. By using Structural Time Series Modelling (STSM) method with Underlying Energy Demand Trend (UEDT) concept, they estimated Turkey's industrial electricity demand for the period between 1960 and 2008 (Dilaver and Hunt, 2011a). In addition, they forecasted the industrial electricity demand for the period of 2009-2020 by implementing three scenarios, namely 'low', 'reference' and 'high'. They found output (industrial value added) and price elasticities as 0.15 and -0.16, respectively. Moreover, electricity demand for Turkish industrial sector was forecasted to be 97 TWh, 121 TWh, and 148 TWh by 2020 in terms of low, reference and high scenarios, respectively (Dilaver and Hunt, 2011a).

Bilgili et al., (2012), on the other hand, used three different model namely; artificial neural network (ANN), linear regression (LR) and nonlinear regression (NLR) methods to analyse the electricity consumption trends of Turkey's residential and industrial sectors. In this study, the performances of the three methods are compared by two different scenarios (powerful and poor). As a result, the authors presented that the empirical findings of the ANN method show better performance than the LR and NLR methods. Moreover, Bilgili et al., (2012) forecasted the possible future electricity consumption in the industrial sector of Turkey by using the data between 1990 and 2003. They found that Turkey's residential sector electricity consumption would be 124.85 TWh in 2015.

Arisoy and Ozturk (2014) used a different model to estimate the price and income elasticities of Turkish industrial and residential electricity demand. They applied a time-varying parameters approach based on the Kalman filter for the data between 1960 and 2008. The income and price elasticities of Turkey's industrial electricity demand were estimated as 0.979 and -0.014, respectively. They concluded that due to the income elasticity that found is lower than one, any increase in per capita energy consumption is smaller than a rise in per capita income. Additionally, the small value of the price elasticity shows that the price variable has not a significant effect on the industrial electricity demand.

A brief summary of the selected industrial electricity demand literature is given in Table 1.

Table 1: Summary of Selected Industrial Electricity Demand Literature

Author(s)	Period/ Country	Methods Used	Focus of Study	Results
Fisher and Kaysen (1962)	1946-1957 US	Multiple Regression and Covariance Analysis Techniques	Industrial and Residential Electricity Demand	The short term price elasticities are -0.16 and -0.25, respectively. The short term income elasticities are 0.07 and 0.33, respectively. The long term price and income elasticities are found statistically insignificant.
Beenstock et al., (1999)	1962-1994 India	Dynamic Regression Model and Cointegration	Industrial Electricity Demand	The long term price elasticities are -0.31 and -0.44, respectively. The long term income elasticities are 0.99 and 1.12, respectively. The short term price and income elasticities are found statistically insignificant
El-Shazly (2006)	1982-2010 Egypt	Panel Cointegration Approach	Industry, Agriculture, Public Utilities, Commercial, Residential	The industrial price, exchange rate and income elasticities are estimated as

			and Government Electricity Demand Analyses	0.05, 0.17 and 1.33, respectively.
Akay and Atak (2007)	1970-2004 Turkey	Grey Prediction with Rolling Mechanism	Industrial and Total Electricity Consumption	Industrial and total electricity consumptions are estimated as 140.37 TWh and 265.7 TWh for 2015, correspondingly.
Dilaver and Hunt (2011a)	1960-2008 Turkey	Structural Time Series Model	Industrial Electricity Demand	Income and price elasticities are estimated as 0.15 and -0.16, respectively. Turkish industrial electricity demand will be 97, 121 and 148 TWh by 2020 according to low, reference and high scenarios, correspondingly.
Bilgili et al., (2012)	1990-2003 Turkey	ANN, Linear Regression & Nonlinear Regression	Residential and Industrial Electric Energy Demand	Turkey's industrial electricity consumption would increase to 124.85 TWh by 2015 according to ANN model with poor scenario.
Arisoy and	1960-2008 Turkey	Time Varying Parameters Model based	Industrial and Residential	Income elasticities of industrial

Ozturk (2014)		on Kalman Filter	Electricity Demand	electricity demand are 0.979. Price elasticity of industrial energy demand is -0.014.
Campbell (2018)	1970-2014 Jamaica	ARDL Bounds Testing Method	Industrial Electricity Demand	The price and income elasticities are estimated as -0.25 and 1.22, respectively.
Cialani and Mortazavi (2018)	1995-2015 29 European Countries	Generalized Method of Moment (GMM) and Maximum Likelihood (ML) Approaches	Household and Industrial Electricity Demand	GMM method results The price and income elasticities are -0.02 and 0.18, respectively. LM method results The price and income elasticities are -0.05 and 0.16, respectively.

3. Econometric Methodology and Data

The methodological framework used in this study is the Autoregressive Distributed Lag (ARDL) Bounds Testing Method. Pesaran et al., (2001) introduced this model to the literature and the ARDL Bounds Testing approach is widely used in the econometric analysis because of its several advantages over other cointegration techniques such as Engle-Granger Two-Step and Johansen Cointegration methods. First, the ARDL Bounds Testing method can be used with a mixture of *I(0)* and *I(1)* data. Second, contrary to the Johansen approach, this method can give more consistent results determining the cointegration relation in small sample size. Third, the short- and long-run relationships among variables can be tested simultaneously. Fourth, this method allows appropriate lag length for each variable, and thus the model can have a more dynamic structure.

In addition, by using optimal lags, the ARDL model is free from serial correlation. Finally, the ARDL framework can distinguish between dependent and independent variables which enables to avoid the endogeneity problem.

In econometric analysis, one of the most significant data is time series. Since the time series data involve trend, when we add these data sets into a regression without any transformation, the results of the regression analysis may be misleading. In other words, the results of the econometric studies that using these kinds of data do not usually reflect the reality. For this reason, the stationarity of the variables is very important qualification in time series analyses. The results of the estimations using such variables can be valid statistically only if the time series data are stationary. In general, the unit root tests are used for testing the stationarity of the time series. After the stationarity of a series is determined, the cointegration tests can be applied.

By using the stationarity tests, the series can be analysed whether they contain unit root or not. From this point of view, it can be said that the unit root tests are widely used to analyse the stationarity of the variables. In addition, the significance level of the regression analyses can be strengthened by implementing the unit root tests. The main form of the unit root equation is as below:

$$Y_t = \rho Y_{t-1} + u_t \qquad -1 \leq \rho \leq 1 \qquad (1)$$

where u_t is a white noise error term. In Equation (1), the regression model that formed as Y in t period with respect to $t\text{-}1$ period is expressed. In here, the unit root issue or non-stationarity stochastic process occurs if the coefficient of Y_{t-1} (ρ) is equal to 1. Therefore, one year lagged value of Y_t (Y_{t-1}) is modelled in the regression. The next step of the unit root test is determining whether ρ is statistically equal to 1 or not. If this coefficient is equal to 1, then the dependent variable (Y_t) is defined as non-stationary. This fact is valid for the general process of the unit root tests (Gujarati, 2003: 814).

Equation (2) can be formed as follows:

$$Y_t - Y_{t-1} = \rho Y_{t-1} - Y_{t-1} + u_t \qquad (2)$$

$$= (\rho - 1)Y_{t-1} + u_t$$

which can be written as;

$$\Delta Y_t = \delta Y_{t-1} + u_t \quad (3)$$

where $\boldsymbol{\delta} = (\rho - 1)$, Δ is the first difference operator and t is the trend variable.

Instead of analysing Equation (1), Equation (3) can be used. In here, $\delta = 0$ is tested as the null hypothesis. According to the test results, if δ is found as 0 or $\rho = 1$, then the unit root problem arises. In other words, the time series under consideration can be classified as non-stationary. On the other hand, the series (Y_t) is said to be stationary if $\delta < 0$.(Gujarati, 2003; Verbeek, 2004).

Verbeek (2004) indicates that a time series which becomes stationary after d times differencing is stated as integrated in order one, and specified as $I(d)$ in general terms. In parallel with these inferences, Engle and Granger (1987) identify the formal definition of integration and the properties for the higher order of integration.

In this study, several unit root tests such as Augmented Dickey-Fuller, Phillips-Perron, Kwiatkowski-Phillips-Schmidt-Shin will be applied to test the stationarity of the variables. In addition to these, the Zivot-Andrews unit root test that considers possible structural break in the series will be introduced. After than the ARDL Bounds Testing framework will be used to identify the cointegration relationship among variables and estimate the price and income elasticities.

There are three steps of the ARDL Bounds Testing method. Firstly, the cointegration relationship among variables is investigated. Secondly, the long-run and thirdly, the short-run relations among dependent and independent variables are analysed. The basic form of the two variable ARDL Bounds Testing procedure can be specified as:

$$\Delta lnY_t = \beta_0 + \sum_{i=1}^{m} \beta_{1i} \Delta lnY_{t-i} + \sum_{j=0}^{m} \beta_{2j} \Delta lnX_{t-j} + \beta_3 lnY_{t-1} + \beta_4 lnX_{t-1} + \varepsilon_t \quad (4)$$

where Δ is the first difference of the series, m is the lag length, Y and X are the dependent and independent variables, respectively. For estimating the model, the appropriate lag lengths of the variables should be chosen by using Akaike (AIC) or Schwartz-Bayesian (SBC) Information Criteria. The maximum lag length differs depending on the use of monthly, quarterly or annually series. The lowest lag length found from AIC or SBC, without autocorrelation problem, should be chosen to estimate the model. After the convenient model is selected, F statistics is estimated by utilizing the Wald test.[1] Firstly, the null hypothesis ($H_0: \beta_3=\beta_4=0$) is tested against the alternative ($H_1: \beta_3 \neq \beta_4 \neq 0$) to decide the cointegration relationship. The estimated F statistics compare with the critical values tabulated by Pesaran et al., (2001). If the estimated F statistics is greater than the upper bound level, the null hypothesis is rejected, and the cointegration relation among variables can be decided. On the other hand, if the estimated F statistics is below the lower bound level, then the null hypothesis cannot be rejected, and this shows that there is no cointegration. Finally, if computed F statistics is between the lower and upper bound levels, the test result is decided as inconclusive (Pesaran et al., 2001: 299).

After determining the cointegration relationship among variables, the equation that is used to examine the long-term relationship among the dependent variable and independent variables can be generated as follows:

$$lnY_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i} lnY_{t-i} + \sum_{i=0}^{k} \beta_{2i} lnX_{t-i} + \varepsilon_t \quad (5)$$

where p and k are the lag lengths of the variables. These lag lengths are determined independently in long-run analysis different from the Bounds Testing procedure above. The lag lengths of the variables are decided by using the AIC and/or SBC. Then the model is estimated with the appropriate lag length and the long-run coefficients are concluded whether significant or not by checking the F statistics.

After obtaining the long-run relation and estimating the coefficient of the independent variables, the short-run relationship among variables can be analysed via the Error Correction Model (ECM) as in Equation (6):

$$\Delta lnY_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i} \Delta lnY_{t-i} + \sum_{i=1}^{k} \beta_{2i} \Delta lnX_{t-i} + \lambda ECT_{t-1} + \varepsilon_t \quad (6)$$

[1] The Wald Test is a test that determines whether the parameters of the explanatory variables in a model are significant.

where λ represents the coefficient of the error correction term (ECT) in the model. ECT is the residuals gained from the long-run equation, and λ shows the system's power of the converging equilibrium. In addition, the short-run analysis of the ARDL Bounds Testing approach uses the first difference of the variables differently from the long-run model.

3.1. Data

The annual data between 1978 and 2018 are used in this study to analyse the effects of income, price, urbanization rate and average air temperature on Turkey's industrial electricity demand. The variables used in the industrial electricity demand (E_d^I) analysis and the econometric representations of the models are presented as follows:

$$E_d^I = f(IVA, IEP, URBAN, TEMP)$$

$$E_t^I = \alpha_0 + \alpha_1 IVA_t + \alpha_2 IEP_t + \alpha_3 URBAN_t + \alpha_4 TEMP_t + \varepsilon_t \qquad (7)$$

where;

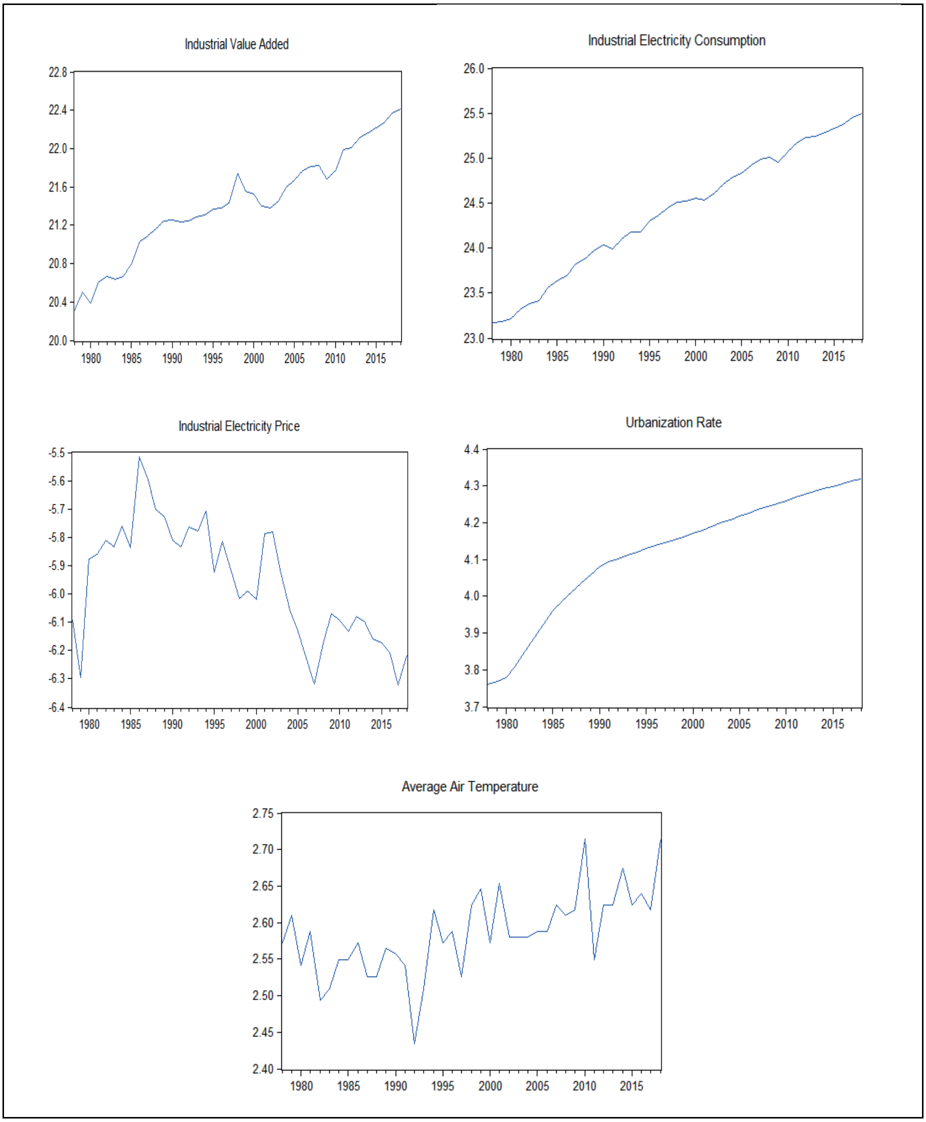
E^I	: Industrial Electricity Consumption
IVA	: Industrial Value Added
IEP	: Industrial Electricity Price
URBAN	: Urbanization rate of total population
TEMP	: Mean Temperature

All variables are in logarithmic form. In Equation (7) α_1, α_2,α_3 and α_4 represent the elasticities of income, price, urbanization and air temperature for Turkey's industrial electricity demand, respectively. The economic theory suggests that the sign of income, urbanization and temperature elasticities of electricity demand should be positive. On the other hand, the price elasticity is expected to affect the consumption negatively.

To analyse the model above, the annual data is obtained from different sources. In this context, E^I is gained from the International Energy Agency in kilowatt-hour (kWh) (IEA, 2019a). *IVA* in constant Turkish Liras (TL) and urbanization rate (*URBAN*) are retrieved from the World Bank database (World Bank, 2020). Nominal *IEP* in TL/kWh are gained from IEA (IEA, 2019b). The nominal prices for the industry sector are deflated by Consumer Price Index (2010=100) of Turkey, available in World Development Indicators (World Bank, 2020). Lastly, the mean temperature (*TEMP*) is obtained from Turkish State Methodological Service (TSMS, 2019).

In Figure 4, the time series graphs of all variables that used in this study is presented.

Figure 4: Time Series Graphs of the Variables Used in the Study



4. Empirical Results

Stationarity is a very important and required specification in time series analyses. Therefore, before starting the modelling processes, stationarity of the series should be checked by unit root tests. The functional form and econometric specification for estimating the industrial electricity demand given in Equation (7) above.

At this stage, these five variables need to be checked whether they contain unit root or not. In line with this objective, ADF, PP, and KPSS unit root tests are used in this study to specify the integration order for each variable. The unit root test results are given in Table 2.

Before using the unit root or stationarity tests, it is necessary to define the optimal lag lengths for the variables. The procedure of selecting the maximum lag length, is generally determined by researchers. In the empirical studies, the lag length is specified as 12 or 24 that use monthly series, and as 4, 8, or 12 in the researches that use annual or seasonal series (Kadilar 2000:54). Modified Akaike Information Criterion (AIC) is utilized in this study to determine the appropriate lag length. As a result of this criterion, the maximum lag length is assigned as 9 to find the optimal length for ADF. On the other hand, for PP and KPSS methods, the bandwidth is chosen by Newey-West selection criteria for the Bartlett Kernel model.

Table 2: The Unit Root Tests Results

	Variables	Level			1st Difference		
		ADF	PP	KPSS	ADF	PP	KPSS
Test Statistics (Constant)	***E^I***	-1.10	-1.37	0.74	-6.35*	-6.36*	0.17*
	IVA	-1.93	-2.44	0.68	-7.33*	-7.47*	0.25*
	IEP	-1.49	-1.42	0.51	-6.97*	-6.91*	0.21*
	URBAN	-2.19	-2.55	0.74	-4,29*	-4.57*	0.38*
	TEMP	-3.60*	-3.66*	0.43*	-	-	-
Critical Values (Constant)	*5%*	***-2.94***	***-2.94***	***0.46***	***-2.94***	***-2.94***	***0.46***
Test Statistics (Constant & Trend)	***E^I***	-1.91	-1.91	0.19	-6.55*	-7.51*	0.05*
	IVA	-2.50	-2.46	0.18	-7.32*	-8.25*	0.13*
	IEP	-2.99	-2.83	0.15	-7.21*	-7.17*	0.12*
	URBAN	-2.76	-1.81	0.18	-11.21*	-11.93*	0.11*
	TEMP	-5.87*	-5.84*	0.11*	-	-	-
Critical Values (Constant & Trend)	*5%*	***-3.53***	***-3.53***	***0.14***	***-3.53***	***-3.53***	***0.14***

Notes: *1. (*) Significant at 5% MacKinnon (1996) critical value for ADF and PP tests.*

2. (*) Significant at 5% Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1) critical value for KPSS test.

3. E^I, IVA, IEP, URBAN and TEMP are natural logs of the industrial electricity consumption, real industrial value added, real industrial electricity price, urbanization rate and mean temperature, respectively.

As it is seen from Table 2, all variables are stationary in their first differences. The test statistics for ADF and PP unit root tests were estimated as lower in the level and greater in the first differences than the critical values in absolute values. Therefore, the null hypotheses of non-stationarity can be rejected for these two unit root tests. On the other hand, the null hypothesis of stationarity cannot be rejected in KPSS unit root test since the estimated test statistics are lower (in absolute values) than the critical values at 5% significance level. In brief, all variables are said to be integrated of order one (*I[1]*) except the TEMP which is stationary in level both in the constant and constant & trend forms. As it is mentioned in the methodology part of this study the ARDL approach can be used with a mixture of *I(0)* and/or *I(1)* data. Therefore, the models of this study can be analysed with the ARDL Bounds Testing method.

In addition to the traditional stationarity tests, the Zivot-Andrews unit root test that considers a structural break in the series is also applied to the variables. Zivot and Andrews (1992) suggested structural break unit root tests for the models with the break in the constant, trend and also constant and trend. The estimated ZA test results for this study are presented in Table 3.

Table 3: Zivot-Andrews Unit Root Test Results

	Variables	**Level**			**1st Difference**		
		ZA	**Lag Length**	**Break Date**	**ZA**	**Lag Length**	**Break Date**
Test Statistics (Constant)	***E^I***	-4.03	0	1984	-6.20*	1	2003
	IVA	-4.62	0	1986	-7.95*	0	1999
	IEP	-3.85	0	2003	-8.23*	0	2008
	URBAN	-4.29	2	1991	-6.74*	2	2008
	TEMP	-6.28*	0	1998	-	-	-
Critical Value (Constant)	***5%***	***-4.80***					
Test Statistics (Constant & Trend)	***E^I***	-4.52	0	1987	-6.13*	1	1990
	IVA	-4.66	0	1986	-7.91*	0	1999
	IEP	-4.03	0	1986	-8.25*	0	2008
	URBAN	-4.74	2	2008	-5.63*	2	1990
	TEMP	-7.75*	0	1994	-	-	-
Critical Value (Constant & Trend)	***5%***	***-5.08***					

Notes: *1. (*) Significant at 5% Zivot and Andrews (1992) critical value.*
2. Max lag length is determined as 4 by using Schwert (1989). ($p_{max}=[4*(T/100)^{1/4}]$)
3. The appropriate lag length was determined by Akaike Information Criteria.
4. E^I, IVA, IEP, URBAN and TEMP are natural logs of the industrial electricity consumption, real industrial value added, real industrial electricity price, urbanization rate and mean temperature, respectively.

According to the ZA unit root test results, the estimated critical values of E^I, *IVA*, *IEP* and URBAN are lower (in absolute terms) than the critical value in the levels. This shows that the null hypothesis of non-stationarity cannot be rejected at 5% significance level. Therefore, it can be said that the series of E^I, *IVA*, *IEP* and URBAN are not stationary in their levels. On the other hand, the critical values of TEMP are greater than the test statistics and thus, the TEMP variable is stationary in its level. After then the ZA test is applied again to the first differences of E^I, *IVA*, *IEP* and URBAN variables. The estimation results show that the series are determined as stationary in their first differences at 5% significance level. In this context, the ZA test results show consistency with the conventional unit root tests (ADF, PP, and KPSS) which do not consider structural breaks in the series.

In terms of the ARDL Bounds Testing method, the cointegration analysis is required to test the long-run relationship among series. Therefore, first, the lag length of the series should be determined. In here, the maximum lag length is chosen as 4 since the number of observation is adequate and the annual data is used. The appropriate lag length is specified as (3,3,3,3,3) based on AIC with no autocorrelation issue. The results of lag length specification can be seen in Table 4.

Table 4: Determination of the Lag Length

Lag Length	AIC	Autocorrelation (LM)
(1,0,0,0,0)	-3.86	1.99 [0.15]
(1,1,1,1,1)	-3.83	2.24 [0.12]
(2,2,2,2,2)	-3.96	3.68 [0.04]
(3,3,3,3,3)*	-4.17	1.07 [0.36]
(4,4,4,4,4)	-4.03	1.76 [0.22]

Notes: *1. (*) indicates minimum AIC value without autocorrelation problem.*
2. p-values of the tests are in square brackets.
3. The Breusch-Godfrey test is performed for maximum 2nd order (AR(2)) serial correlation.

After the optimal lag length is determined, Equation (4) from the methodology section is adapted to Equation (8) as follows:

$$\Delta E_t^I = \beta_0 + \beta_1 trend + \sum_{i=1}^{4} \beta_{2i}\, \Delta E_{t-i}^I + \sum_{i=0}^{4} \beta_{3i}\, \Delta IVA_{t-i} + \sum_{i=0}^{4} \beta_{4i}\, \Delta IEP_{t-i} + \sum_{i=0}^{4} \beta_{5i}\, \Delta URBAN_{t-i} + \sum_{i=0}^{4} \beta_{6i}\, \Delta TEMP_{t-i} + \beta_7 E_{t-1}^I + \beta_8 IVA_{t-1} + \beta_9 IEP_{t-1} + \beta_{10} URBAN_{t-1} + \beta_{11} TEMP_{t-1} + \varepsilon_t \quad (8)$$

where Δ indicates the first difference of the variables.

The estimation results for Equation (8) passes all diagnostic tests. The descriptive statistics of the solved model with appropriate lag length are presented in Table 5 as below. This table shows that the ARDL model is satisfied with respect to the conditions of autocorrelation, heteroscedasticity and normality. In addition, the R-square value is calculated high enough to meet the model selection criteria.

Table 5: Diagnostic Tests Statistics

ARDL (3,3,3,3,3)	
R^2	0.99
Adjusted R^2	0.99
Autocorrelation (LM)	1.07 [0.36]
Heteroscedasticity (White)	13.08 [0.87]
Normality (Jarque-Bera)	1.09 [0.57]
F-stat	9.11
Note: *1. p-values of the tests are in square brackets.*	

The F-statistic (9.11) is found to be greater than the upper bound critical values of both Pesaran et al., (2001) and Narayan (2005) at 1%, 5%, and 10% significance levels (Table 6). Therefore, the null hypothesis of no cointegration among variables is rejected. This means that there is a cointegration relation between variables, and the variables move together in the long-run.

Table 6: Bounds Test Statistics

N=38, k=2	Pesaran		Narayan	
Significance	*I(0)*	*I(1)*	*I(0)*	*I(1)*
1%	4.99	5.85	5.98	6.97
5%	3.88	4.61	4.36	5.13
10%	3.38	4.02	3.66	4.37

Notes: *1. N and k indicate the number of observation and independent variables in the model, respectively.*
2. I(0) and I(1) represent the lower and upper bounds, respectively.
3. The critical values are obtained from Pesaran et al., (2001) and Narayan (2005).
4. The critical values are for the model with unrestricted intercept and restricted trend.

After identifying the cointegration relation among variables, the long-run equation can be estimated. First of all, the maximum and appropriate lag lengths are determined. The proper model, with the maximum lag of 3, is decided as ARDL (2,3,1,3,2). The long-term results and coefficients are represented in Table 7.

Table 7: The Long-Run Model and Coefficients of ARDL Bounds Testing Method

Dependent Variable: E^I		
Variables	**Coefficients**	**Probability Values**
E^I(-1)	0.30	0.09
E^I(-2)	-0.20	0.20
IVA	0.16	0.00
IVA(-1)	0.02	0.66
IVA(-2)	-0.07	0.27
IVA(-3)	-0.12	0.02
IEP	-0.15	0.01
IEP(-1)	-0.07	0.20
URBAN	1.27	0.00
URBAN(-1)	1.78	0.00
URBAN(-2)	2.48	0.00
TEMP	0.08	0.48
TEMP(-1)	0.17	0.12
TEMP(-2)	0.18	0.10
TEMP(-3)	0.20	0.09
C	18.89	0.00
T	0.04	0.00
Long-Term Coefficients		
IVA	0.35*	0.00
IEP	-0.18*	0.04
URBAN	2.16*	0.00
TEMP	0.43*	0.02
C	12.46*	0.00
T	0.03*	0.00
Diagnostic Statistics		
R^2: 0.99	DW: 1.61	
Adjusted R^2: 0.99	F stat: 1927.3 (0.00)	
Autocorrelation (LM): 1.03 (0.37)	χ^2_{White}: 9.87 (0.77)	
χ^2_{Norm}: 1.20 (0.54)	χ^2_{Ramsey}: 2.08 (0.14)	

Notes:	*1. E^I, IVA, IEP, URBAN and TEMP are natural logs of the industrial electricity consumption, real industrial value added, real industrial electricity price, urbanization rate and mean temperature, respectively. T is the trend variable.* *2. (*) indicates significancy at least 5% significance level.* *3. Autocorrelation (LM), χ^2_{White}, χ^2_{Norm}, χ^2_{Ramsey} represents Breusch-Godfrey Serial Correlation Test, White Heteroscedasticity Test, Jarque-Bera Normality Test and Ramsey RESET test, respectively.* *4. The prob. values are in the parenthesis.*

The statistically significant long-term coefficients of the industrial electricity demand are presented in Equation (9).

$$E_t^I = 12.46 + 0.35IVA_t - 0.18IEP_t + 2.16URBAN_t + 0.43TEMP_t + 0.03T \quad (9)$$

In the next stage of the ARDL Bounds Testing approach, the short-term equation is estimated by using the information from the long-term model. The results of the dynamic short-term model are given in Table 8.

Table 8: The Short-Run Model and Coefficients of ARDL Bounds Testing Method

Dependent Variable: ΔE^I		
Variables	**Coefficients**	**Probability Values**
C	18.30*	0.00
Δ*IVA*	0.15*	0.02
Δ*IEP*	-0.14*	0.00
Δ*URBAN*	1.30*	0.00
Δ*TEMP*	0.20*	0.04
ECT(-1)	-0.81*	0.00
Diagnostic Statistics		
Std. error of regression: 0.025	ARCH (1): F=0.08 [0.47]	
Autocorrelation (LM): 2.46 (0.11)	χ^2_{White}: 5.28 (0.50)	
χ^2_{Norm}: 2.88 (0.23)	χ^2_{Ramsey}: 2.77 (0.09)	

Notes: *1. E^I, IVA, IEP, URBAN and TEMP are natural logs of the industrial electricity consumption, real industrial value added, real industrial electricity price, urbanization rate and mean temperature, respectively.*
2. (*) indicates significancy at least 5% significance level.
3. Autocorrelation (LM), χ^2_{White}, χ^2_{Norm}, χ^2_{Ramsey} represents Breusch-Godfrey Serial Correlation Test, White Heteroscedasticity Test, Jarque-Bera Normality Test and Ramsey RESET test, respectively.
4. The prob values are in the parenthesis.

The short-term dynamic equation of ARDL model is given by

$$\Delta E_t^I = -18.30 + 0.15\Delta IVA_t - 0.14\Delta IEP_t + 1.30\Delta URBAN_t + 0.20\Delta TEMP_t + 0.81ECT_{t-1} \quad (10)$$

where the error correction term of this equation is $ECT_t = E_t^I - 12.46 - 0.35IVA_t + 0.18IEP_t - 2.16URBAN_t - 0.43TEMP_t - 0.03T$ and the coefficient of this term can be interpreted as 81% of any disequilibrium is adjusted in each year.

As a result, all the variables are found to be significant in both short and long term equations. Therefore, none of the variables that used in this study are omitted from the models.

5. Conclusion

Turkey's industrial electricity demand has been analysed in this study. For this purpose, the ARDL Bounds Testing method is used to estimate the factors that affecting the industrial electricity demand between the period of 1978 and 2018. The empirical findings suggest that the price elasticities are found negative as expected and statistically significant both in the short and long term. The short and long run price elasticities for Turkey's industrial electricity demand are estimated as -0.14 and -0.18, respectively. On the other hand, the income elasticities of industrial electricity demand are found as 0.15 and 0.35 in the short and long term, respectively. Moreover, the urbanization rate elasticities for the industrial electricity demand are 1.30 for the short term and 2.16 for the long term. Additionally, the mean temperature variable is added to the model to see the effect of the change in the temperature on the electricity consumption trend of the industry. This variable is also found significant and estimated as 0.20 and 0.43 for the short and long term, respectively.

These results indicate that the price elasticities for short and long term are estimated as small and close to each other. The small price elasticities in the industrial sector may be explained by cost-pass-through principle. This principle is used in Turkish industrial sector like all over the world. The electricity usage and the price of electricity constitute an important cost for the industry. Therefore, the price of electricity is directly reflected to the final tariffs of the commodities that produced in this sector. In other words, the electricity prices of the industrial sector which are accepted as cost can be transferred to the final consumers. Thus, it can be said that the price is not very effective on industrial electricity demand of Turkey. In this context, the small price elasticities can be explained by cost-pass-through principle for this study.

On the other hand, the income elasticities found for the short and long run are inelastic. This means that the degree of the effectiveness of income changes on industrial electricity demand is small. In other words, when the income rises by 1 percent, the consumption increases by less than 1 percent.

In addition, the urbanization rate which is very important parameter for the electricity consumption trend is found significant in terms of industrial sector in Turkey. The elasticities of this variable are estimated as bigger than 1 for both short and long terms. This means that when the urbanization rate increases, the electricity consumption in the industrial sector increases more than this rate. As a consequence, it can be said that the urbanization rate and the electricity demand show parallelism in Turkish industrial sector.

Last but not the least, the change in air temperature has a significant effect on Turkey's industrial electricity demand. This means that based on the air temperature the electricity consumption trend of Turkish industrial sector may change. In other words, the need for electricity in the industry may variate with respect to the weather and climate events in Turkey.

As it is mentioned in the introduction part of this study, Turkey's high dependency rate to the external suppliers brings along some political and economic risks for the country. Since electricity is one of the main sources in Turkey's industrial sector, this situation should be changed immediately. To overcome these risks and to ensure the security of energy supply, it is necessary to develop effective policies based on the usage of energy resources as efficiently. The "National Energy Efficiency Action Plan" shows that the Ministry of Energy and Natural Resources is aimed to save almost 8.4 billion dollars in energy expenditures up to 2023 (MENR, 2017). This quantity is approximately 20% of Turkey's ten years average energy expenditure. For this reason, in Turkey, the efficient usage of energy is vitally important in terms of the policies that developed for satisfying the energy demands. In addition, based on the results of this study, the energy prices are not very effective on consumption. Therefore, to overcome the high energy expenditures, some non-price mechanisms should be implemented such as energy efficiency.

In addition, Turkey should determine the priority energy resources to compete with the world in terms of energy. In this respect, the potential of renewable energy sources such as wind, solar, geothermal, biomass, and hydro should be utilized as soon as possible. As a result of these efforts, Turkey will make progress in the fields of ensuring the security of energy supply, decreasing the energy expenditures and producing energy in domestic sources.

Consequently, this study is expected to fill a gap in the energy demand literature. Therefore, the results, inferences, and projections obtained by this study should be of particular importance for researchers, academicians, and policymakers to guide long-term energy plans and to help in understanding the future energy demand trends.

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