Theoretical and Applied Economics
Volume XXIX (2022), No. 1(630), Spring, pp. 101-122

Long-term price and income elasticity of residential natural gas demand in Turkey[1]

Halim TATLI
Bingol University, Turkey
htatli@bingol.edu.tr

Abstract. *The aim of this study is to estimate the price and income elasticity of long-term residential natural gas demand. The variables of the econometric model created within this scope are the natural gas consumption of the residential sector, the price of natural gas, the real income per capita, the price of electricity, the heating degree-days indicating the climatic conditions and urbanization rate. This study analyzes Turkey's long-term demand for natural gas in the residential sector during the 1990-2019 period using the methods of ARDL bound test, Full Corrected ordinary least squares and Canonical Cointegration Regression. Based on the analyses, the price of natural gas and income had a significant negative effect, while the price of electricity, climate, and urbanization rate respectively had a significant positive effect on long-term natural gas demand. In the long term, both price and income elasticity of natural gas demand are estimated to be bigger than 1. The results of this study show that in the residential sector of Turkey, natural gas is an inferior good. It was also found that housing sector electricity consumption is a substitute good for housing sector natural gas consumption.*

Keywords: Turkey's natural gas demand, climate and demand for natural gas, heating degree days, the price elasticity of demand for natural gas.

JEL Classification: Q41, D12, C31.

1. Introduction

Among the fossil energy types, natural gas, which has the best environmental and least pollution emission characteristics, is used in many fields. In recent years, natural gas consumption has been increasing rapidly all over the world. Global natural gas demand in 2017 reached 3757 billion cubic meters (m^3), an increase of 3.2% compared with 2016 (International Energy Agency (IEA), 2018). Natural gas is the most commonly used type of energy after electricity in the housing sector in the world. The use of natural gas in the housing sector started after the 1970s. The consumption was 3468 million m^3 in 1990 but reached 46452 million m^3 in 2016, which is about 14 times larger (IEA, 2017). Turkey's total natural gas consumption is rapidly increasing. It was 53 598 million m^3 in 2017, about 15-fold larger compared with its 1990 value (IEA, 2018). Similarly, Turkey's natural gas consumption in the residential sector is increasing rapidly. Accordingly, the natural gas consumption in this sector, which was 3218 million m^3 in 2000, increased by 4 times and reached 11 620 million m^3 in 2016 (IEA, 2018). However, production is very low in response to this increase in Turkey's consumption of natural gas. In 2017, natural gas production in Turkey was 354 million m^3 (IEA, 2018). The shortage of supply caused by the lack of production is met through imports. In 2000, Turkey's natural gas imports amounted to 14.38 billion m^3; this expanded to 55.12 billion m^3 in 2017 – approximately 4-fold larger. Investments are being made in natural gas storage areas to avoid the risk of supply disruption. In this context, with the newly established natural gas storage area in 2016, a higher storage capacity of imported natural gas was reached.

In the last decade, the average price increase in terms of gross calorific value in terms of TL per MWh was 47%. In this context, the price of natural gas used in the housing sector in terms of gross calorific value in terms of TL per MWh was 74 TL in 2008 and increased to 109 TL in 2017 (IEA, 2018).

Some reforms were executed to increase competition in the domestic gas market in Turkey. In this respect, the Natural Gas Market Law, which entered into force in May 2001, was made in order to establish a competitive market structure. With this law, BOTAŞ's monopoly rights regarding natural gas import, wholesale and distribution were terminated, and an independent regulatory authority, Energy Market Regulatory Authority (EMRA), was established. According to the law, natural gas market activities in Turkey (natural gas import and export, wholesale, distribution, transmission and storage) were separated. By the end of 2017, EMRA had issued 61 import licenses, 8 export licenses, 51 wholesale licenses, 1 transmission license, 16 LNG transmission licenses and 8 storage licenses.

Natural gas, a commodity that facilitates human life, is an energy source used both as a final product and an intermediate product in the production process. In general, the demand of a good is influenced by its price, the consumer's income, and the price of other goods. Like other goods, most studies have determined that natural gas demand is influenced by its price, the price of other goods and the consumer's income. In this study, the impacts of Heating Day Degree (HDD) (which is accepted as representative of the climate variable) and the above-mentioned factors on natural gas consumption, particularly in the residential sector, in Turkey were examined. This study was performed to enhance effective decision-making by consumers and firms in the competitive market, the effectiveness of tax policies applied by the state with respect to natural gas, the creating of a competitive market and the ongoing reform of the natural gas market in Turkey.

The model used in this study and the results of the analysis of this model would be beneficial to decision-makers in Turkey's natural gas market and contribute to natural gas literature in energy economy. Moreover, this study analyzes the issue with new data and gives the opportunity of comparison with the results of past studies on this subject in Turkey. The main objectives of the current study are to determine the factors affecting the long-run demand of residential natural gas in Turkey's energy sector, to predict the long-run price and income elasticity of natural gas demand and to reveal the impact of climate on the long-run natural gas demand in the residential sector.

The rest of the study is arranged as follows: The second section provides a literature review on the subject of the study. The third section provides information about the study data and the estimation method. The fourth section gives empirical results, and the fifth section presents the main findings and statements of policy recommendations.

2. Literature review

An analysis of the literature concerning the subject of this study indicates that studies in this field have been conducted both in Turkey and abroad. For example, the study conducted by Goncu et al. (2013) in Istanbul, the largest city in Turkey in terms of population, concluded that HDD is the main determinant of natural gas demand. Another study conducted in Turkey reported that the elasticity of natural gas demand is very low; therefore, consumers do not react to possible price increases by reducing their natural gas demand or by substituting natural gas with other energy sources (Erdogdu, 2010).

Analyses of studies on natural gas demand abroad show that natural gas demand is analyzed with the use of similar and different variables in different countries. For example, in a study conducted to investigate the factors affecting the demand of natural gas used by households living in Vlaardingen in the Netherlands for heating purposes, analyses were conducted on 145 households during the 1976-1977 period. The result of the study indicates that the demographic characteristics of the households as well as the housing characteristics, such as insulation, location and structure, of the house were the factors affecting natural gas demand (Verhallen and Van Raaij, 1981). Liu (1983) performed a study on the price and cross-price elasticity of natural gas demand in the US residential, commercial and industrial sectors. He found that the long-term price elasticity of natural gas demand was higher than that of the short-term and that the industrial sector was less sensitive to the prices of natural gas. The results of a similar study conducted in the Patagonia region in the south of Argentina, involving household data, revealed that the main reason for high natural gas expenditure in the region was the structure of buildings and the use of heating devices (Gonzales et al., 2007). In an empirical study on households in China, based on analysis of the survey data, it was determined that the natural gas demand of Chinese households responded to price changes, and the price elasticity of natural gas demand was -0.898 (Zeng et al. 2018). Another study on China was conducted by Yu et al. (2014). In the study, they used 216 dataset on natural gas consumption of households of Chinese cities during the

2006-2009 period. Based on the analysis, they determined the price elasticity as -1.431 and the income elasticity as 0.206. In a study examining the determinants of residential natural gas demand in Ireland, it was concluded that weather conditions have the greatest effect on daily household natural gas consumption (Harold et al., 2015). Another study examined the effect of air change on natural gas consumption based on statistical analysis of annual and monthly temperatures in European countries for the period 1980-2009 (Tihanyi and Szunyog, 2012). Dagher (2012) analyzed the data of his study using the Autoregressive Distributed Lag (ARDL) method for natural gas demand in the United States of America (USA). The results of the study show that the responses of demand to price and income are lower than the results suggested in previous studies. Ranson et al. (2014) investigated the effects of climate change on space heating in residential and commercial buildings; it was found that energy use for heating was very high at very low temperatures and that energy use for cooling was very high at very high temperatures. Timmer and Lamb (2007) obtained a very high correlation between natural gas consumption and temperature in their study performed in the central and eastern regions of the USA.

In an empirical study examining natural gas demand in eight OECD countries, it was found that there was a positive relationship between natural gas demand and income and that the elasticity of natural gas was 1.333 (Bilgili, 2014). In the same study, it was stated that there was a negative relationship between natural gas demand and price, and natural gas price elasticity was 1.126. Zhang et al. (2018) investigated price and revenue elasticity of natural gas demand in different sectors of China. They found that the price elasticity of natural gas demand in the housing sector was 0.2323 in both the long and short term and that the income elasticity was 2.051. In the same study, they concluded that the price elasticity of natural gas demand in the non-housing sector was greater than 0 and that there is a substitution relationship between natural gas and liquefied petroleum oil. Gautam and Paudel (2018) conducted a study to investigate natural gas demand in the residential, commercial and industrial sectors, using state-level panel data covering between 1997 and 2016, in the nine-state Northeast USA. Estimated results show that the price elasticity of long-term demand for natural gas in the housing, commercial and industrial sectors are -0.14, -0.29 and -0.28 respectively. In addition, the fuel cross-price elasticity of natural gas demand in the residential, commercial and industrial sectors were found to be 0.19, 0.52 and 0.24 respectively. They found that in the long run, natural gas demand in all three sectors was not affected by revenue, and heating degree days (HDD) had a positive impact on natural gas demand in all three sectors.

There are many studies in literature that examined the effects of climate, demographic characteristics, economic factors (GDP, natural gas price) and properties of buildings on natural gas consumption (Villar and Joutz, 2006; Timmer and Lamb, 2007; Brown and Yücel, 2008; Harold et al., 2015). Therefore, changes in these factors may affect natural gas consumption and price.

Table 1. *Studies on price and income elasticity of long-term natural gas and electricity demand in Turkey*

Author(s)	Long-run prices elasticity	Long-run income elasticity	Energy species	Consumer species	Period	Method
Akan and Tak (2003)	-	0.88	Electricity	Residence	1970-2000	ECM
Akan and Tak (2003)	-0.22	1.81	Electricity	Total	1970-2000	ECM
Akarsu (2017)	-0.51	0.93	Electricity	Total	1990-2001	Dynamic spatial lag panel data
Akbostancı et al. (2009)	-1.21	-0.50	Energy	Total	1985-2004	ECM
Bakırtaş et al. (2000)	-	3.13	Electricity	Total	1962-1996	Linear ECM
Çatık and Deliktaş (2016)	-0.98	0.75	Natural gas	Total	1960-2012	Cointegration model, ECM
Çetin and Yüksel (2014)	-0.17	2.34	Natural gas	Total	1989Q1-2010Q4	Cointegration model, ECM
Dilaver and Hunt (2011)	-0.38	1.57	Electricity	Residence	1960-2008	Structural time Series Model
Erdogdu (2010)	1.85	5.11	Natural gas	Power generation	1988-2005	Partial adjustment model
Erdogdu (2010)	-31.9	6.92	Natural gas	Residence	1988-2005	Partial adjustment model
Erdogdu (2010)	-7.81	4.73	Natural gas	Industrial	1988-2005	Partial adjustment model
Erdogdu (2007)	-0.91	1.09	Electricity	Total	1984-2004	Partial adjustment model
Erdogdu (2014)	0.95	0.52	LPG	Fuel	2006Q2-2010Q4	Partial adjustment model
Halıcioglu (2007)	-0.52	0.7	Electricity	Residence	1968-2005	ARDL
Lebe and Yaylalı (2013)	-0.51	0.47	Electricity	Residence	1978-2009	ARDL
Maden and Baykul (2012)	-6.85	0.93	Electricity	Total	1970-2009	Cointegration model, ECM
Nişancı (2005)	.	3.56	Electricity	Residence	1970-2003	Cointegration model, ECM
Nişancı (2005)	.	2.88	Electricity	Total	1970-2003	Cointegration model, ECM
Saygılı (2010)	.	1.32	Electricity	Total	1970-2008	Cointegration model, ECM
Tatlı (2017)	-0.12	1.27	Electricity	Residence	1990-2014	ARDL
Topallı (2012)	-0.18	2.01	Electricity	Residence	1964-2009	ARDL
Yamak and Güngör (1998)	-0.27	0.67	Electricity	Residence	1950-1991	Cointegration model, ECM

The price and income elasticity values of long-term demand for natural gas and electricity in Turkey given in Table 1 are a summary of existing literature on the basis of year, consumer type, sampling period and estimation method. Table 1 shows that the long-term income elasticity values of natural gas demand in Turkey are forecasted in some studies to be less than one (Altinay and Yalta, 2016; Çatık and Deliktaş, 2016; Çetin and Yüksel, 2014); however, in other studies (Erdogdu, 2010), the estimates are greater than one. Similar to the income elasticity of natural gas demand, the price elasticity of natural gas demand in Turkey was found to be smaller than one in some years and greater than one in other years (Table 1).

When empirical studies on the subject in literature are examined, it was observed that price and income elasticity values vary greatly depending on the region, market structure, climate factors and economic conditions.

3. Materials and methods

In literature, different methods are used in the analysis of natural gas demand based on the data obtained. In this study, Augmented Dickey-Fuller (ADF) (1979) and Phillips-Perron (1988) tests were used to determine the stability of the data, and Zivot and Andrews (1992) structural root unit test was used to test structural fracture. In order to determine the existence of long-term cointegration between the variables, the F test used in the ARDL method developed by Pesaran et al. (2001) was preferred. Finally, Full Corrected OLS (FMOLS) and Canonical Cointegration Regression (CCR) coefficient estimation methods were used to estimate the long-term relationship between dependent and independent variables.

3.1. Empirical model and data

The variables used in this study, definitions of these variables and their sources are given in Table 2. GP, PerGDP, EP, HDD and URATE were used as independent variables, while GQ was used as dependent variable in the analysis. It is assumed that the close functional relationship between dependent and independent variables is as given in Equation 1:

$$\mathrm{GQ} = f(\mathrm{GP, PerGDP, EP, HDD, URATE}) \tag{1}$$

In this study, double logarithmic model was used, and the model coefficients give the elasticity values. The model used for the long-term relationship between dependent and independent variables is assumed to be as given in Equation 2:

$$GQ_t = \alpha_0 + \alpha_1 GP_t + \alpha_2 EP_t + \alpha_3 PerGDP_t + \alpha_4 HDD_t + \alpha_5 URATE_t + \varepsilon_t \tag{2}$$

where: α_0 is the constant term, and ε_t is the error term. The parameters $\alpha_1,\ \alpha_2,\ \alpha_3, \alpha_4\ and\ \alpha_5$ represent long-term elasticity values, because all of the variables are used in logarithmic form.

Table 2. *Variables and their descriptions*

Variables	Descriptions	Sources
GQ	Use of natural gas for residential sectors in Turkey, million cubic meters	IEA
GP	Natural gas prices for residential sectors in Turkey, US $/MWh *	IEA
EP	Electricity prices for residential sectors in Turkey, $/kWh *	IEA
$PerGDP$	Real GDP per capita in Turkey (constant 2010 $)	World Bank Database
HDD	An index used to estimate the amount of natural gas for residential sector during the cool season **	World Bank Database Climate Change Information Portal
$URATE$	Urbanization Rate	World Bank Database

Note:
* Deflated using the GDP deflator of the United States.
**HDD = (18^{0}C – T) * D if T is less than or equal to the heating threshold of 18^{0}C or zero if T is greater than this threshold, where T is the average out door temperature over a period of D days (Yu et al., 2014).

The descriptive statistics of values of the variables used in this study are given in Table 3. Based on the value of Jargue-Bera statistic, it can be stated that the series are not normally distributed.

Table 3. *Descriptive statistics of variables*

	GQ	GP	PerGDP	EP	HDD	URATE
Mean	5653.500	0.361992	10046.98	1.368844	326.3582	67.54370
Median	4854.000	0.317857	9445.788	1.317533	331.4278	67.53250
Maximum	14396.00	0.629511	15190.10	2.006283	379.7327	75.63000
Minimum	49.00000	0.228478	6708.664	0.832845	265.2375	59.20300
Standard Deviation	4344.029	0.110543	2790.448	0.319973	27.95898	5.042966
Skewnes	0.429451	0.790817	0.562030	0.593673	-0.349851	0.001836
Kurtosis	1.992483	2.426294	1.977488	2.326898	2.467820	1.741004
Jarque-Bera	2.191003	3.538382	2.886301	2.328571	0.965998	1.981355
Probability	0.334	0.170	0.236	0.312	0.616	0.371
Observations	30	30	30	30	30	30

Figure 1. *Time series graphs of the variables*

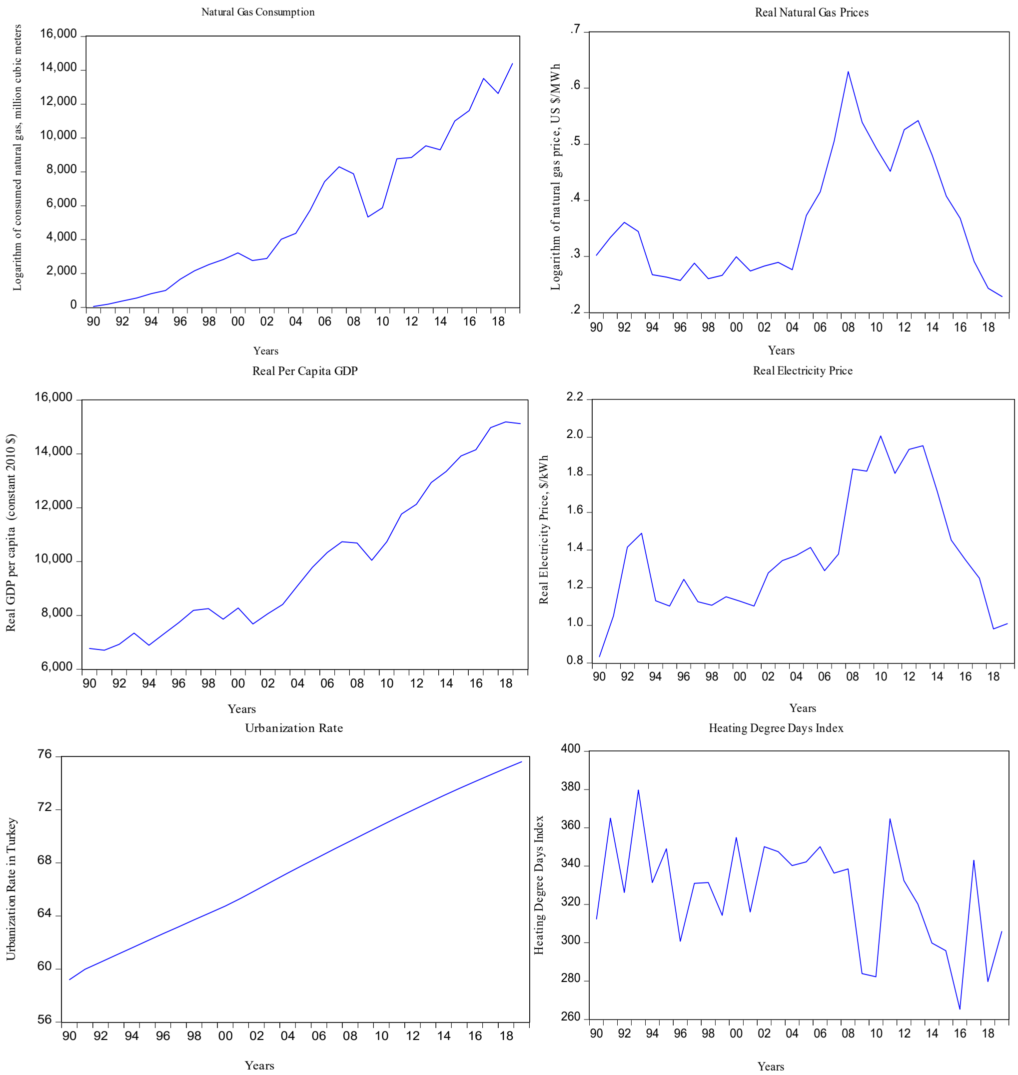

Figure 1 presents the time series plot of the variables by year in Turkey. The graph shows a steady increase in natural gas consumption despite fluctuations in some years. Furthermore, it was observed that a little drop in natural gas consumption occurred in 2000 and 2008; this could be as a result of the Turkish economic crisis of 2000 and the 2008 global financial crisis. On the other hand, real natural gas and electricity prices have increased largely due to the economic crisis that occurred in Turkey in 2000 and indicated a downward trend during the 2012-2013 period. Real GDP per capita also generally increased during the analyzed period, with the exception of the periods of the Turkish economic crisis of 2000 and the 2008 global financial crisis. HDD exhibited fluctuations, increases and decreases, over the years. In addition, a continuous increase in the rate of urbanization is observed.

In this study, the cointegration relationship between dependent and independent variables was demonstrated using ARDL method. The ARDL method, expressed as a boundary test, was described by Pesaran and Smith (1999) and Pesaran et al. (2001). After determining the cointegration relationship between the variables, the long-term natural gas demand in the housing sector during the 1990-2019 period was analyzed using FMOLS and CCR methods.

3.2. Estimating methods

3.2.1. Testing for unit root

In the Augmented Dickey-Fuller (ADF) (1981) unit root test, the stability of a series was determined, while the lagged values of the dependent variable were included as independent variables. The length of the lag is determined, and the presence of the unit root is investigated. In this study, the determination of lag length was done by taking into consideration Schwarz information criterion. The unit root estimate of a variable was obtained as given in Equation (3).

$$\Delta y_t = \alpha_0 + \alpha_1 T + \omega y_{t-1} + \sum_{i=}^{k} \beta_i \Delta y_{t-i} + u_i \quad (3)$$

where α_0 is the term constant, T is the trend variable, and u is the term error. In the equation, the null hypothesis that the variable is not stationary is tested against the alternative where the variable is stationary.

$H_0: \omega = 0$ in case there is unit root (the series is non-stationary).

$H_0: \omega < 0$ in case there is no unit root (the series is stationary).

The ADF test assumes that the error term has a statistically independent and constant variance. In the context of this assumption, Phillips-Perron (1988) unit root test is more flexible than ADF unit root test. The Phillips-Perron approach tests the existence of the unit root, not just the equality of the ADF but simply a transformation into test statistics. The unit root estimate of the variable for this test is written as given in Equation (4).

$$\Delta y_t = \alpha_0 + \alpha_1 T + \omega y_{t-1} + u_i \quad (4)$$

The difference between the PP unit root test and the ADF unit root test is that the lagged values of the dependent variable are not included in the model as independent variables. Variations in time series variables may occur due to different conditions and processes that often occur over a period of time. Such changes may cause structural changes in the data. Therefore, it is necessary to test whether the series of variables are affected by structural breaks. One of the tests that do this is Zivot-Andrews (1992) unit root test. This test endogenously determines the structural breakage. In a series, three models are used to test whether the unit is a root or not (Zivot and Andrews, 1992).

Model A: $y_t = \mu + \beta t + \lambda y_{t-1} + \lambda_1 DU(\Phi) + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varpi_t$ (5)

Model B: $y_t = \mu + \beta t + \lambda y_{t-1} + \lambda_2 DT(\Phi) + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varpi_t$ (6)

Model C: $y_t = \mu + \beta t + \lambda y_{t-1} + \lambda_2 DT(\Phi) + \lambda_1 DU(\Phi) + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varpi_t$ (7)

Model A, Model B and Model C refer to structural break at level, slope and both slope and level respectively. In all models, t = 1, 2, ..., T is the time, T_B is the break year, and $\Phi = T_B / T$ is the relative breaking point. The Φ representing the dummy variable is determined for each year between $i = 2 / T$ and $i = T-1 / T$ and is estimated by the Least Squares Method for each model dummy variable. Then, the t-statistic values to be used to test the hypothesis $\lambda_i = 1$ are calculated. When estimating the models, the number of additional variables, k, is determined separately using the model selection criterion for each value. After the year of fracture is determined, the t-statistic is compared with the table values of Zivot-Andrews (1992, Tables 2, 3 and 4), and the null hypothesis is tested as "series is no stable value with structural break". If the calculated test statistic is greater than the absolute value of Zivot-Andrews, the null hypothesis is rejected.

3.2.2. Testing the cointegration relationship

The cointegration test was used to model and estimate the long-term relationship between time series of non-stationary variables at the level. If there is a cointegration relationship between the variables, it means that there is a long-term relationship between the variables. In this study, in order to determine the cointegration relationship between time series of variables, F test performed within the scope of ARDL method was used. With the help of the variables of the study, the ARDL equation can be written as follows:

$$\Delta LnGQ_t = \phi_0 + \sum_{t-1}^{n} \phi_{1i} \Delta Ln\,GQ_{t-i} + \sum_{t-0}^{n} \phi_{2i} \Delta\,LnGP_{t-i} + \sum_{t-1}^{n} \phi_{3i} \Delta\,LnEP_{t-i} + \sum_{t-1}^{n} \phi_{4i} \Delta\,LnPerGDP_{t-i} + \sum_{t-1}^{n} \phi_{5i} \Delta\,LnHDD_{t-i} + \sum_{t-1}^{n} \phi_{6i} \Delta\,URATE_{t-i} + \theta_1 LnGQ_{t-1} + \theta_2 LnGP_{t-1} + \theta_3 LnEP_{t-1} + \theta_4 LnPerGDP_{t-1} + \theta_5 LnHDD_{t-1} + \theta_6 URATE_{t-1} + \varepsilon_t \quad (8)$$

where: Δ is the difference operator, ε_t is the standard error term, φ_1, φ_2, φ_3, φ_4, φ_5 and φ_6 represent short-term relationships, while θ_1, θ_2, θ_3, θ_4, θ_5 and θ_6 are long-term relationships.

In the ARDL method, the existence of cointegration between the variables in the system is determined by the boundary test. Therefore, the F test statistic is used to determine the presence of cointegration between variables. The F test statistic is used to determine whether there is cointegration between variables by testing the common significance of delay level coefficients. LnGQ in Equation (8) is a dependent variable. H_0: $\theta_1 = \theta_2 = \theta_3 = \theta_4 = \theta_5 = \theta_6 = 0$ forms the null hypothesis and assumes that there is no cointegration relationship, whereas H_1: $\theta_1 \neq \theta_2 \neq \theta_3 \neq \theta_4 \neq \theta_5 \neq \theta_6 \neq 0$ assumes cointegration. In case of cointegration, the null hypothesis is not accepted. The asymptotic critical value limits of the F test statistics obtained by the boundary test have a non-standard distribution provided by Pesaran et al. (2001). If the calculated F test statistic is higher than the upper critical bound, the null hypothesis claiming that there is no cointegration is rejected, which means that there is cointegration. If the calculated F test statistic is below the lower critical bound, the null hypothesis is not rejected, which means that there is no cointegration. If the calculated F test statistic is between the upper and lower limits, it cannot be determined with certainty whether there is cointegration.

3.2.3. Coefficient estimators

If co-integration between the variables has been determined, long-term coefficients should be estimated with appropriate estimation methods. In this section, three different methods for estimating long-term coefficients between variables are discussed. These methods include the Fully-Modified Ordinary Least Squares (FMOLS), proposed by Phillips and Hansen (1990) and the Canonical Cointegration Regression (CCR), developed by Park (1992), and the ARDL bound test, developed Pesaran and Smith (1999) and Pesaran et al. (2001). These methods take into account the autocorrelation problem between error terms as well as the internality relationship between the independent variables and the error term. These three methods are superior to ordinary least squares estimation in these aspects.

Fully-modified ordinary least squares

FMOLS is based on the study of Phillips and Hansen (1990). This method reveals consistent estimates for a small sample and provides a chance to check for the reliability of the estimation results. Since FMOLS is the only equation method, it is based on the assumption that there is a single co-integration vector. The prerequisite for the implementation of this method is that the series are cointegrated in the first difference I (1). Phillips and Hansen (1990) stated that the FMOLS estimator has super consistent and asymptotically deviant characteristics. Moreover, they showed that this method gives good results even in a small sample. The FMOLS method is performed by considering LnGQ, which is the dependent variable of the study, and following the steps below:

The time series vector (n+1) dimension $[GQ_t, X']$ based on the cointegration equation is expressed as shown in Equation 9.

$$GQ_t = X'\beta + D_{1t}'\gamma_1 + u_{1t} \tag{9}$$

where $D_t' = (D_{1t}', D_{2t}')$ deterministic trend and n stochastic variables are determined by the $X_t = (\text{GP, PerGDP, EP, HDD, URATE})$ equation system.

$$X_t = \Gamma_{21}' D_{1t} + \Gamma_{22}' D_{2t} + \varepsilon_{2t} \tag{10}$$

$$\Delta\varepsilon_{2t} = u_{2t} \tag{11}$$

It is assumed that the error term is stationary, and the mean is zero. The concurrent covariance matrix Π, unilateral long-term covariance matrix Ψ and covariance matrix Ω, which is obtained by segmenting the error term, are expressed as shown in Equation 12, Equation 13 and Equation 14 respectively.

$$\Pi = E(u_t, u_t') = \begin{bmatrix} \sigma_{11} & \sigma_{12} \\ \sigma_{21} & \Pi_{22} \end{bmatrix} \tag{12}$$

$$\Psi = \sum_{j=0}^{\infty} E(u_t, u_{t-j}') = \begin{bmatrix} \vartheta_{11} & \vartheta_{12} \\ \vartheta_{21} & \Psi_{22} \end{bmatrix} \tag{13}$$

$$\Omega = \sum_{j=-\infty}^{\infty} E(u_t, u_{t-j}') = \begin{bmatrix} \eta_{11} & \eta_{12} \\ \eta_{21} & \Omega_{22} \end{bmatrix} = \psi + \psi' - \Pi \tag{14}$$

The FMOLS estimator first gives $\hat{u}_{1t}$ from the symmetrical and one-sided long-term covariance matrix of error terms with the help of Equation 9 and then $u_{2t} = \Delta\varepsilon_{2t}$ with the help of Equation 11. Using the obtained error terms, $\hat{u}_t = (u_{1t}, u_{2t}')$, long term covariance matrices $(\hat{\Psi}\ ve\ \hat{\Omega})$ are estimated. The corrected data can be written as follows:

$$GQ_t^{+} = GQ_t + \hat{\eta}_{12}\hat{\Omega}_{22}^{-1}\hat{u}_2 \tag{15}$$

The term deviation correction is derived from the following equation.

$$\hat{\vartheta}_{12}^{+} = \hat{\vartheta}_{12} - \hat{\eta}_{12}\hat{\Omega}_{22}^{-1}\hat{\Psi}_{22} \tag{16}$$

The FMOLS estimator is achieved by the following equation.

$$\hat{\varphi}_{FMOLS} = \begin{bmatrix} \hat{\beta} \\ \hat{\gamma} \end{bmatrix} = \left(\sum_{t=1}^{T} Z_t Z_t'\right)^{-1} \left(\sum_{t=1}^{T} Z_t GQ_t^{+} - T \begin{bmatrix} \hat{\vartheta}_{12}^{+} \\ 0 \end{bmatrix}'\right) \tag{17}$$

where $Z_t = \left(X_t' D_t'\right)'$. In the FMOLS estimator, t-statistics converge asymptotically to the standard normal distribution. The most important consideration when obtaining the FMOLS estimator is to estimate long-term covariance matrices $(\hat{\Psi}\ ve\ \hat{\Omega})$.

Canonical cointegration regression

This method was developed by Park (1992) to eliminate long-term correlation between the cointegration equation and stochastic shocks. The CCR method is associated with the FMOLS method.

The difference between CCR and FMOLS is that stationary series' values are used instead of level series in the analysis. In the CCR estimator analysis, as in FMOLS, error terms,

$\hat{u}_t = (u_{1t}, u_{2t}^{'})$, and long-term covariance matrices $(\hat{\Psi}\ ve\ \hat{\Omega})$ are first estimated. The CCR method is modeled as given in Equation 18.

$$\hat{\varphi}_{CCR} = \begin{bmatrix}\hat{\beta} \\ \hat{\gamma}\end{bmatrix} = \left(\sum_{t=1}^{T} Z_t^* Z_t^{*'}\right)^{-1} \sum_{t=1}^{T} Z_t^* GQ_t^{\;*} \qquad (18)$$

where $Z_t^* = (Z_t^{*'} D_t^{'})$ in the CCR estimator, and t-statistics are also considered to asymptotically converge to the standard normal distribution. Another aspect of this estimator that differs from the FMOLS method is that it requires a consistent estimator of the simultaneous covariance matrix $\hat{\Pi}$.

4. The empirical results

Stationarity of the series was analyzed using Augmented Dickey-Fuller (ADF) (1979) and Phillips-Perron (1988) tests. The unit root test estimation results are given in Table 4. When the estimation results of both tests are examined, it is observed that variables other than HDD have unit roots, i.e. they are not stationary. In order to stabilize these non-stationary series, the first order differences of the series were taken, and it was determined that the series were stationary at I (1) level.

Table 4. *Unit Root Test results*

Variable	ADF		PP	
	Intercept	Intercept and trend	Intercept	Intercept and trend
In levels			*In levels*	
GQ	0.427 (0.980)	-2.541 (0.307)	-2.3542 (0.998)	-1.967 (0.593)
GP	-1.522 (0.507)	-0.459 (0.979)	-1.318 (0.607)	-0.459 (0.979)
PerGDP	0.893 (0.993)	-1.799 (0.679)	-1.149 (0.997)	-1.799 (0.679)
EP	-1.736 (0.403)	-0714 (0.962)	-2.018 (0.277)	-2.029 (0.558)
HDD	-4.762 (0.000)	-6.361 (0.000)	-3.926 (0.005)	-7.152 (0.000)
URATE	1.222 (0.650)	-2.027 (0.560)	-1.007 (0.737)	-1.399 (0.839)
First differences			*First differences*	
ΔGQ	-5.194 (0.000)	-5.010 (0.002)	-6.286 (0.000)	-8.923 (0.000)
ΔGP	-3.593 (0.012)	-3.645 (0.043)	-3.797 (0.007)	-3.645 (0.043)
ΔPerGDP	-4.755 (0.000)	-5.046 (0.002)	-4.747 (0.000)	-4.888 (0.002)
ΔEP	-4.880 (0.000)	-4.888 (0.002)	-4.338(0.001)	-3.940 (0.025)
ΔHDD	-10.866 (0.000)	-4.287 (0.012)	-41.131(0.000)	-40.108 (0.000)
URATE	-4.687 (0.000)	-3.996 (0.020)	-4.051 (0.004)	-3.978 (0.021)

It is required to test whether there is a structural break in the series that are stationary in the first difference. Zivot and Andrews (1992) structural break unit root test, which tests for stationarity under structural break, was used to determine whether the series related to the variables of the study were affected by structural breaks. The test statistics created for breaking in the constant, the constant and trend of the series, the corresponding critical values and the structural break periods determined according to the minimum t statistic are given in Table 5. The null hypothesis that there is a unit root with structural break is not rejected in both the constant and trend models for all variables. Therefore, structural breaks in the series of Zivot-Andrews unit root test results do not significantly affect the traditional ADF unit root test results, and all series are I (1).

Table 5. *Zivot-Andrews unit root test results*

	Intercept		Intercept and trend	
Variable	Min. t-statistic	Break Point	Min.t-statistic	Break Point
GQ	-2.918 (0)	2014	-4.325 (0)	2009**
GP	-2.837 (1)	2005**	-3.322 (1)	2007*
PerGDP	-3.381 (0)	1999*	-3.748 (0)	2001
EP	-2.125 (0)	2014**	-4.306 (0)	2008**
URATE	-2.950 (1)	2004	-3799 (1)	2015
Critical values: 1% -5.34 5% -4.93			Critical values: 1% -5.57 5% -5.08	

Note: ** Indicates significance at the 1% level. *Indicates significance at the 5% level. Values in parentheses indicate the number of delays. Critical values in both models were taken from Zivot and Andrews (1992, p. 258).

In Turkey's household sector, the cointengration relationship between natural gas demand and factors affecting the demand for natural gas was investigated by bounds testing approach. After determining the appropriate lag length as 4, the F test used in the ARDL method was used to check whether there was a long-term cointegration relationship between the variables. Table 6 shows the results of the F test. When the calculated F statistic of the Wald test is higher than the upper critical limit values, the null hypothesis that there is no cointegration is rejected. The rejection of the null hypothesis results in a long-term cointegration relationship between the selected variables. The F test value is 8.646. This value is significant at 1% since it is higher than Narayan's (2005) upper critical limits.

The results of our estimates based on the Schwarz criterion information (SIC) indicate that our model follows an ARDL process (3, 1, 0, 1, 0, 1) in which the variables GQ, GP, EP, PerGDP, HDD and URATE take respectively lag 3, 1, 0, 1, 0, 1.

Table 6. *Boundary test results for cointegration (1990-2019)*

Test Statistics	Value	k
F- statistics	8.646***	5
Critical Boundary Values		
Significance level	Upper bound-I(0)	Lower bound -I(1)
10%	2.407	3.576*
5%	2.910	4.193**
1%	4.134	5.761***

Note: *** Significant at 1% significance level. **Significant at 5% significance level. Significant at 1% significance level. k represents the number of independent variables in the model. Critical values is taken from Narayan (2005) (Case III).

The accuracy of the cointegration relationship is determined by testing the assumptions of classical linear regression.

The results presented in Table 7 confirm that there is no problem of normality, autocorrelation and heteroscedasticity in the test equations of ARDL in the long run. Furthermore, Ramsey RESET test confirms that the model is correctly identified. However, at the 10% significance level, it raises suspicion of the existence of autocorrelation in the model. To remove this doubt, the Newey-West HAC Standard Error and Covariance procedure was used.

Table 7. *Diagnostic tests results*

Diagnostic tests	Statistics value (χ^2)	p-probability
JB Normality test (1) (χ^2_{NORM})	3.057	0.216
Breusch–Godfrey LM test (1) (χ^2_{BG})	3.006	0.083
Breusch-Pagan-Godfrey heteroscedasticity test (χ^2_{BPG})	4.913	0.953
Ramsey RESET (1) (χ^2_{RAMSEY})	0.408	0.532
R^2	0.990	
F- Statistics	254.835	0.000
DW	2.526	

Note: $\chi^2_{BG}, \chi^2_{RAMSEY}, \chi^2_{NORM},$ and χ^2_{BPB} respectively are Breusch-Godfrey sequential dependency, Ramsey regression model building error, Jarque-Bera normality and Breusch-Pagan-Godfrey tests used for heteroscedasticity testing. DW is the Durbin-Watson test value.

In ARDL technique, the stability of long and short-term parameters is determined by applying cumulative total (CUSUM) and cumulative total squares (CUSUMsq) tests (Pesaran and Shin, 1999).

Figure 2 shows the graphs of CUSUM and CUSUMsq respectively. Both graphs show that CUSUM and CUSUMsq values are within the critical limits at 5% significance level.

Since the values shown in Figure 2 are among the critical limits, the long and short term variables that affect the natural gas demand of the household sector are stable. Moreover, this result shows that there is no structural breakage; therefore, the ARDL test is not affected. Finally, based on diagnostic tests and CUSUM and CUSUMsq tests, the ARDL model is determined in a stable and appropriate manner.

Figure 2. *CUSUM and CUSUM of squares tests of parameter stability for the estimated ARDL*

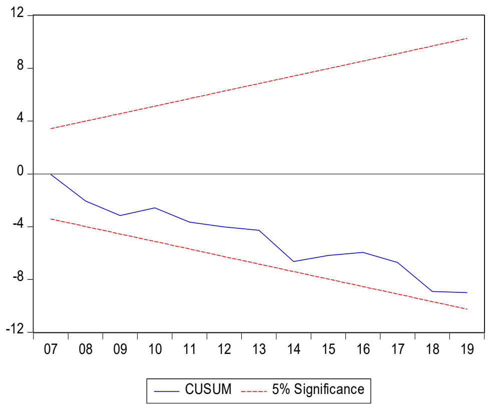

Table 8 shows the long-run estimation results of the ARDL outcomes. In the time period covered, long-term residential natural gas demand in Turkey was found to be significantly negatively affected by natural gas price and URATE and significantly positively affected by electricity prices, real per capita GDP and HDD. During long-run analysis outcomes revealed that GP has adverse influence with GQ and the coefficient (-0.990433) with probability value (0.0792), while the variable EP, PerGDP and HDD revealed a positive linkage with GQ with coefficients (1.060894), (11.26979) and (1.327956) and probability values are (0.1472), (0.0013) and (0.0629) respectively.

The results also expose that URATE has negative linkage with GQ with having values (-0.481506) and probability values (0.0118).

Table 8. *Log-run estimated coefficients (Dependent variable: GQ)*

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GP	-0.990433	0.525961	-1.883094	0.0792*
EP	1.060894	0.693993	1.528681	0.1472
PerGDP	11.26979	2.844729	3.961638	0.0013***
HDD	1.327956	0.661055	2.008842	0.0629***
URATE	-0.481506	0.168008	-2.865966	0.0118**
C	-74.58324	18.33340	-4.068161	0.0010***

Note: *** significant at 1%; **significant at 5%; *significant at 10%.

The short-run estimation results of the ARDL model are shown by Table 9.

The consequences of short-run investigation expose that GP has an adverse relation with GQ having coefficient (0.061515) by P-value (0.7694). The results also reveal that EP, PerGDP and HDD has positive linkage with GQ with having values (0.489050), (2.805412) and (0.612160) and probability values (0.1824), (0.0000) and (0.0041) correspondingly. URATE has positive linkage with GQ with having values (2.568963) and probability values (0.0370).

Table 9. *Short-run dynamic relationship results of ARDL-ECM*

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GQ(-1)	-0.473508	0.110705	-4.277202	0.0007***
GQ(-2)	-0.490161	0.088388	-5.545561	0.0001***
GP	0.061515	0.206025	0.298579	0.7694
GP(-1)	-0.518084	0.100323	-5.164163	0.0001***
EP	0.489050	0.349761	1.398239	0.1824
PerGDP	2.805412	0.440378	6.370461	0.0000***
PerGDP(-1))	2.389727	1.175205	2.033455	0.0601*
HDD	0.612160	0.180836	3.385162	0.0041***
URATE	2.568963	1.122063	2.289501	0.0370**
URATE(-1)	-2.790927	1.169758	-2.385902	0.0307**
C	-34.38133	7.983499	-4.306548	0.0006***
CointEq(−1)	-0.460979	0.050080	-9.204921	0.0000***

Note: *** significant at 1%; **significant at 5%; *significant at 10%.

For both urbanization and income variables, the coefficients estimated by the ARDL model are not in line with theoretical expectations. FMOLS and CCR models, which are long-term estimators, yielded results consistent with theoretical expectations. Reliable results are from FMOLS and CCR models.

Table 10 presents the results of FMOLS and CCR by considering the double logarithmic model in which the natural gas consumption of the household sector is accepted as the dependent variable. When the estimation results are examined, it was observed that the results of FMOLS and CCR estimators are similar.

The results of the FMOLS and CCR estimators demonstrates that intercept is insignificant and that the coefficients of other variables are similar in terms of significance and magnitude. The values obtained from the models are approximately consistent. When the results of the FMOLS estimator are taken into consideration, it was observed that household natural gas demand is significantly negatively affected by its price. On the other hand, natural gas demand is positively affected by the price of electricity in the sector, HDD and URATE. In addition, real per capita income negatively affects the natural gas demand in the residential sector. Namely, as revenue increases, natural gas demand also decreases. In the long-term analysis, it was estimated that the coefficients of all variables affecting household gas demand were statistically significant.

The coefficient of GP, which is -1.091, implies that 1% increase in GP leads to 1.090% decrease in natural gas demand in the residential sector in the long term. In the long-run, a one percent increase in real per capita income causes a 2.9% decrease in natural gas demand. The price of the electricity in the residential sector, urbanization rate and a one percent increase in the heating day temperature led to an increase in natural gas demand by 1.52%, 0.38% and 2% respectively.

HDD is positive and statistically significant at the 1% level, implying that colder periods have a stronger demand for natural gas. This finding is consistent with the expectation of this study because the general view is that more natural gas is needed in the residential sector during the cooler seasons. Natural gas is generally used for heating purposes in houses. Also, it is well known that cities and large towns in Turkey use more natural gas for heating.

A significant and positive relationship was found between natural gas demand and urbanization rate in the long run. The elasticity between urbanization ratio and natural gas demand is 0.039, which means that for each 1% increase in urbanization ratio in Turkey, its natural gas demand will increase by %0.39. Cai et al. (2021) also obtained a result similar to this finding in their studies.

Table 10. *FMOLS and CCR cointegration test estimation results*

Variables	Coefficients	Standard deviation	t-statistic	P
FMOLS estimations results				
GP	-1.091726	0.222242	-4.912321	0.0001***
EP	1.521044	0.310958	4.891472	0.0001***
PerGDP	-2.893594	0.600330	-4.820004	0.0001***
HDD	2.008296	0.393965	5.097651	0.0000***
URATE	0.389926	0.035984	10.83595	0.0000***
Constant	-6.783340	4.135309	-1.640347	0.1145
CCR estimations results				
GP	-1.015104	0.275942	-3.678683	0.0012***
EP	1.415459	0.394115	3.591486	0.0015***
PerGDP	-2.916529	0.734660	-3.969905	0.0006***
HDD	1.922784	0.722107	2.662741	0.0139***
URATE	0.390014	0.043583	8.948704	0.0000***
Constant	-5.878073	6.275458	-0.936676	0.3587

Note: *** significant at 1%; **significant at 5%.

According to FMOLS, CCR and ARDL models, the price, cross and income elasticity results of residential sector natural gas demand are presented in Table 11.

The partial elasticity of natural gas demand with respect to price is approximately same in all three methods, and all three are statistically significant at the 1% significance level. The price elasticity of natural gas demand is unit elastic.

The long-term natural gas price elasticity is found to be approximately -1. This result shows that residential natural gas demand is price unit elastic. An increase of 1% in natural gas price decreases demand by approximately 1%.

Similarly, the income elasticity of natural gas demand in the long run is negative at the 1% significance level and more than one (2.9) in the FMOLS and CCR. Natural gas can be said to be an inferior good in the residential sector in the long term. This result is consistent with other empirical results (see, for example, Maddala et al., 1997; Baltagi and Griffin, 1997; Haas and Schipper, 1998; Asche et al., 2008; Waheed and Martin, 2013). We attribute this result to the fact that people attach importance to energy efficiency and increase environmental awareness, rather than natural gas being an inferior good. According to the results of ARDL method, income elasticity of natural gas demand was found to be significantly positive. However, the income elasticity value was found to be very high (11.27), inconsistent with the theoretical and practical realities.

The cross-price elasticity of natural gas demand was found to be greater than 1 at the 1% significance level in both FMOLS and CCR models. However, in the ARDL model, although the sign of the cross-price elasticity of natural gas demand is positive, it was found to be insignificant. In the long run, the cross-price elasticity of natural gas demand is positive and greater than 1 (Table 11).

This result shows that electricity used in the residential sector is a substitute for natural gas in the long term. This is expected because in the long run, natural gas and electricity can used interchangeably for cooking, heating, washing and other household uses.

Table 11. *Calculated elasticity of residential natural gas demand in Turkey*

Estimation Technique	Long-Term Value elasticity		
	Price elasticity	Cross price elasticity	Income elasticity
FMOLS	-1.091726***	1.521044***	-2.893594***
CCR	-1.015104***	1.415459***	-2.916529***
ARDL	-0.990433*	1.060894	11.26979***

Note: * indicates that the coefficients are significant at 1% level. Table 11 shows the results of the FMOLS, CCR and ARDL methods.

5. Discussion and conclusion

In this study, the price and income elasticity of demand for natural gas in conjunction with the factors affecting residential demand for natural gas between 1990 and 2019 in Turkey were estimated by ARDL bound test, FMOLS and CRR methods.

The results of the analysis indicate that the residential natural gas price and real income per capita in Turkey in the long term has a significant negative impact on the demand. In addition, the values of electricity price, heating degree-days and urbanization rate had a significant positive impact on the demand for residential natural gas in the long-run.

In the long term, the price elasticity value of demand for residential natural gas was found to be equal to one. Therefore, given the relationship between long-term residential natural gas demand and price elasticity, if the price elasticity of demand is equal to 1 and negative, a decrease (or increase) in natural gas prices causes at the same rate an increase (or decrease) in the demand of natural gas in the residential sector. Accordingly, the long term demand for residential natural gas in Turkey is unit elastic. In this context, consumers in Turkey in the long term could reduce the use of natural gas by substituting at the same rate it with other energy sources in reaction to price increase.

On the other hand, the income elasticity of residential natural gas demand is estimated to be higher than one in the long-run. The study reveals that the price elasticity of natural gas demand in the long run is high with new data. The income elasticity of demand for residential natural gas exceeds 1, which indicates that natural gas is inferior good for the housing sector. These results in the long term offer important information to policy makers about income tax rules to be proposed. By increasing the income tax in Turkey, the demand for natural gas in the housing sector in the long term can be reduced.

In addition, the cross-price elasticity coefficient of natural gas demand of the housing sector is found to be significant and positive. Accordingly, electricity is a substitute good for natural gas in the housing sector. In the long run, a tax on electricity in the housing sector could increase the demand for natural gas. In other words, natural gas and electricity consumption in the housing sector in the long-term could be regulated through taxation according to economic conditions.

A significant and positive relationship was obtained between climate and natural gas demand in the long-run. This result is compatible to the expectations of the study. This finding shows that the natural gas required for heating in winter will increase depending on the air temperature in the long term. It also shows that different uses of natural gas other than the purpose of heating in the long term will be more. In recent years, natural gas has been made available to all provinces and some large districts in Turkey.

In the natural gas investment plan, it is intended that natural gas will be made available to the districts of the provinces. In other words, the reason for the positive relationship between the climate variable and natural gas demand could be the increase in natural gas consumption per person in the housing sector over time. Hooijmvans (2016) found a positive relationship between HDD and natural gas consumption for the Netherlands, which is in accordance with the results of this study.

The price and income elasticity values of the long-term demand for natural gas obtained in this study are generally consistent with those of other studies in literature. Finally, Turkey's natural gas demand can be said to be sensitive to price and temperature changes. In future studies, natural gas demand could be assessed with a broader set of data that will emerge at the regional level (e.g. monthly data) and the main variables of demand theory.

Note

(1) This study is a revised and extended version of the paper presented at Al-Farabi Congress, held 2-5 May 2019.

References

Akan, Y. and S. Tak., 2003. Türkiye Elektrik Enerjisi Ekonometrik Talep Analizi. *Journal of Economics and Administrative Sciences, 17*, 1-2, pp. 21-49.

Akbostanci, E., Tunc, G.I. and Turut-Asik, S., 2009. Türkiye'nin Enerji Talebini Belirleyen Etkenler. Paper presented at the *11th Turkey Energy Congress*. İzmir, Turkey, 21-23 October 2009. Available from <http://www.dektmk.org.tr/pdf/enerji_ kongresi_11/57.pdf>

Altinay, G., and Yalta, A.T., 2016. Estimating the evolution of elasticities of natural gas demand: the case of Istanbul, Turkey. *Empirical Economics*, *51*(1), pp. 201-220.

Asche, F., Nilsen, O.B. and Tveteras, R., 2008. Natural gas demand in the European household sector. The Energy Journal, *29*(3), pp. 27-46. <https://doi.org/10.5547/ISSN0195-6574-EJ-Vol29-No3-2>

Bakırtaş, T., Karbuz, S. and Bildirici1, M., 2000. An econometric analysis of electricity demand in Turkey. *METU Studies in Development*, *27*(1-2), pp. 23-34

Bilgili, F., 2014. Long run elasticities of demand for natural gas: OECD panel data evidence. Energy Sources. *Part B: Economics, Planning and Policy*, *9*(4), pp. 334-341. <https://doi.org/ 10.1080/15567249.2010.497793>

Brown, S.P. and Yücel, M.K., 2008. What drives natural gas prices? *The Energy Journal*, *29*(2), pp. 45-60.

Çatık, A.N. and Deliktaş, E., 2016. Türkiye'de Petrol, Kömür ve Doğal Gaz Talebinin Fiyat ve Gelir Esnekliklerinin Tahmin Edilmesi. *Pamukkale Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 25*(1), pp. 1-20.

Cetin, T. and Yuksel, F., 2014. Empirical investigation on energy dependence-consumption nexus: Evidence from Turkish natural gas market. *Applied Energy,* 133, pp. 243-251.

Dagher, L., 2012. Natural gas demand at the utility level: an application of dynamic elasticities. *Energy Economic*, *34*(4), pp. 961-9.

Dickey, D.A. and Fuller, W.A., 1979. Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Society, 74*(366), pp. 427-431.

Dilaver, Z. and Hunt, L.C., 2011. Modelling and Forecasting Turkish Residential Electricity Demand. *Energy Policy, 39*(6), pp. 3117-3127.

Erdogdu, E. 2007. Electricity demand analysis using cointegration and ARIMA modelling: A case study of Turkey. *Energy Policy, 35*, pp. 1129-1146.

Erdogdu, E., 2010. Natural gas demand in Turkey. *Applied Energy*, *87*(1), pp. 211-219. <https://doi.org/10.1016/j.apenergy.2009.07.006>

Erdogdu, E., 2014. Motor fuel prices in Turkey. *Energy Policy*, *69*, pp. 143-153.

Gautam, T.K. and Paudel, K.P., 2018. The demand for natural gas in the Northeastern United States. *Energy, 158*, pp. 890-898.

Goncu, A., Karahan, M.O. and Kuzubas, T.U., 2013. Forecasting Daily Residential Natural Gas Consumption: A Dynamic Temperature Modelling Approach. *Working Papers Bogazici University, Department of Economics,* pp. 1-24. <https://pdfs.semanticscholar.org/9466/1d76c5901e55d322fe6f3aca4aa9649ce53b.pdf>

Gonzales, A.D., Carlsson-Kanyama, A., Crivelli, E.S. and Gortari, S., 2007. Residential energy use in one-family households with natural gas provision in a city of the Patagonian Andean Region. *Energy Policy*, *35*(4), pp. 2141-2150.

Haas, R. and Schipper, L., 1998. Residential energy demand in OECD countries and the role of irreversible efficiency improvements. *Energy Economics*, *20*(4), pp. 421-442. <https://doi.org/10.1016/S0140-9883(98)00003-6>

Halicioglu, F., 2007. Residential Electricity Demand Dynamics in Turkey. *Energy Economics* 29, pp. 199-210.

Harold, J., Lyons, S. and Cullinan, J. 2015. The determinants of residential gas demand in Ireland. *Energy Economics*, *51*, pp. 475-483. <https://doi.org/10.1016/j.eneco.2015.08.015>

Hooijmans, M., 2016. Modelling the non-linear relation between natural gas consumption and Temperature: An Alternative Framework, Available from <https://pdfs.semanticscholar.org/b8ec/576f35af27e98ac1f0732df447a124edd315.pdf?_ga=2.117323393.667412295.1555770930-1839714157.1555660319> (20.04.2019).

International Energy Agency, IEA, 2017. Natural Gas Information (2017 edition), Paris, France.

International Energy Agency, IEA, 2018. Natural gas information statistics. France: International Energy Agency, Paris.

Ji, Q., Fan, Y., Troilo, M., Ripple, R. and Feng, L., 2018. China's Natural Gas Demand Projections and Supply Capacity Analysis in 2030. *The Energy Journal*, *39*(6), pp. 53-76.

Liu, B., 1983. Natural gas price elasticities: variations by region and by sector in the USA. *Energy Economics*, *5*(3), pp. 195-201.

Maddals, G.S., Trost, R.P., Li, H. and Joutz, F., 1997. Estimation of short-run and long-run elasticity of energy demand from panel data using shrinkage estimators. *Journal of Business & Economics Statistics*, 15(1), pp. 90-100.

Maden, S., and Baykul, A., 2012. *Co-Integration analyses of price an income elasticities power consumption in Turkey*. *European Journal of Social Sciences*, 30(4), pp. 523-534.

Narayan, P.K., 2005. The saving and investment nexus in China: evidence from Cointegration ration test. *Applied Economics*, *37*(17), pp. 1979-1990.

Nişancı, M., 2005. Türkiye'de Elektrik Enerjisi Talebi ve Elektrik Tüketimi ile Ekonomik Büyüme Arasındaki İlişki. *Selçuk Üniversitesi İktisadi ve İdari Bilimler Fakültesi Sosyal ve Ekonomik Araştırmalar Dergisi, 9*, pp. 107-121.

Park, J.Y., 1992. Canonical Cointegrating Regressions. *Econometrica: Journal of the Econometric Society*, *60*(1) pp. 119-143.

Pesaran, M., Shin, Y. and Smith, R.J., 2001. Bounds Testing Approaches to the Analysis of Level Relationships. *Journal of Applied Econometrics*, *16*, pp. 289-326.

Pesaran, M.H. and Shin, Y., 1999. An Autoregressive Distributed Lag-Modeling Approaches to Cointegration Analysis. Econometrics and Economics Theory in the 20th Century: The Ragnar Frisch Centennial Symposium. Strom S.-Cambridge University Press, Cambridge.

Phillips, P.C. and Hansen, B.E., 1990. Statistical Inference in Instrumental Variables Regression with I (1) Processes. *The Review of Economic Studies*, *57*, pp. 99-125.

Phillips, P.C.B. and Perron, P., 1988. Testing for unit root in time series regression, *Biometrica*, *75*(2), pp. 335-346.

Ranson, M., Morris, L. and Kats-Rubin, A., 2014. Climate Change and Space Heating Energy Demand: A Review of the Literature, 1-43, NCEE Working Paper Series No. 201407, National Center for Environmental Economics, US Environmental Protection Agency. <https://www.epa.gov/sites/production/files/201501/documents/climate_change_and_space_heating_energy_demand.pdf>

Sanderson, M., 1983. Heating degree day research in Alberta: residents conserve natural gas. *The Professional Geographer*, *35*(4), pp. 437-440. <https://doi.org/10.1111/j.0033-0124.1983.00437.x>

Saygılı, T.O., 2010. Türkiye'de Toplam Elektrik Talebinin Fiyat ve Gelir Esneklikleri, 1970-2008. Atılım Üniversitesi Sosyal Bilimler Enstitüsü Yüksek Lisans Tezi. Ankara.

Tatli, H., 2017. Short-and long-term determinants of residential electricity demand in Turkey. *International Journal Economic Manage Account*, *25*, pp. 443-464.

Tihanyi, L. and Szunyog, I., 2012. The Effects of Weather Changes on Natural Gas Consumption. *Geosciences and Engineering*, *1*(2), pp. 303-314.

Timmer, R.P. and Lamb, P.J., 2007. Relations between temperature and residential natural gas consumption in the Central and Eastern United States. *Journal of Applied Meteorology and Climatology*, *46*(11), pp. 1993-2013.

Topallı, N., 2012. Enerji Etkinliği ve Türkiye'de Konut Elektriği Tüketiminin Geri Tepme (Rebound Effect) Etkisi, Doktora Tezi Sosyal Bilimler Enstitüsü İktisat Anabilim Dalı, Konya.

Verhallen, T.M.M. and Raaij, W.F.V., 1981. Household Behavior and the Use of Natural Gas for Home Heating. *Journal of Consumer Research*, *8*(3), pp. 253-257.

Villar, J.A. and Joutz, F.L., 2006. The relationship between crude oil and natural gas prices. *Energy Information Administration, Office of Oil and Gas*, pp. 1-43.

Waheed, A. and Martin, F., 2013. Estimating the demand elasticities of residential natural gas in Louisiana. *The Global Journal of Finance and Economics*, *10*(2), pp. 183-189.

Yamak, R. and Güngör, B., 1998. Konut Elektrik Talep Denkleminin Tahmini: Türkiye Örneği, 1950-1991**.** *Ekonomik Yaklaşım*, *9*(31), p. 78.

Yaylali, M. and Lebe, F., 2013. Electricity Demand of Residential Sector: Demand Estimation and Forecasting for Turkey. *Nevsehir Haci Bektas Veli University Journal of Social Sciences, 3*, pp. 119-145.

Yu, Y., Zheng, X. and Han, Y., 2014. On the demand for natural gas in urban China. *Energy Policy*, *70*, pp. 57-63. <https://doi.org/10.1016/j.enpol.2014.03.032>

Zeng, S., Chen, Z.M., Alsaedi, A. and Hayat, T., 2018. Price elasticity, block tariffs, and equity of natural gas demand in China: Investigation based on household-level survey dat. *Journal of Cleaner Production*, *179*, pp. 441-449.

Zhang, Y., Ji, Q. and Fan, Y. 2018. The price and income elasticity of China's natural gas demand: a multi-sectoral perspective. *Energy Policy*, *113*, pp. 332-341.

Cai, Z., Yu, C.H. and Zhu, C., 2021. Government-led urbanization and natural gas demand in China. *Renewable and Sustainable Energy Rev*iews, *147*(111231), pp. 1-9.

Zivot, E. and Andrews, D., 1992. Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis. *Journal of Business & Economic Statistics, 10*(3), pp. 251-270.