Forecasting Turkey's Natural Gas Consumption by Using Time Series Methods

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Abstract

Strategic energy planning processes, which include natural gas demand, are commonly used as a tool to design the regional and local energy system and encourage renewable energy development. The oil and natural gas market plays a very important role in the strategic energy planning process in a country. In recent years, natural gas consumption has become the fastest growing primary energy source in Turkey. In this study, natural gas consumptions of Turkey in different time periods are forecasted by using various time series methods such as exponential smoothing, winters' forecasting and Box-Jenkins methods. These methods are compared with each other in terms of the superiority in forecasting performance. The findings reveal that in the yearly data set, double exponential smoothing model outperforms the other alternative forecasting models. On the other hand, in term of monthly data set, SARIMA model provides the better results than the others.

Keywords: *Forecasting, Time Series, Natural Gas*

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Introduction

Energy is one of the most important inputs required to maintain social and economical improvement in a country. It is necessary that energy demand should be performed at the right time economically, and be of good quality and respectful of increasing environmental consciousness in order to preserve national development and a high standard of living. Natural gas is an alternative energy source that has cleanliness, burning easiness, high thermal value and resource availability (Aras and Aras, 2003). All over the world, the use of natural gas is projected to nearly double between 1999 and 2020, providing a relatively clean fuel for efficient new gas turbine power plants. The largest increases in gas use are expected in Central and South America and in developing Asia, and the developing countries as a whole are expected to add a larger increment to gas use by 2020 than are the industrialized countries.

Turkey is located at a strategic place between the Middle and Near East, where rich oil and natural gas reserves prevail, and the Western world, where the main energy consumption takes place. Turkey is also situated near the Caspian Sea, where natural gas and oil production are expected to increase substantially. Turkey has made a remarkable contribution to the stability of the region and still continues to maintain this policy. It is accepted that creating a balanced international cooperation setting is an important factor for acquiring more reliable energy supply (Ozturk and Hepbasli, 2003).

Turkey is an important candidate to be the ‘‘energy corridor’’ in the transmission of the abundant oil and natural gas resources of the Middle East and Middle Asia countries to the Western market. Furthermore, Turkey is planning to increase its oil and gas pipeline infrastructure to accommodate its increased energy consumption. Naturally, Turkish natural gas usage is projected to increase remarkably in coming years, with the prime consumers, expected to be industry and power plants (Kilic, 2006). Turkish energy consumption has risen dramatically over the past 20 years due to the combined demands of industrialization and urbanization.

The usage of the natural gas can be classified into 3 groups; the residential users, the industrial users and the commercial users. The demand characteristics of these three categories differ significantly. The residential customer demands are typically temperature sensitive, increasing on weekends. The commercial customers are also typically temperature sensitive, but decreasing on weekends. Industrial customer demand is much less temperature sensitive, decreasing significantly on weekends. Historically, many methods have been used to predict daily demand. Gas controllers have used methods such as looking at use patterns on similar historical days and scatter plots of use versus temperature. Often these methods are only successfully applied by experts with years of experience at a Local Distribution Company (LDC). LDC firms are taken into consideration as distributors for cities. LDC faces many challenges in the business of supplying gas to their customers. The gas supply system of an LDC consists of gate stations, compressors, gas storage, and customers. The LDC must operate these systems to assure delivery of gas in adequate volumes at required pressures under all circumstances. For efficient, economical, and safe operation, the daily gas demanded by the customers must be known in advance with some degree of accuracy. The customer base of an LDC consists of many individual customers, each with unique demand characteristics. Customers use gas for space heating, known as heating load, for heating water, drying, cooking and baking, and other processes, known as base load, and for electric power generation (Brown et al., 2005).

Forecasting the natural gas demand is important for planning gas production and transmission. The challenges of this forecasting are the volatility of consumer profile, the strong dependency on weather conditions and the lack of historical data (Viet and Mandziuk, 2000).

Forecasting Natural Gas Consumption

There is wide range of studies about forecasting natural gas consumption in the literature. Liu and Lin (1991) estimated the residential consumption of natural gas in Taiwan by using linear transfer function method. Brown and Matin (1995) made a study about development of feed-forward artificial neural network models to forecast daily gas consumption in Wisconsin. Durmayaz et al. (2000) estimated the residential heating energy requirement and fuel consumption in Istanbul based on degree-hours method. Khotanzad et al. (2000) has used the artificial neural network (ANN) forecasters with application the prediction of daily natural gas consumption needed by gas utilities. Gumrah et al. (2001) analyzed the factors and their relationships that influencing the gas consumption in Ankara, and they suggested a model based on degree-day concept including annual number of customers, average degree days, and the usage per customer. Sarak and Satman (2003) forecast the residential heating natural gas consumption in Turkey by using degree-day method. Aras and Aras (2003) have described an approach to obtain appropriate models for forecasting residential monthly natural gas consumption in terms of time series analyses and degree-day method. Viet and Mandziuk (2003) analyzed and tested the several approaches to prediction of natural gas consumption with neural and fuzzy neural systems for natural gas load in two different regions of Poland. Siemek et al. (2003) implemented the Hubbert model based upon Starzman modification to describe the possible scenario of the development of the Poland gas sector. Liu et al. (2004) used the support vector regression (SVM) technique for natural gas load forecasting of Xi'an city, and they compared the result with the 7-lead day forecasting of neural network based model. Gil and Deferrari (2004) presented a generalized model which predicts mainly the residential and commercial natural gas consumption in urban areas of Argentina, for the short and intermediate ranges of time. Brown et al. (2005) presented the mathematical models for gas forecasting in their study. Gutiérrez et al. (2005) used Gompertz-type innovation diffusion process as a stochastic growth model of natural gas consumption in Spain and compared stochastic logistic innovation modeling and stochastic lognormal growth modeling of a non-innovation diffusion process. Al-Fattah (2006) presents a methodology for developing forecasting models for predicting U.S. natural gas production, proved reserves, and annual depletion to year 2025 using time series modeling approach. Kenisarin and Kenisarina (2006) investigated the energy saving potential in the residential sector of Uzbekistan. Ivezić (2006) showed the results of investigation of an artificial neural network (ANN) model for short term natural gas consumption forecasting. This methodology uses multilayer artificial neural networks to incorporate historical weather and consumption data. Wong-Parodi et al. (2006) compared the accuracy of the forecasts for the natural gas prices of Energy Information Administration's short term energy outlook and the futures market for the period from 1999 to 2004. Potocnik et al. (2007) proposed a strategy to estimate forecasting risk of natural gas consumption in Slovenia. This strategy combines an energy demand forecasting model, an economic incentive model and a risk model. Sanchez-Ubeda and Berzosa (2007) presented a model based on decomposition approach to capture demand patterns in a very large number of different historical profiles. Ediger and Akar (2007) used ARIMA and SARIMA methods to estimate the future primary energy demand of Turkey from 2005 to 2020. Kızılaslan and Karl»k (2009) used seven neural networks algorithms as forecasting models they tried to find the best solution on forecasting of monthly natural gas consumption

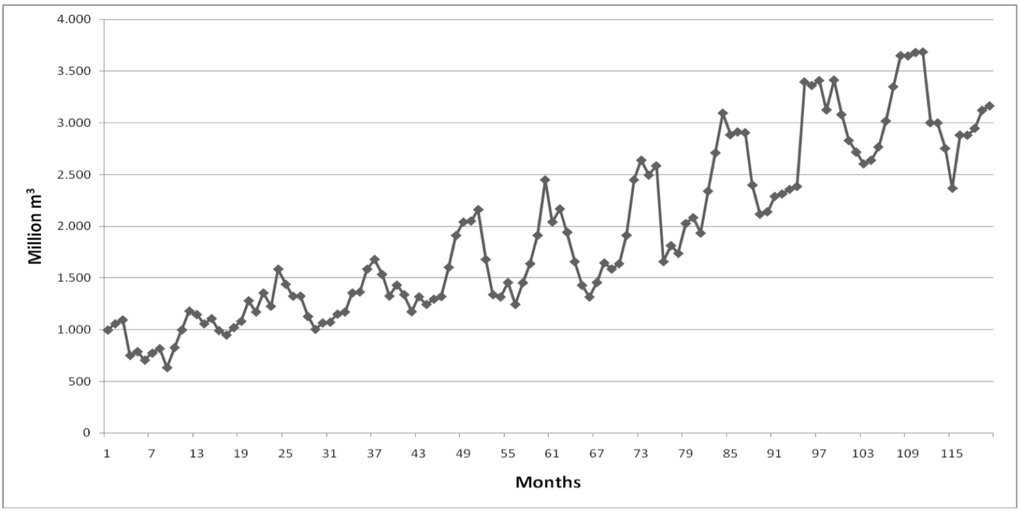
The Research Study

The analyses used in this study are conducted in two stages. First stage involves monthly forecasting analysis based on a various time series models. In the second stage, yearly data set has been considered to forecast the natural gas consumption in Turkey. Finally, these time series methods are compared with each other in terms of the superiority in forecasting performance. Data set was collected from the state-owned Turkish Pipeline Corporation (BOTAŞ). All these stages are explained in the following subsections.

Monthly Natural Gas Consumption of Turkey

In this part of study monthly natural gas consumption data of Turkey are taken into account. The consumption values were provided by International Energy Agency (IEA) from 1999 to 2008. In total 120 data points are observed. When we plot the monthly natural gas consumption of Turkey, it exhibits seasonality and increasing trend as clearly seen in Figure 1. Like other natural gas consumption data sets, the consumption values are increasing in winter months and decreasing in summer months. As Turkey's total natural consumption is growing the data has an increasing trend.

Figure 1 Monthly natural gas consumption of Turkey from 1999 to 2008 (IEA)



Forecasting Monthly Natural Gas Consumption with Exponential Smoothing Type Methods

SmartForecasts software is utilized for a search on forecasting methods. The data values from years 1999 to 2007 were used. The consumption values of 2008 were used for testing the selected forecasting method. The results obtained from SmartForecasts are given below in Table 1.

Table 1 SmartForecasts results

Rank	% Worse	Avg Error	Forecasting Method
1	(winner)	160.10	Winters' Multiplicative, weights = 26% 26% 26%
2	33.8%	214.21	Winters' Additive, weights = 54% 54% 54%
3	37.1%	219.49	Simple Moving Average of 1 periods
4	37.4%	219.93	Single Exponential Smoothing, weight = 97%
5	76.2%	282.05	Double Exponential Smoothing, weight = 69%
6	82.4%	292.01	Linear Moving Average of 12 periods

Winters' multiplicative method with weights 0,26; 0,26; 0,26 is suggested by SmartForecasts for monthly data. The forecasts for 2008 are presented in Table 2.

Table 2 Winters' multiplicative method forecasts

2008	Real	Winters' Method with 0,26; 0,26; 0,26	Lower Limit	Upper Limit	Error
January	3647	3,831	3,480	4,182	184
February	3680	3,622	3,261	3,982	-58
March	3685	3,574	3,202	3,945	-111
April	3001	2,874	2,491	3,258	-127
May	*3000*	*2,579*	*2,182*	*2,975*	*-421*
June	2753	2,442	2,031	2,852	-311
July	2368	2,552	2,127	2,977	184
August	2882	2,576	2,135	3,017	-306
September	2880	2,557	2,100	3,015	-323
October	2947	2,778	2,303	3,252	-169
November	3121	3,241	2,749	3,733	120
December	3164	3,657	3,146	4,167	493
				MAD	234

Forecasting Monthly Natural Gas Consumption with Seasonal Autoregressive Integrated Moving Average (SARIMA) Model

We have generated Box-Jenkins SARIMA model for forecasting monthly natural gas consumption of Turkey in 2008. We have also used the consumption values from 1999 to 2007 to form the SARIMA model. SPSS time series function module is utilized.

SPSS Time Series function recommends SARIMA (0,0,2)(1,1,0) model. The model constant is estimated as 263,224 where as MA(1) parameter estimate is -0,473 and MA(2) is -0,471. Seasonal AR(1) parameter estimate is -0,425. The forecasts obtained from SARIMA model are given in Table 3. SARIMA has slightly better MAD value than Winters' multiplicative method and unlike Winters all the real values are in forecasted limits. (The consumption value of May was out of the Winters forecasted limit.) SARIMA should be selected for forecasting method to predict monthly natural gas consumption of Turkey.

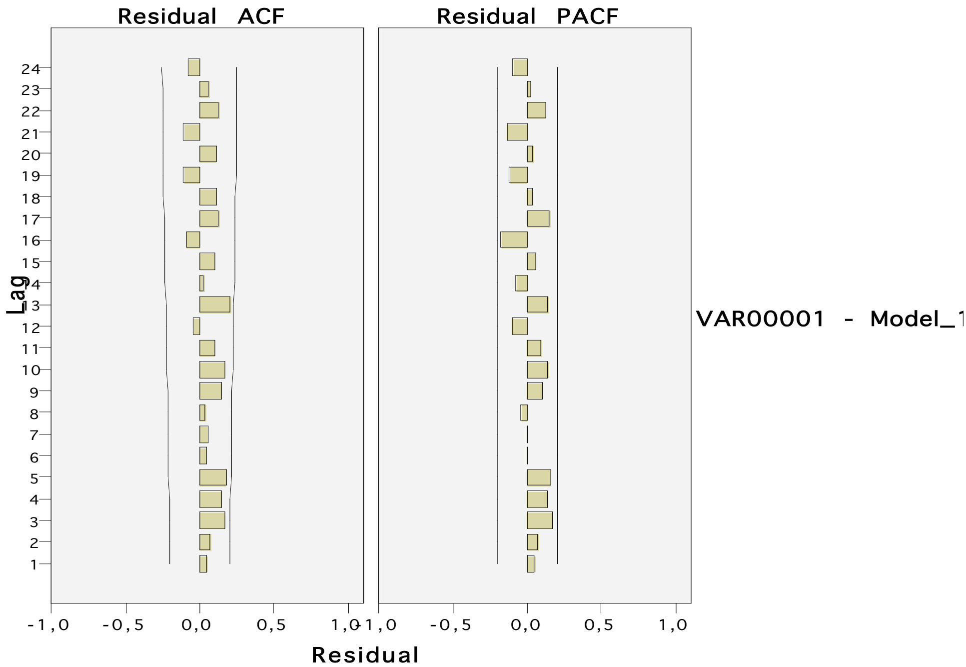
Lastly to diagnose whether the proposed model is appropriate for this data and the underlying assumption of uncorrelated residuals (error terms) is violated or not we have drawn the autocorrelation and partial autocorrelation function of the residuals. As clearly seen from Figure 2 there is no significant correlation between the residuals and our model is appropriate for the monthly consumption data.

Table 3 Forecasts of SARIMA Model.

2008	Real	SARIMA	Lower Limit	Upper Limit	Error
January	3647	3,364	2,889	3,839	-283
February	3680	3,323	2,746	3,900	-357
March	3685	3,332	2,683	3,982	-353
April	3001	2,971	2,321	3,621	-30
May	3000	2,715	2,065	3,365	-285
June	2753	2,625	1,975	3,274	-128
July	2368	2,553	1,904	3,203	185
August	2882	2,586	1,936	3,236	-296
September	2880	2,701	2,051	3,351	-179
October	2947	2,916	2,266	3,565	-31
November	3121	3,357	2,707	4,006	236
December	3164	3,604	2,954	4,254	440
				MAD	233.64

Residual ACF and PACF plots are given in Figure 2.

Figure 2 Residual ACF and PACF plots of SARIMA(0,0,2)(1,1,0)

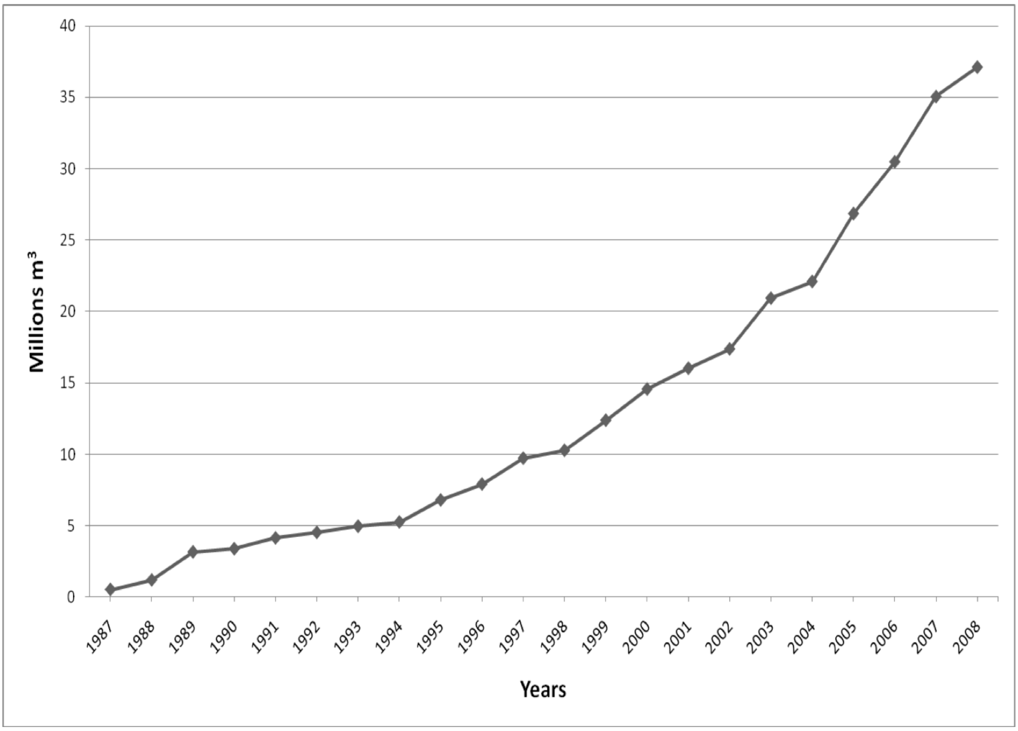


Annual Natural Gas Consumption

Turkey's need for energy sources is growing fastly therefore total natural gas consumption has risen rapidly in the last 20 years. Annual natural gas consumption values from 1987 to 2008 are provided by BOTAS (Turkey's petroleum and natural gas pipeline corporation).

The plot of annual natural gas consumption data shows an obvious increasing trend and no seasonality in Figure 3. Trend analysis would be meaningful to explore future expectations about annual natural gas consumption of Turkey.

Figure 3 Annual natural gas consumption of Turkey from 1987 to 2008 (BOTAS)



Forecasting the Annual Natural Gas Consumption of Turkey with Trend Analysis

Trend analysis can be done with different ways in time series models. Commonly used models are linear trend model and quadratic trend model. Linear trend model accounts for linearity in the trend. Quadratic trend model accounts for curvature in the trend. In this research double exponential smoothing is investigated for forecasting annual natural gas consumption of Turkey. More over double exponential smoothing's level and trend parameters were optimized in MINITAB software. The plots of all three methods are drawn in Figures 4, 5 and 6 and Error values of these models are listed in the Table 4.

Figure 4 Trend analysis plot of annual natural gas consumption of Turkey by applying regression model

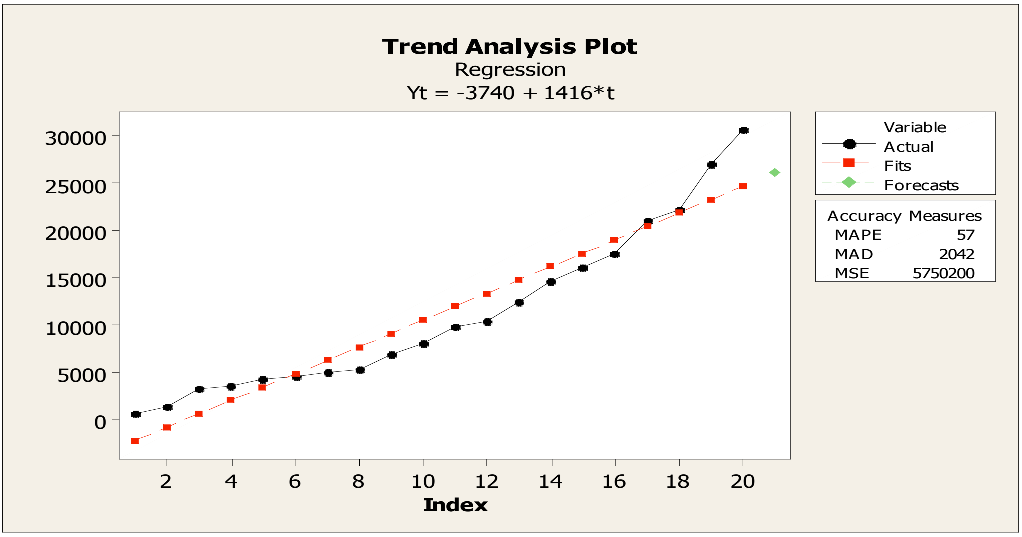


Figure 5 Trend Analysis plot of annual natural gas consumption of Turkey by applying quadratic trend model

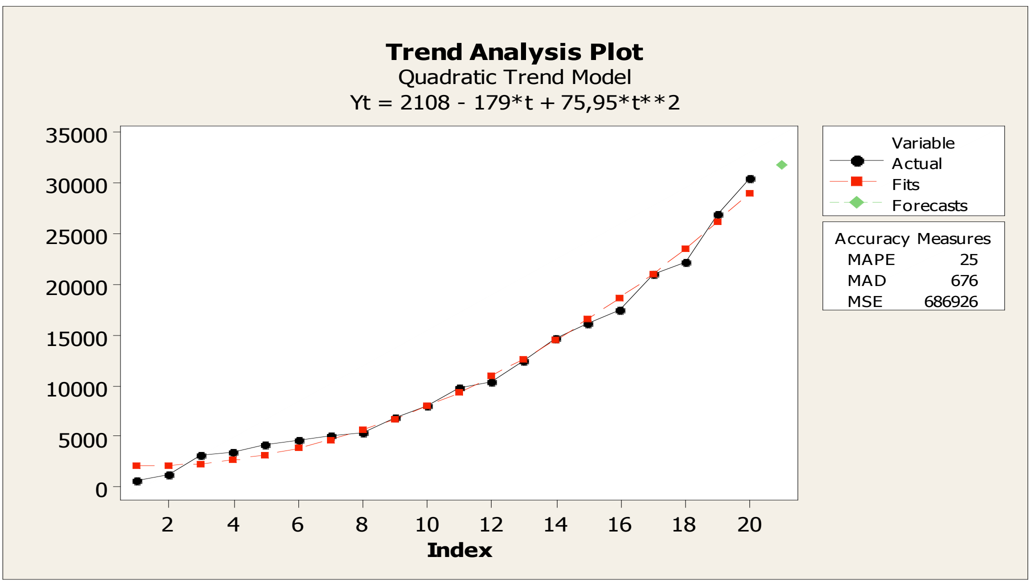


Figure 6 Plot of annual natural gas consumption in Turkey by applying double exponential smoothing model

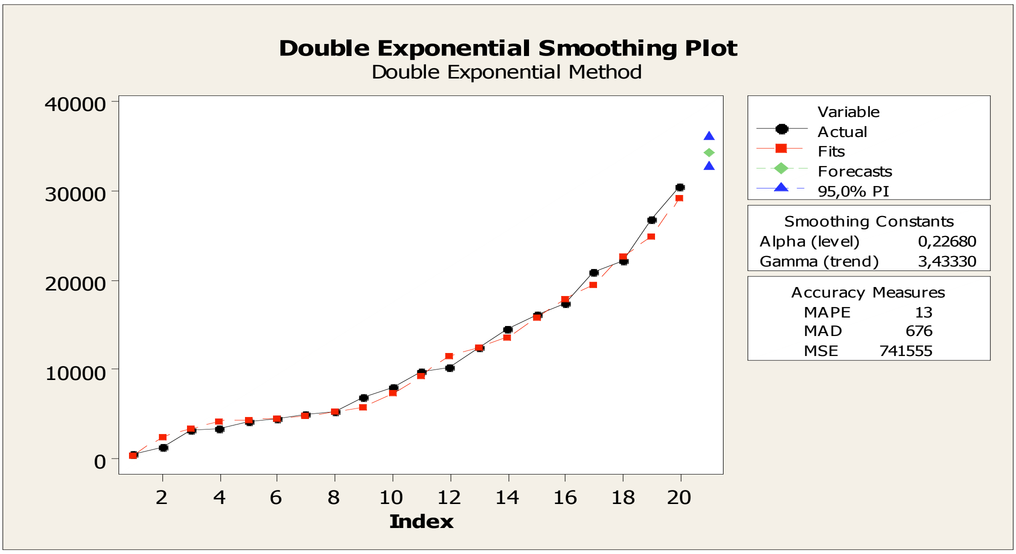


Table 4 Error values of different models

Methods	MAPE	MAD
Regression	57	2.042
Quadratic Trend	25	676
Double Exponential Smoothing with 0,23 and 3,43 weights	13	676

The mean absolute percentage error (MAPE) and the mean absolute deviation (MAD) values of quadratic trend and double exponential smoothing are lower than linear regression in Table 4 therefore, quadratic trend and double exponential smoothing are appropriate models for forecasting.

We use consumptions from 1987 to 2006 for forming the model and forecast 2007, 2008 consumptions for testing the model. The SmartForecasts software is used to forecast the annual consumptions of 2007 and 2008. SmartForecasts runs automatic search to select forecasting method with minimum error and proposed double exponential smoothing method with both 0,71 weights as the best method. Forecasts of double exponential smoothing and quadratic trend for 2007 and 2008 are shown below in Table 5. Note that LL is lower limit and UL is upper limit of forecasts.

Table 5 Forecasts for 2007 and 2008

Years	Real	Quadratic Trend	Error	DES (0,71; 0,71)	UL	LL	Error
2007	35,064	31,842	-3,222	34,031	36,440	31,623	-1,033
2008	37,128	34,928	-2,200	37,864	40,922	34,805	736
MAD		2,711		**MAD**			884

The forecast values demonstrated that double exponential smoothing method has minimum MAD value and acceptable lower and upper limits. We suggest double exponential smoothing model to make long term forecasts.

For further improvement, we made a parameter search on double exponential smoothing. For level and trend constants we have tried parameters values of 0,2; 0,4 and 0,6. The results in Table 6 have shown that parameter values of (0,6; 0,6) combination has a lower MAD value than others.

Table 6 Parameter search on double exponential smoothing

DES		MAD
Level	**Trend**	
0.2	0.2	7811
0.2	0.4	5826
0.2	0.6	3635
0.4	0.2	4482
0.4	0.4	2754
0.4	0.6	2001
0.6	0.2	3019
0.6	0.4	1671
0.6	*0.6*	*866*

In Table 7 the limits and MAD value of (0,6; 0,6) parametered model is compared with double exponential smoothing with (0,71; 0,71) parameters. Here also Double exponential smoothing with 0.6 and 0.6 parameters has better MAD value. So we can take that model as our forecasting model.

Table 7 Comparison of double exponential smoothing models

DES (0.6; 0.6)						DES (0.71; 0.71)			
Year	Real	Forecast	LLr	UL	Error	Forecast	LLr	UL	Error
2007	35,064	33,437	30,870	36,004	(1,627)	34,031	36,440	31,623	(1,033)
2008	37,128	37,023	33,961	40,086	(105)	37,864	40,922	34,805	736
				MAD	866			**MAD**	884

Forecasting the Annual Natural Gas Consumption with Autoregressive Integrated Moving Average (ARIMA) Model

As clearly seen in Figure 3, annual natural gas consumption of Turkey has an increasing trend. That makes the data non-stationary one. This kind of series must be transformed into stationary form in order to make time series analysis according to Box-Jenkins procedure.

Differencing is one of the transformation methods to make the data stationary. It is particularly useful for removing a trend. For non-seasonal data, first-order differencing is usually sufficient to attain apparent stationarity, so that the new series $\{y_1, \ldots, y_{N-1}\}$ is formed from the original series $\{x_1, \ldots, x_N\}$ by

$$y_t = x_{t+1} - x_t = \nabla x_{t+1}$$

First-order differencing is widely used. Occasionally second-order differencing is required using the operator ∇^2, where (Chatfield, 1996)

$$\nabla^2 x_{t+2} = \nabla x_{t+2} - \nabla x_{t+1} = x_{t+2} - 2x_{t+1} + x_t$$

Firstly, we take the first difference of the data and then we plot the new data in Figure 7. Time series plot of first difference of the data has a trend. Autocorrelation function (ACF) is reducing slowly in Figure 8. The autocorrelation function shows high correlation coefficients with lags. The slow decline of the ACF and time plot of first difference of data suggests that second differencing is required.

Figure 7 Time series plot after first difference of annual natural gas consumption of Turkey

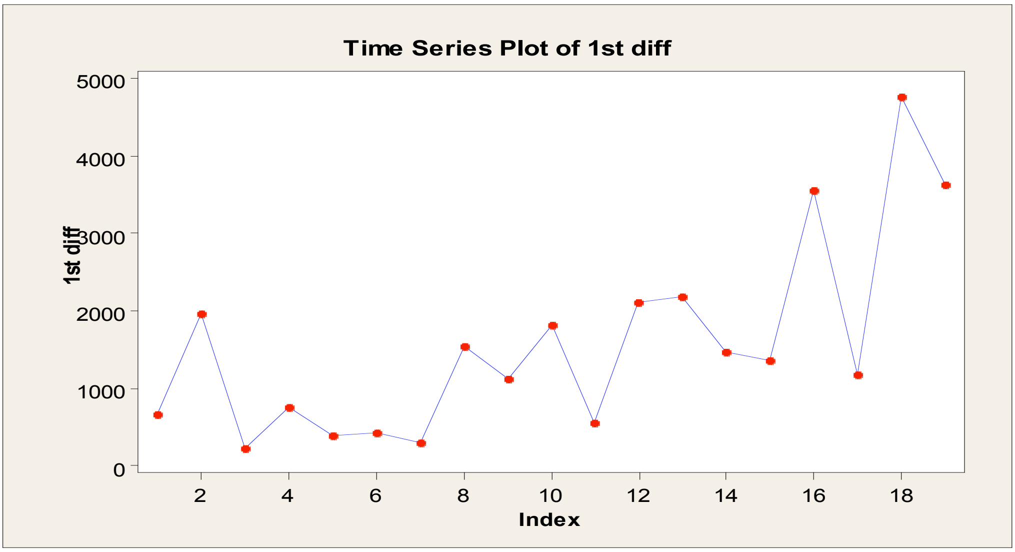
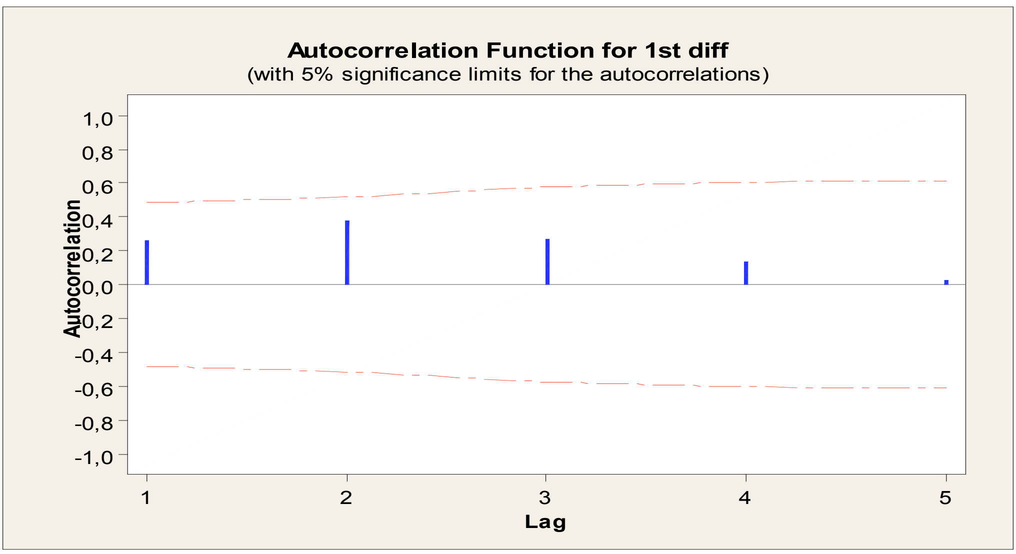


Figure 8 Autocorrelation function plot of first difference of annual natural gas consumption of Turkey



Second difference of the data is plotted in Figure 9. The trend is removed and the stationarity is obtained. Its autocorrelation and partial autocorrelation function plots are also shown in Figure 10 and Figure 11 respectively.

Figure 9 Time series plot after second difference of annual natural gas consumption of Turkey

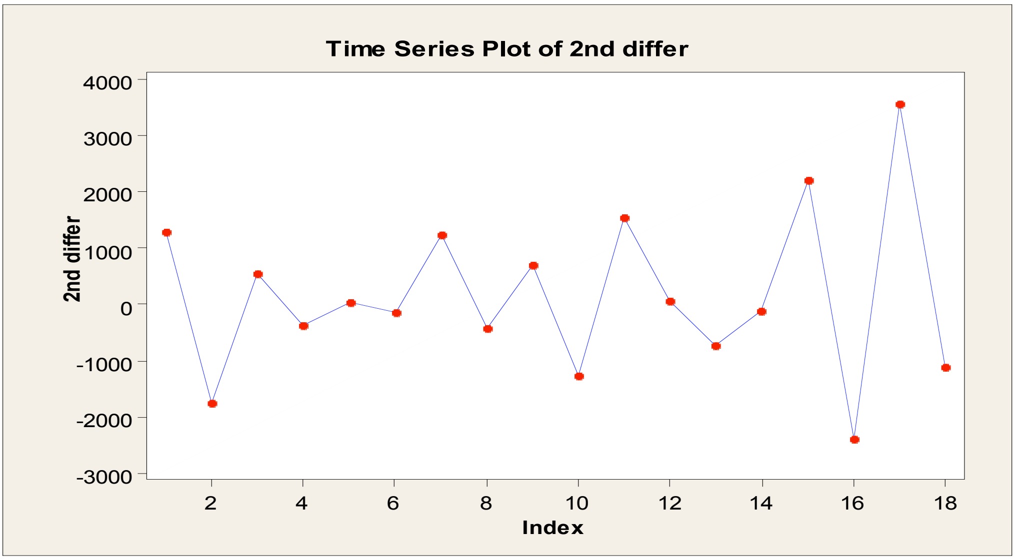


Figure 10 Autocorrelation function plot of second difference of annual natural gas consumption of Turkey

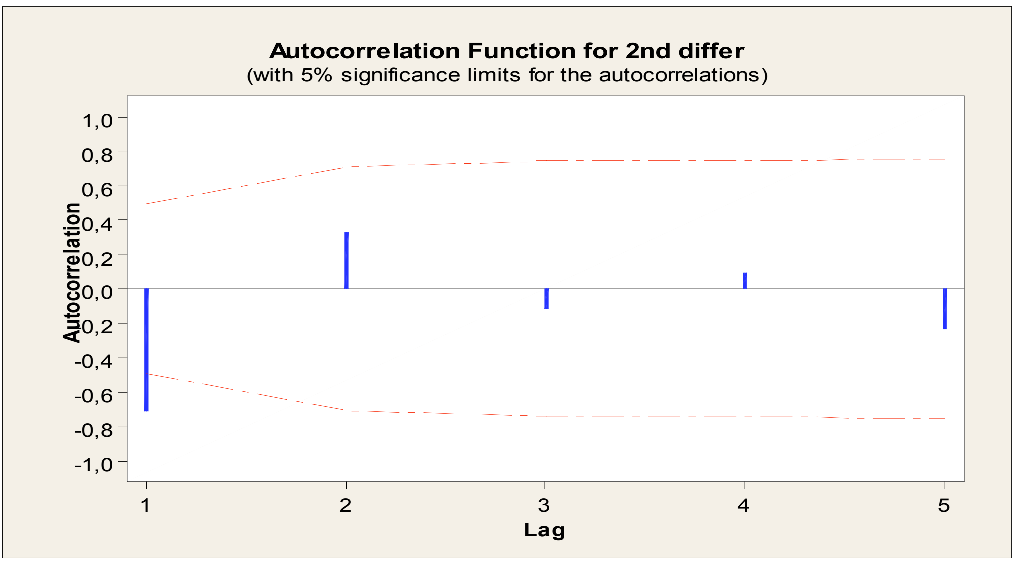
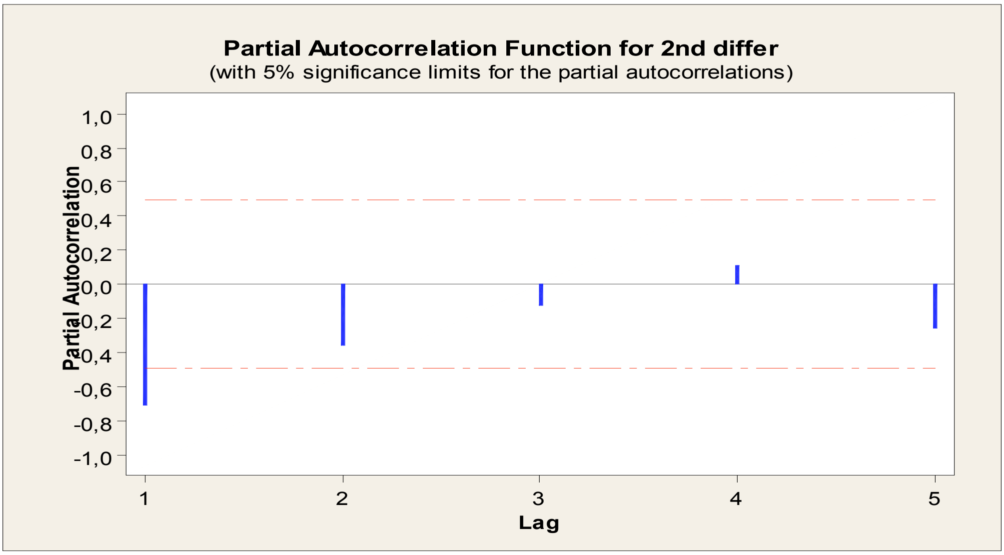


Figure 11 Partial autocorrelation function plot of second difference of annual natural gas consumption of Turkey



Order of autoregressive process of the ARIMA model is determined by the number of partial autocorrelation function coefficients. Similarly, order of moving average of the ARIMA model is decided by the number of autocorrelation function coefficients. The peak points of these functions show the order of models (Goktas, 2005). This approach is employed to find out the orders of annual natural gas consumption of ARIMA model. Autocorrelation function plot of the second difference in Figure 10 has the peak point at the first lag. Moving average order should be first order. Partial correlation function plot of second difference in Figure 11 has the peak at the first lag. So autoregressive process order should be first order for the model. As a result of that analysis, ARIMA (1,2,1) is decided to make annual natural gas consumption forecasts of Turkey.

In order to check our findings we also run SPSS software. SPSS made an automatic search on the orders of ARIMA and suggested the ARIMA(1,2,0) model for annual gas consumption data of Turkey. Coefficients of both ARIMA models are listed in Table 8. We have compared forecasting performance of both models in Table 9. ARIMA(1,2,1) model is performing better than ARIMA(1,2,0) model in forecasting 2007 and 2008.

Table 8 Coefficients of ARIMA models

Model	Coefficients	
	AR(1)	MA(1)
ARIMA (1,2,0)	-0,708	
ARIMA (1,2,1)	-0,642	0,194

Table 9 Results of ARIMA models

Years	Real	ARIMA (1,2,0)	UL	LL	Error	ARIMA (1,2,1)	UL	LL	Error
2007	35,064	34,920	37,080	32,760	-144	34,872	37,103	32,642	-192
2008	37,128	38,782	42,311	35,253	1,654	38,725	42,331	35,119	1,597
				MAD	899			**MAD**	894

The ARIMA(1,2,1) model compared with double exponential smoothing in terms of forecast and limit values in Table 10. Double exponential smoothing with 0,60 and 0,60 parameters error value is lower than ARIMA(1,2,1). As a result, double exponential smoothing produces better long term forecasts than ARIMA for annual natural gas consumption of Turkey.

Table 10 Comparison between ARIMA model and double exponential smoothing

Years	Real	DES (0.6; 0.6)	UL	LL	Error	ARIMA (1,2,1)	UL	LL	Error
2007	35,064	33,437	36,004	30,870	-1,627	34,872	37,103	32,642	-192
2008	37,128	37,023	40,086	33,961	-105	38,725	42,331	35,119	1,597
				MAD	866			**MAD**	894

Forecasting the Last Four Years of Annual Natural Gas Consumption of Turkey and Comparing with Ediger and Akar's Arima Study.

Ediger and Akar (2007) made a study about forecasting of primary energy demand by fuel in Turkey. They have used autoregressive integrated moving average (ARIMA) method to predict future primary energy demand of Turkey from 2005 to 2020.

One of the findings of Ediger and Akar is that natural gas will continue to be a key element of the Turkish energy system in the future. In order to understand the future changes, they forecasted the consumption values of natural gas period between 2005 and 2020.

This section of our study provides the comparison of forecast values between our study and the Ediger and Akar's study. Annual natural gas consumption data of Turkey from 1987 to 2004 is used. As our previous findings recommend double exponential smoothing we have used the same data and make forecasting with double exponential smoothing. Table 11 represents the comparison table of forecasts related to applied methods. Our double exponential smoothing forecasts were performed better than Ediger and Akar's ARIMA model for forecasting 2005 to 2008.

Table 11 Comparison table of methods

Methods	2005	2006	2007	2008	MAD
Ediger and Akar's Study Forecast	22,319	24,155	26,569	28,378	7,032
Double Exponential Smoothing Forecast	24,623	26,919	29,216	31,512	4,320
Real Values	26,865	30,493	35,064	37,128	

Double exponential smoothing with 0,41 and 1,37 parameters should be considered for forecasting years of 2005, 2006, 2007 and 2008.

Conclusion

Recently, considerable attention has been focused on the energy resources and energy policies in Turkey. Energy is one of Turkey's most important development priorities. Natural gas consumption is the fastest growing primary energy source in Turkey. Turkish natural gas is projected to increase dramatically in coming years. Energy planning is not possible without a reasonable knowledge of past and present natural gas consumption and likely future natural gas demand. Overestimating the natural gas demand may cause redundancy in resources, while underestimating may cause series energy crises. Therefore forecasting the gas demand became very important aspect to manage the energy policy with respect to gas consumption and use in Turkey.

Time series forecasting is one of the most important quantitative model that has received considerable amount of attention in the literature. The accuracy of time series forecasting is fundamental to many decision processes and hence the research for improving the effectiveness of forecasting models has never stopped. With the efforts of Box and Jenkins, the ARIMA, exponential smoothing and SARIMA models have become one of the most popular and traditional methods in the forecasting research and practice.

In this study, natural gas consumptions of Turkey are forecasted by using various time series methods such as exponential smoothing, Winters' forecasting and Box-Jenkins methods in a monthly and yearly base. These methods are compared with each other in terms of the superiority in forecasting performance. The findings reveal that in the yearly data set, double exponential smoothing model gives the better results than the other alternative forecasting models. On the other hand, in term of monthly data set, SARIMA model provides the better results than the others. However, this study does not claim that double exponential smoothing and SARIMA models are superior to other alternative forecasting methods.

In future study, more sophisticated analytical techniques such as genetic algorithms, neural networks, and fuzzy models must be utilized to forecast the natural gas consumption in Turkey. In addition that it will be very valuable to add some other variables such as price and weather temperature when developing and improving the forecasting model. This study can be extended by measuring the relationship between gas consumption of Turkey and gas price and weather temperature and their influence on gas consumption.

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