ARIMA Forecasting of Primary Energy Production and Consumption in Turkey: 1923–2006

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Abstract

The optimal use of national energy resources requires long term, accurate and reliable energy forecasting. The primary concern of this study is to develop appropriate ARIMA models for forecasting of primary energy production and consumption levels in Turkey and compare the obtained results with recent previous studies.

The results of this study show that the forecast values almost coincides with the MAED scenario 2 results and with Erdoğdu for the short term forecast results. The other most outstanding outcome from the comparison is the fact that there is especially a substantial difference between this study and the official projection (MAED) scenario 1 and Erdoğdu (2007) projections in the long-term period.

Keywords: Energy, ARIMA forecasting, Turkey

Türkiye'de Birincil Enerji Üretim ve Tüketiminin ARIMA Öngörüsü: 1923–2006

Özet

Ulusal enerji kaynaklarının etkin kullanımı, uzun dönemli, uygun ve güvenilir enerji öngörülerini gerektirmektedir. Bu çalışmada, Türkiye'de birincil enerji üretim ve tüketim düzeyleri en uygun ARIMA modelleriyle tahmin edilmekte ve elde edilen sonuçlar en son yapılan çalışmalarla karşılaştırılmaktadır.

Araştırmada elde edilen öngörü değerleri ile MAED'in Senaryo–2 ve Erdoğdu (2007) kısa dönemli öngörü sonuçlarının birbiriyle oldukça örtüştüğü görülmüştür. Diğer taraftan bu çalışmanın öngörü değerleri ile MAED'in Senaryo–1 ve Erdoğdu (2007) uzun dönemli öngörüleri arasında önemli farklılıklar olduğu saptanmıştır.

Anahtar Kelimeler: Enerji, ARIMA öngörüsü, Türkiye

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1. Introduction

Energy consumption in developing countries has been rising sharply as a result of high population growth rate, for better living standards and industrialization. For this reason, the importance of forecasting primary energy production and consumption sources cannot be overlooked or underestimated. An appropriate forecasting technique is essential for accurate and reliable investment planning of energy production/generation and distribution/consumption. Accurate forecasts provide the foundation for daily operations, market planning and risk management. Today's marketplace and the deregulation of energy markets bring new challenges to energy providers.

Similar to most countries, energy forecasting is mostly done on for consumption side of the energy in Turkey. Forecasting energy consumption of Turkey is searched in studies such as Ediger and Tatlıdil (2002), Yumurtacı and Asmaz (2004), Ceylan and Öztürk (2004), Ceylan et al. (2005a, b), Sözen et al. (2005), Hamzaçebi (2007), Erdoğdu (2007) and Ediger and Akar (2007).

Ediger and Tatlıdil (2002) proposed a new technique of analyzing the cyclic patterns in the time series data of annual additional amounts of energy consumption and compared the results with those of the Winters' exponential smoothing method. The paper also includes a comparison of all previous energy demand forecasts done in Turkey. Ediger et al. (2006b) developed a decision support system for forecasting fossil fuel production by using regression, ARIMA and SARIMA methods to the historical data from 1950 to 2003 in a comparative approach. Ediger and Akar (2007) established an ARIMA forecasting of the total primary energy demand appearing to be more reliable than the summation of the individual forecasts.

As seen in the Table 1, various forecasting techniques have been used in energy demand forecasting of Turkey, such as Winters smoothing, cycle analysis, linear and multivariate regression, autoregression, genetic algorithm, artificial neural network, comparative descriptive analysis, ARIMA and SARIMA. Sarak and Satman (2003) modeled the natural gas demand for residential heating in Turkey based on degree-day concept, which was first applied by Durmayaz et al. (2000) and Gümrah et al. (2001) in Turkey. Later in 2004, linear multivariate regression (Yumurtacı and Asmaz, 2004; Görücü and Gümrah 2004), first-order autoregressive time series modeling (Aras and Aras, 2004), genetic algorithm energy demand model (Ceylan and Öztürk, 2004; Öztürk et al., 2004; Haldenbilen and

Ceylan 2005; Ceylan et al., 2005a, b), artificial neural network (Görücü et al., 2004; Sözen et al., 2005; Hamzaçebi, 2007), ARIMA and SARIMA (Ediger et al., 2006; Erdoğdu, 2007; Ediger and Akar, 2007) forecasting techniques were used respectively. A summary of the studies used for forecasting energy production and consumption of Turkey is given in the Table 1.

The studies on energy demand forecasting in Turkey dates back to 1960s. The tradition of energy forecasting by using simple regression techniques was initiated by the State Planning Organization (SPO). Similar studies later have been continued by the Ministry of Energy and Natural Resources of Turkey (MENR) and a number of academicians. These early forecasts consistently predicted much higher values than the consumptions that actually realized. Later, starting from 1984, several econometric modeling techniques have been employed. Among them, the Model for Analysis of Energy Demand (MAED), which was used in energy planning and policy making by MENR, has been the most commonly applied one (Ediger and Akar, 2007).

As seen in the Table 1, most of these studies used various forms of econometric modeling. Traditionally determinants such as gross domestic product (GDP), GDP growth rate, energy prices, income and population have been widely used in a multivariate modeling approach. Ediger and Tatlıdil (2002) have demonstrated clearly that the estimated economic and demographic parameters usually deviate from their realizations. For instance, GDP growth rates that are used in MAED applications are traditionally estimated much higher than actually realized. For the periods between 1985 and 1990, 1990 and 1995, and 1995 and 2000 years, MAED used the GNP growth rates of 6–7%, 7–8% and 7–7.5% in 1986; 6.4%, 6.8%, and 6.2% in 1990; and 5.7%, 4.8%, and 6% in 1994, respectively. But the realizations for the same periods have been around 4%, 3%, and 4%, respectively (Ediger and Akar, 2007). In addition, the relationship between energy consumption and economic development in Turkey has not been clearly demonstrated yet (Ediger, 2004). Reexamining the causal relationship between GDP, energy consumption and employment, Soytaş and Sarı (2003) and Sarı and Soytaş (2004) recommended that the causality runs from energy consumption to GDP in Turkey. This indicates that in the long run decreasing energy consumption may harm economic growth in Turkey. However, others argued that there is no evidence of causality between energy consumption and GDP in Turkey (Altınay and Karagöz, 2004) and that consumption of different energy sources may have different effects on income in Turkey (Sarı and Soytaş, 2004).

Table 1: Studies on Forecasting Energy Demand in Turkey between 2002 and Present

Reference	Method Used	Data Used	Forecasting for	Forecast Years
Ediger and Tatlıdil (2002)	Winters' Exponential Smoothing Method And Cycle Analysis	1950-99	Primary Energy Demand	2000-2010
Sarak and Satman (2003)	Modeling Based on Degree-Day Concept	1990-97	Natural Gas Demand by Residential Heating in Turkey	2000, 2005, 2010, 2015, 2020, 2023
Yumurtacı and Asmaz (2004)	Linear Regression	1980-02	Electricity Demand of Turkey	2003–2050
Görücü and Gümrah (2004)	Multivariable Regression Model	1991-01	Gas Consumption for Ankara	2002 and 2005
Aras and Aras (2004)	Autoregressive Time Series Model	1996-01	Natural Gas Demand of Eskisehir	Model is established
Ceylan and Öztürk (2004)	Genetic Algorithm Energy Demand Model	1970-01	Energy Demand of Turkey	2002–2025
Öztürk et al. (2004)	Genetic Algorithm Exergy Consumption	1990-00	Petroleum Exergy Demand	2001–2020
Görücü et al. (2004)	Artificial Neural Network	1998-01	Gas Consumption for Ankara	2002 and 2005
Haldenbilen and Ceylan (2005)	Genetic Algorithm Transport Energy Demand Estimation	1970-00	Transport Energy Demand of Turkey	2001–2020
Ceylan et al. (2005a, b)	Genetic Algorithm Energy and Exergy Estimating Models.	1990-00	Energy and Exergy Consumption of Turkey	2001–2020
Sözen et al. (2005)	Artificial Neural-Network	1975-03	Net Energy Consumption of Turkey	Two models are established
Tunç et al. (2006)	Comparative Descriptive Analysis	2001-03	Turkey Versus World	None
Ediger, Akar and Uğurlu (2006)	ARIMA and Cooperative Regression	1950-03	Production of Fossil Fuel Sources	2004-2028
Hamzaçebi (2007)	Artificial Neural Network	1970-02	Net Electricity Energy Consumption	2003-2020
Erdoğdu (2007)	ARIMA Modeling	1923-04	Electricity Consumption	2005-2014
Sözen et al. (2007)	Artificial Neural-Network	1975-05	Greenhouse Gas Prediction of Turkey	2007-2020
Ediger and Akar (2007)	ARIMA And SARIMA	1950-04	Primary Energy Demand	2005-2010, 2015, 2020

Source: This table is originally obtained from Ediger and Akar (2007) and updated.

Time series analysis provides modeling approach which requires only data on the modeled variables, thus saving the researcher from the trouble of determining the influential variables and suggesting a form for the relation between them. Univariate Box-Jenkins analysis (Box and Jenkins, 1976) has been widely used for modeling and forecasting with numerous applications. In this study, we aimed at forecasting primary energy production and consumption in Turkey by using ARIMA technique for this purpose. As seen in Table 2, the total production (1950-2006) and sub production sources data such as hard coal (1950-2006), lignite (1950-2006), asphaltit (1966-2006), natural gas (1976-2006), petroleum (1950-2006), hydraulic (1950-2006), geothermal heat (1963-2006), solar (1986-2006), wood (1950-2006), animal and vegetable waste (1950-2006) are used for the different historical period between 1950 and 2006. Three other important energy sources such as wind energy, bio fuel and nuclear are not taken into consideration since their time series data are not sufficient to apply the ARIMA method.

Table 2: Variable Names, Measurement Units and Data Used for Estimation Period

Variable Name	Unit	Data Used	Variable Name	Unit	Data Used
Total Production	TTOE	1950-2006	Total Consumption	Million KWh	1923-2006
Hard Coal	TTOE	1950-2006	Residential Consumption	Million KWh	1945-2006
Lignite	TTOE	1950-2006	Governmental Offices Consumption	Million KWh	1945-2006
Asphaltit	TTOE	1966-2006	Street Illumination Consumption	Million KWh	1945-2006
Natural Gas	TTOE	1976-2006	Industrial and Other Consumption	Million KWh	1945-2006
Petroleum	TTOE	1950-2006			
Hydraulic	TTOE	1950-2006			
Geothermal Heat	TTOE	1963-2006			
Solar Energy	TTOE	1986-2006	Installed Capacity (IC)	Thousand KWh	1923-2006
Wood	TTOE	1950-2006	Installed Capacity Per Capita (ICPC)	W	1923-2006
Animal and Vegetable Waste (AVW)	TTOE	1950-2006	Consumption Per Capita (CPC)	KWh	1923-2006

TTOE: Thousand Tons of Oil Equivalents

The sub consumption data for residential, governmental, street illumination, industrial and other are used for the period between 1945 and 2006. Total consumption, installed capacity, installed capacity per capita and consumption per capita series are used for the period between 1923 and 2006 (Table 2). Data used in this study relating to primary energy production and consumption is provided by the Ministry and Natural Resources, data on electric power is provided by the Turkish Electricity Generation Transmission Corporation General Management (TSI, 2007).

The ARIMA forecasting techniques and methodology will be discussed in the following section. In Section 3, the results will be discussed and compared with the previous studies available. The final section includes the conclusions together with recommendations to the energy decision and policy makers.

2. Forecasting Technique and Methodology

ARIMA models are flexible and widely used in time series analysis. Box-Jenkins ARIMA analysis refers to a systematic method of identifying, fitting, checking, and using integrated autoregressive, moving average (ARIMA) time series models. The method is appropriate for time series of medium to long length. Most of what is presented here is summarized from the books on time series analysis written by Box and Jenkins (1976) and Hintze (2007).

The ARMA (autoregressive moving average) model is defined as follows:

$$X_t = \phi X_{t-1} + \phi X_{t-2} + \cdots + \phi X_{t-p} + \alpha_t + \theta_1 \alpha_{t-1} - \theta_2 \alpha_{t-2} - \cdots - \theta_q \alpha_{t-q} \quad (1)$$

where the ϕ 's are the autoregressive parameters to be estimated, the θ's are the moving average parameters to be estimated, the X's are the original series, and the α 's are a series of unknown random errors which are assumed to follow the normal probability distribution.

Box and Jenkins use the backshift operator to make writing these models easier. The backshift operator, B, has the effect of changing time period t to time period t-1. Thus $BX_t = X_{t-1}$ and $B^2 X_t = X_{t-2}$. Using this backshift notation, the above model may be rewritten as:

$$\left(1 - \phi_1 B - \cdots - \phi_p B^p\right) X_t = \left(1 - \theta_1 B - \cdots - \theta_q B^q\right) \alpha_t \quad (2)$$

This may be abbreviated even further by writing:

$$\phi_p(B)X_t = \theta_q(B)\alpha_t \tag{3}$$

Where $\phi_p(B) = \left(1 - \phi_1 B - \cdots - \phi_p B^p\right)$ and $\theta_q(B) = \left(1 - \theta_1 B - \cdots - \theta_q B^q\right)$

These formulas show that the operators $\phi_p(B)$ and $\theta_q(B)$ are polynomials in *B* of orders *p* and *q* respectively. One of the benefits of writing models in this fashion is that we can see why several models may be equivalent.

The Box-Jenkins method refers to the iterative application of the three steps: (1) Identification: using plots of the data, autocorrelations, partial autocorrelations, and other information, a class of simple ARIMA models is selected. This amount to estimating appropriate values for *p, d* and *q*. (2) Estimation: the phis and thetas of the selected model are estimated using maximum likelihood techniques, backcasting, etc., as outlined in Box-Jenkins (1976). (3) Diagnostic Checking: the fitted model is checked for inadequacies by considering the autocorrelations of the residual series. These steps are applied iteratively until step three does not produce any improvement in the model.

Assuming for the moment that there is no seasonal variation, the objective of the model identification step is to select values of *d* and then *p* and *q* in the *ARIMA (p-d-q)* model. When the series exhibits a trend, we may either fit and remove a deterministic trend or difference the series. Box and Jenkins seem to prefer differencing, while several other authors prefer the deterministic trend removal. If large autocorrelations persist even after several lags, this indicates that either a trend should be removed or that the series should be differenced. The next step would be to difference the series. If the differenced series still does not appear stationary, it would have been differenced again.

The identification phase determines the values of *d* (differencing), *p* (autoregressive order), and *q* (moving average order). By studying the two autocorrelation plots, estimate these values. The level of differencing is estimated by considering the autocorrelation plots. When the autocorrelations die out quickly, the appropriate value of *d* has been found. The value of *p* is determined from the partial autocorrelations of the appropriately differenced series. If the partial autocorrelations cut off after a few lags, the last lag with a large value would be the estimated value of *p*. If the partial autocorrelations do not cut off, you either have a moving average model *(p=0)* or an *ARIMA* model with positive *p* and *q*. The value of *q* is found from the autocorrelations of the appropriately differenced series. If the autocorrelations cut off after a few lags, the last lag with a large value would be the estimated value of *q*. If the autocorrelations do not cut off, you either have an autoregressive model *(q=0)* or an *ARIMA* model with a positive *p* and *q*. When neither the autocorrelations nor the partial autocorrelations cut off, a mixed model is suggested. In an *ARIMA (p-d-q)* model, the autocorrelation function will be a mixture of exponential decay and damped sine waves after the first *q-p* lags.

Once *p, d*, and *q* are estimated, they can be used in estimation of the phis and thetas. Once a model has been fit, the final step is the diagnostic checking of the model.[1] The checking is carried out by studying the autocorrelation plots of the residuals to see if further structure (large correlation values) can be found. If all the autocorrelations and partial autocorrelations are small, the model is considered adequate and forecasts are made. If some of the autocorrelations are large, the values of *p* and/or *q* are adjusted and the model is re-estimated. This process of checking the residuals and adjusting the values of *p* and *q* continues until the resulting residuals contain no additional structure.

The ARIMA forecasting gives results in three different options which are UCL, LCL and forecasted values. UCL and LCL provide a confidence interval of 95%, in other words any realization within the confidence limits will be acceptable. In this study it is used the forecasted values in the graphs for simplicity and forecasted series confidence intervals are given in the Table 6.

The accuracy and fit statistics of the built models are checked with the model stationary *R*-square (SR^2), R^2, root mean square error (RMSE), mean absolute percentage error (MAPE), mean absolute error (MAE), maximum absolute percentage error (MaxAPE), maximum error (ME), normalized biased information criteria (NBIC) and Ljung-Box *Q*. For all measures except R^2, smaller values of model fit statistics generally indicate a better fitting model. The built model can be considered as adequate, if the significant level of Ljung-Box *Q* statistics is greater than %5.

3. Results and Discussions

The descriptive statistics for estimation period of primary energy production and consumption series are given in the Table 3. This table shows that the available number of years for series changes from 21 to 84. The average annual increases for given periods differ from 1% to 25%.

[1] SPSS 15 is used to establish the ARIMA models.

Namely, from 1950 to 2006 (57 years) the annual total energy production is increased about 3% per year, with energy consumption growing at an average annual rate of about 10% for the period 1923-2006.

Total primary energy production was increased from 6427 to 26677 TTOE between 1950 and 2006. In this period the production of lignite was increased from 279 to 11600 TTOE and covering from 4% to 45% (with a 23.6% mean) of total production. The rest of production was obtained in average primarily from wood 24.8% (4427/17837), petroleum 13.1% (2327/17837) and coal 11.9% (2129/17837). Geothermal heat is used in producing energy in 1963; asphaltit energy from 1966, natural gas energy from 1976 and solar energy from 1986 were added to the national energy production sources from 1950 to 2006. Due to the differences between energy production to consumption, the ratio of compensating the energy demand consistently reduced from 9.47 (1950) to 0.19 (2007). Then the governments decided to put more investment on different energy production sources but the contribution of private sector was very low. Still energy production could not compensate the energy demand.

Total primary energy consumption was increased from 41 to 143071 million KWh between 1950 and 2006 with a 10% average increase. In this period industrial and residential consumption was increased from 366 to 78353 and from 53 to 54722 respectively. In average, the proportions of energy consumptions are realized as industrial 70.6%, residential 22.6%, government 3.6% and street illumination 2.9% from 1950 to 2006.[2]

As seen in the Table 3, the coefficient of variation for wood (CV=576), animal and vegetable waste (CV=385), hard coal (CV=349), and total energy production (CV=250) series show the maximum dispersion in estimation period. On the other hand the most homogeneous series are total consumption (CV=65) and residential consumption (CV=70) series respectively.

Table 4 shows goodness of fit and models adequacy statistics of the built ARIMA models. Fit statistics such as stationary *R*-square, *R*-squared, root mean square errors (RMSE), mean absolute percentage error (MAPE), mean absolute error (MAE), maximum absolute percentage error (MaxAPE), maximum absolute error (MaxAE) and normalized biased information criterion (NBIC) are calculated across all of the models.

[2] In this period the maximum-minimum values are 55%-95%, 12%-38%, 2%-5% and 1%-5% respectively.

Table 3: Descriptive Statistics of Primary Energy Production and Consumption

Series	Year	AI	Minimum	Maximum	Mean	SD	CV	Skewness	Kurtosis
Production	**57**	**0.03**	**6427**	**29324**	**17837**	**7173**	**249.68**	**-0.055**	**-1.414**
Coal	57	0.02	1030	3069	2129	610	349.28	-0.413	-0.930
Lignite	57	0.07	279	12792	5192	4331	119.89	0.357	-1.593
Asphaltit	41	0.14	2	382	125	116	108.18	0.612	-0.777
Natural Gas	31	0.17	7	825	254	247	102.91	1.031	0.021
Petroleum	57	0.10	19	4674	2327	1348	172.59	-0.487	-0.934
Hydraulic	57	0.14	3	4048	1277	1334	95.72	0.773	-0.907
Geothermal Heat	44	0.15	10	1081	293	293	100.11	0.918	-0.078
Solar	21	0.25	5	403	176	138	127.38	0.272	-1.359
Wood	57	0.01	2952	5512	4427	769	575.79	-0.057	-1.233
AVW	57	0.02	1146	2951	1986	516	385.30	0.263	-0.988
Consumption	**84**	**0.10**	**41**	**143071**	**23483**	**35945**	**65.33**	**1.726**	**2.042**
Residential	62	0.12	53	54722	9532	13658	69.79	1.725	2.191
Government	62	0.11	13	6045	1265	1662	76.09	1.365	0.506
Street	62	0.11	11	5104	1089	1600	68.10	1.444	0.564
Industrial	62	0.09	366	78353	19855	22046	90.06	1.073	0.009
Installed Capacity	**84**	**0.09**	**33**	**40501**	**7215**	**10713**	**67.35**	**1.645**	**1.701**
ICPC	84	0.07	3	555	127	155	81.80	1.308	0.493
CPC	84	0.08	3	1961	405	523	77.38	1.369	0.778

AI: Annual Increase; SD: Standard Deviation; CV: Coefficient of Variation

Absolute percentage error is a measure of how much a dependent series varies from its model-predicted level. By examining the mean and maximum across all models, you can get an indication of the uncertainty in your predictions. And looking at summary statistics of percentage errors, rather than absolute errors, is advisable since the dependent series represent series with different measurement unit of varying sizes.

Table 4: Model Fit and Model Accuracy Statistics

Model	Model Fit Statistics								Ljung-Box Q		
	SR^2	R^2	RMSE	MAPE	MAE	MaxAPE	MaxAE	NBIC	Statistics	*df*	*Sig.*
1-Production	0.987	0.997	426.67	1.90	313.99	6.29	932.12	12.54	14.77	17	0.612
2-Coal	0.826	0.960	126.55	4.83	96.54	15.21	278.81	9.97	8.76	16	0.923
3-Lignite	0.972	0.999	126.57	3.33	79.19	16.77	311.04	10.83	17.52	16	0.353
4-Asphaltit	0.906	0.716	65.91	36.45	36.12	158.48	229.66	8.92	13.01	17	0.736
5-Natural Gas	0.833	0.958	56.95	42.31	37.02	595.79	126.17	8.89	10.63	16	0.832
6-Petroleum	0.892	0.995	104.89	6.56	68.37	52.35	344.62	10.03	17.25	16	0.369
7-Hydraulic	0.965	0.997	83.53	12.90	53.20	60.54	208.19	9.79	22.70	16	0.122
8-GT Heat	0.864	0.998	13.07	8.95	9.10	54.55	26.01	5.75	19.43	15	0.195
9-Solar	0.595	0.998	6.79	7.78	5.40	50.00	13.51	4.13	18.46	17	0.360
10-Wood	0.978	0.999	19.09	0.23	9.39	3.15	96.00	6.76	6.26	16	0.985
11-AVW	0.949	0.998	27.67	0.91	18.68	3.62	62.84	7.29	15.48	15	0.418
12-Consumption	0.996	0.999	131.08	3.13	64.32	30.52	364.88	11.26	17.34	13	0.244
13-Residential	0.974	0.999	137.85	3.22	83.76	17.58	307.45	11.01	25.02	16	0.690
14-Government	0.999	0.999	11.58	3.40	6.71	20.31	21.74	6.58	8.21	14	0.878
15-Street	0.999	0.999	4.94	2.39	2.80	14.61	13.00	4.67	15.48	16	0.489
16-Industrial	0.992	0.999	97.23	2.59	108.46	24.56	426.24	12.07	17.29	16	0.367
17-I. Capacity	0.994	0.999	76.53	4.72	43.10	30.54	202.91	10.06	18.95	14	0.167
18-ICPC	0.974	0.999	2.02	4.35	1.24	25.83	5.19	2.54	15.89	14	0.320
19-CPC	0.997	0.999	1.43	2.61	0.86	40.00	3.88	2.38	4.16	17	0.656

SR^2: Stationary R^2; RMSE: Root Mean Square Error; MAPE: Mean Absolute Percentage Error; MAE: Mean Absolute Error; MaxAPE: Maximum Absolute Percentage Error; MaxAE: Maximum Absolute Error; NBIC: Normalized Biased Information Criteria.

Larger values of *R*-squared indicate a better fit. The *R*-square values of built models range between 95.5% and 99.9% (except series 4) mean that the models do an excellent job of explaining the observed variation in the series.

The Ljung-Box *Q* statistic, also known as the modified Box-Pierce *Q* statistic, provides an indication of whether the models are correctly specified. A significance value less than 0.05 implies that there is a structure in the observed series which is not accounted for by the model. The values of Box-Pierce *Q* statistics for built models range from 12.2% to 98.5% shown here are not significant, so we can be confident that the models are correctly specified.

The ARIMA model parameters in the Table 5 display values for all of the parameters in the models. For 19 built models the *p* parameters take the values of 1, 2 or 3, while *d* and *q* parameters equal to 0, 1 or 2. All estimated parameters are significant at 5% level and all produced models are adequate based on Box-Pierce *Q* statistics.

Table 6 contains the forecasted values of the dependent series. The Table 6 also includes the 95% upper confidence limit (UCL) and lower confidence limit (LCL) for the forecasting. The forecasted values for each series from 2007 to 2015 are given in the Table 6. As seen in the Table 6, in average, all but total production (-0%), petroleum (-1%), wood (-6%), animal–vegetable waste (-4%), street illumination (-1%) will still be increasing in the period from 2007 to 2015. On the other hand Table 3 shows that the annual increase rates are 10% for total consumption, 9% for installed capacity, 7% for installed capacity per capita, 8% for consumption per capita, 12% for residential consumption, 11% for government, 11% for street illumination, 3% for total energy production, 2% for hard coal, 7% for lignite, 1% for wood, 2% for animal and vegetable waste, 17% for natural gas, 25% for solar energy with corresponding period. Briefly, energy consumption rates are always higher than production. This could be a signal for energy crisis in the near future.

Table 6 shows that the average annual increase rate of total primary energy production will be greater than -4% and less than 3% in forecasting period with a 95% confidence interval. On the other hand, the average annual rate of total primary energy consumption will increase between 5% and 7%. Both for estimation and forecasting periods, the estimation and forecast values are between LCL and UCL for all series. These results also show that the built models are accurate.

Table 5: ARIMA Model Parameters

		ARIMA Model Coefficient Estimates									
Model	ARIMA (*p-d-g*)	*AR1*	*Sig.*	*AR2*	*Sig.*	*AR3*	*Sig.*	*MA1*	*Sig.*	*MA2*	*Sig.*
1-Production	ARIMA (1-1-0)	0.768	.000								
2-Coal	ARIMA (1-1-1)	0.907	.000					0.998	.000		
3-Lignite	ARIMA (1-1-1)	0.532	.000					0.673	.000		
4-Asphaltit	ARIMA (1-0-0)	0.976	.000								
5-Natural Gas	ARIMA (1-1-1)	0.480	.016					1.000	.000		
6-Petroleum	ARIMA (2-1-0)	0.899	.000	0.217	.007						
7-Hydraulic	ARIMA (1-1-1)	0.918	.000					0,180	.002		
8-GT Heat	ARIMA (2-1-1)	1.868	.000	0.889	.001			0.961	.013		
9-Solar	ARIMA (1-1-0)	0.941	.000								
10-Wood	ARIMA (2-1-0)	0.661	.000	0.330	.011						
11-AVW	ARIMA (2-1-1)	1.551	.000	0.556	.002			0.829	.000		
12-Consumption	ARIMA (3-2-2)	1.251	.000	1.090	.000	2.070	.000	0.153	.000	0.937	.000
13-Residential	ARIMA (2-2-0)	0.330	.046	0.446	.014						
14-Government	ARIMA (3-1-1)	0.697	.000	0.539	.000	0.837	.000	0.819	.000		
15-Street	ARIMA (1-1-1)	0.768	.000					0.193	.000		
16-Industrial	ARIMA (1-2-1)	0.228	.009					0.607	.000		
17-I. Capacity	ARIMA (2-1-2)	0.432	.000	0.545	.000			0.216	.018	0.716	.000
18-ICPC	ARIMA (2-2-2)	0.781	.000	0.907	.000			1.069	.000	0.891	.000
19-CPC	ARIMA (1-2-0)	0.335	.000								

Table 6: Model Forecasts for Energy Production and Consumption (2007-2015)

		Forecast Year									
Model		2007	2008	2009	2010	2011	2012	2013	2014	2015	AI
1-Production	Forecast	25012	25238	25412	25546	25648	25726	25419	25182	25001	0.00
	LCL	24156	23500	22749	21959	21157	20365	19223	18191	17251	0.04
	UCL	25867	26976	28074	29133	30138	31088	31615	32174	32751	0.03
2-Coal	Forecast	1236	1251	1243	1255	1248	1259	1254	1263	1260	0.00
	LCL	1091	1039	991	963	928	908	881	864	842	0.03
	UCL	1396	1494	1539	1609	1645	1704	1736	1788	1818	0.03
3-Lignite	Forecast	11414	12048	12505	12738	12981	13231	13450	13687	13939	0.03
	LCL	11158	11429	11550	11482	11459	11469	11473	11512	11582	0.01
	UCL	11669	12667	13461	13993	14504	14992	15428	15862	16296	0.04
4-Asphaltit	Forecast	256	287	319	354	392	312	344	379	414	0.06
	LCL	95	68	53	43	37	23	20	18	17	0.19
	UCL	570	831	1103	1393	1703	1475	1742	2026	2327	0.19
5-Natural Gas	Forecast	783	820	815	826	827	831	833	834	835	0.01
	LCL	667	611	559	525	489	459	430	402	376	0.07
	UCL	899	1029	1069	1127	1165	1203	1236	1266	1294	0.04
6-Petroleum	Forecast	2183	2116	2078	2058	2048	2043	2042	2041	2041	0.01
	LCL	1972	1663	1383	1142	934	753	592	446	313	0.21
	UCL	2394	2569	2772	2974	3162	3334	3492	3636	3768	0.06
7-Hydraulic	Forecast	4173	4231	4474	4516	4731	4779	5074	5042	5308	0.03
	LCL	4005	4037	4222	4244	4417	4448	4709	4662	4899	0.02
	UCL	4341	4424	4727	4787	5045	5110	5438	5422	5716	0.04
8-G.Heat	Forecast	1192	1302	1409	1513	1613	1709	1802	1889	1983	0.06
	LCL	1166	1245	1317	1384	1447	1505	1560	1612	1673	0.05
	UCL	1218	1359	1500	1641	1779	1914	2043	2166	2294	0.08
9-Solar	Forecast	420	436	451	465	478	490	502	513	523	0.03
	LCL	406	405	401	393	382	370	356	341	324	0.03
	UCL	434	467	501	536	573	610	647	685	723	0.07

LCL: Lower Control Limit, UCL: Upper Control Limit, TTOE: Thousand Tons of Oil Equivalent, AI: Average Increase.

Table 6: (Continued)

10-Wood	Forecast	3811	3642	3473	3304	3134	2966	2798	2629	2461	0.06
	LCL	3786	3593	3394	3191	2984	2776	2564	2349	2132	0.07
	UCL	3836	3692	3552	3417	3284	3157	3032	2909	2789	0.04
11-AVW	Forecast	1120	1087	1054	1021	984	947	910	874	839	0.04
	LCL	1065	978	887	796	699	601	503	403	303	0.15
	UCL	1175	1196	1221	1246	1269	1292	1318	1345	1374	0.02
12-Consumption	Forecast	137966	146819	153812	163780	177577	189623	202413	216102	228082	0.06
	LCL	137704	146466	153175	162846	176395	188080	200501	213842	225395	0.05
	UCL	138227	147172	154448	164714	178759	191166	204324	218361	230767	0.07
13-Residential	Forecast	57808	62240	66816	71514	76317	81209	86177	91209	96297	0.06
	LCL	57530	61535	65449	69263	72952	76502	79903	83150	86237	0.05
	UCL	58086	62945	68183	73764	79682	85915	92450	99269	106357	0.08
14-Government	Forecast	6352	6480	6545	6973	7345	7429	7646	8050	8303	0.03
	LCL	6328	6449	6513	6936	7298	7377	7592	7989	8232	0.03
	UCL	6375	6511	6577	7009	7392	7480	7700	8112	8373	0.04
15-Street	Forecast	4042	3920	3751	3650	3597	3582	3596	3662	3737	0.01
	LCL	4032	3901	3723	3614	3553	3530	3536	3594	3662	0.01
	UCL	4052	3939	3778	3686	3642	3635	3657	3729	3812	0.01
16-Industrial	Forecast	79036	82697	86383	90062	93744	97425	101106	104787	108468	0.04
	LCL	78637	82084	85520	88932	92323	95694	99047	102382	105701	0.03
	UCL	79435	83309	87245	91193	95165	99155	103164	107192	111235	0.05
17-I.Capacity	Forecast	42191	43849	45509	47110	48932	50614	52357	54040	55733	0.04
	LCL	42038	43554	45109	46592	48298	49857	51474	53025	54584	0.03
	UCL	42344	44144	45908	47628	49566	51372	53241	55054	56883	0.04
18-ICPC	Forecast	566	581	600	621	637	644	650	662	682	0.02
	LCL	562	573	588	605	616	616	615	620	631	0.01
	UCL	571	589	612	637	659	673	686	706	732	0.03
19-CPC	Forecast	2041	2157	2274	2390	2506	2622	2738	2854	2971	0.05
	LCL	2038	2152	2265	2377	2489	2600	2711	2822	2933	0.05
	UCL	2044	2163	2283	2403	2523	2644	2765	2886	3008	0.05

LCL: Lower Control Limit, UCL: Upper Control Limit, TTOE: Thousand Tons of Oil Equivalent, AI: Average Increase.

The minimum, maximum and arithmetic mean of primary energy production and consumption ratios in four different periods (1945-1980, 1981-1990, 1991-2006 for estimation periods and 2007-2015 for forecasting period) are given in the Table 7. As seen in the Table 7, primary energy production sources in four periods are lignite (11.5%, 33.5%, 40.8% and 51.8%), wood (34.2%, 23.5%, 19.3% and 12.4%), petroleum (12%, 11.9%, 12.5% and 18.6) and hydraulic (0.3%, 1%, 2.4% and 6.3%) respectively. In these periods, coal/total production ratios are gradually decreased 22.2% to 5% and forecasted to be 4.9% in 2007-2015. Natural gas production, which provides 0.01% in 1945-1980, 0.05% in 1981-1990 of total primary energy production, has increased to 1.6% in 1991-2006 due to natural gas discoveries in Trakya area Sevindik-1 and Göçerler-1.[3]

Rapid increase of energy consumption in Turkey is causing the energy sources to be more vital. In 1927, the population of Turkey was 13.648.270. Between 1927 and 2006, the population of Turkey has increased almost five times to 70.586.256, while energy consumption per person has increased more than 392 time (1961/5) in the same period.

There is no problem right now as it can be met energy consumption demand with current infrastructure. But as the results show, Turkey will face an energy crisis in the near future. Lessening dependence on outside sources for energy, implementing policies for the use of local renewable energy resources and supporting public investments can remedy this problem. Otherwise, the entire infrastructure and industry of the country will sustain irreparable damage.

Studying the relationship between energy and economy, Ediger (2004) have shown that the industrialization in Turkey has not been completed yet and energy consumption should be increasing faster than national income until the energy intensity of the country reaches to a peak. Therefore, the decrease in the rate of energy consumption may be interpreted as an indication that the energy intensity peak will be achieved in the coming decades. However, a close relationship exists between energy and economy of Turkey and the average rate of change in GDP and primary energy consumption are 4.5 and 4.9, respectively (Ediger and Huvaz, 2006). Also, Soytaş and Sarı (2003) discovered causality from energy consumption to GDP in Turkey.

[3] Almost 3.3% of total primary energy production will be produced from natural gas in 2007-2015.

Table 7: Structural Changes of Primary Energy Productions and Consumptions

Production and Consumption Series Ratio	1945-1980*			1981-1990*			1991-2006*			2007-2015**		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
Coal / Production	.130	.300	**.222**	.080	.130	**.101**	.040	.070	**.050**	.050	.050	**.049**
Lignite / Production	.042	.227	**.115**	.233	.410	**.335**	.360	.453	**.408**	.456	.558	**.508**
Asphaltit / Production	.000	.014	**.006**	.005	.019	**.012**	.000	.016	**.003**	.010	.017	**.013**
Natural Gas / Production	.001	.002	**.001**	.000	.018	**.005**	.006	.033	**.016**	.031	.033	**.033**
Petroleum / Production	.003	.259	**.120**	.101	.153	**.119**	.086	.183	**.125**	.079	.087	**.082**
Hydraulic / Production	.000	.056	**.017**	.045	.104	**.064**	.079	.166	**.121**	.167	.212	**.186**
Geothermal / Production	.001	.004	**.003**	.003	.014	**.010**	.014	.041	**.024**	.048	.079	**.063**
Solar / Production	-	-	**-**	.000	.001	**.001**	.002	.016	**.009**	.017	.021	**.019**
Wood / Production	.254	.460	**.342**	.208	.265	**.235**	.149	.211	**.193**	.098	.152	**.124**
AVW / Production	.143	.225	**.179**	.072	.159	**.120**	.043	.071	**.055**	.034	.045	**.039**
Residential / Consumption	.116	.240	**.184**	.212	.248	**.229**	.273	.382	**.319**	.419	.437	**.427**
Government / Consumption	.024	.050	**.034**	.025	.032	**.030**	.036	.054	**.043**	.036	.046	**.041**
Street / Consumption	.014	.036	**.026**	.012	.026	**.018**	.028	.050	**.040**	.016	.029	**.021**
Industrial / Consumption	.719	.936	**.749**	.694	.748	**.724**	.548	.655	**.598**	.476	.573	**.528**

*Note: * Estimation periods ** forecasting period results.*

Graphs of observed and forecasted primary energy productions (TTOE) for total production, hard coal, lignite, asphaltit, natural gas, petroleum, hydraulic, geothermal heat, solar, wood, animal and vegetable waste series are shown in the Figure 1. Graph of observed and forecasted primary energy consumptions (million KWh) for total energy consumption, residential and commercial, government offices, street illumination, industrial and other consumption series are shown in the Figure 2. Graph of observed and forecasted for installed capacity (1000 KWh) is shown in the Figure 3. Graph of observed and forecasted for installed capacity per capita (W) and for consumption per capita (KWh) are shown in the Figure 4.

Figure 1: Observed and Forecasted Primary Energy Productions (TTOE)

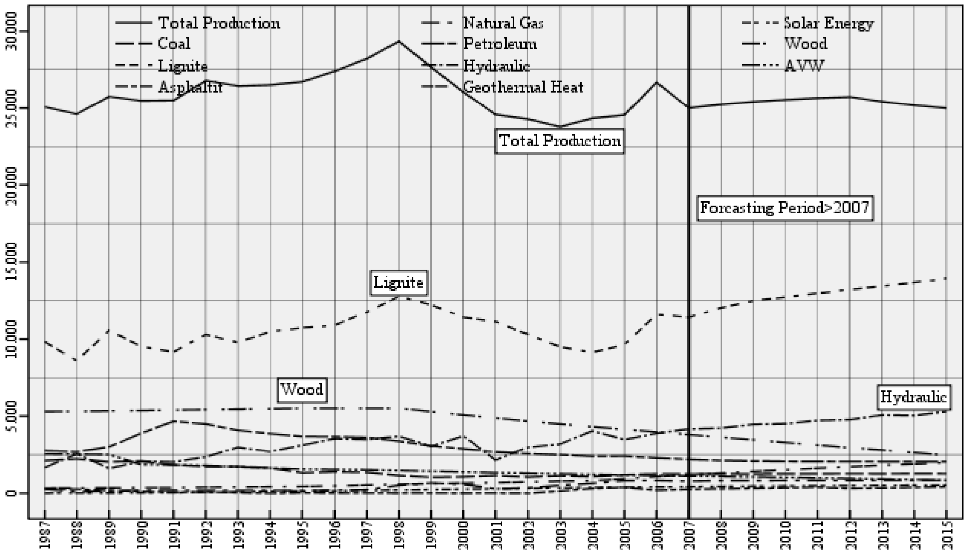


Figure 2: Observed and Forecasted Energy Consumptions (Million KWh)

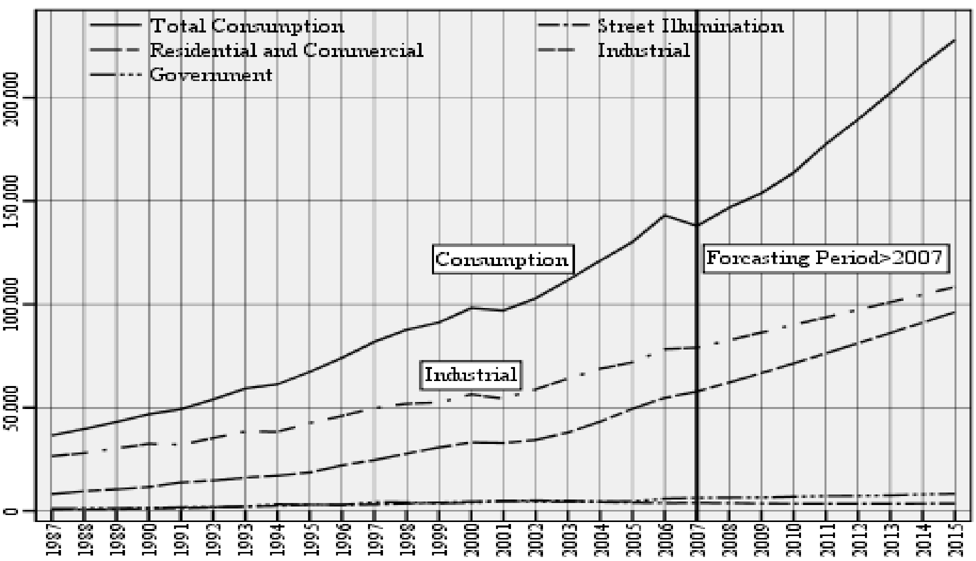


Figure 3: Observed and Forecasted Installed Capacity (1000 KWh)

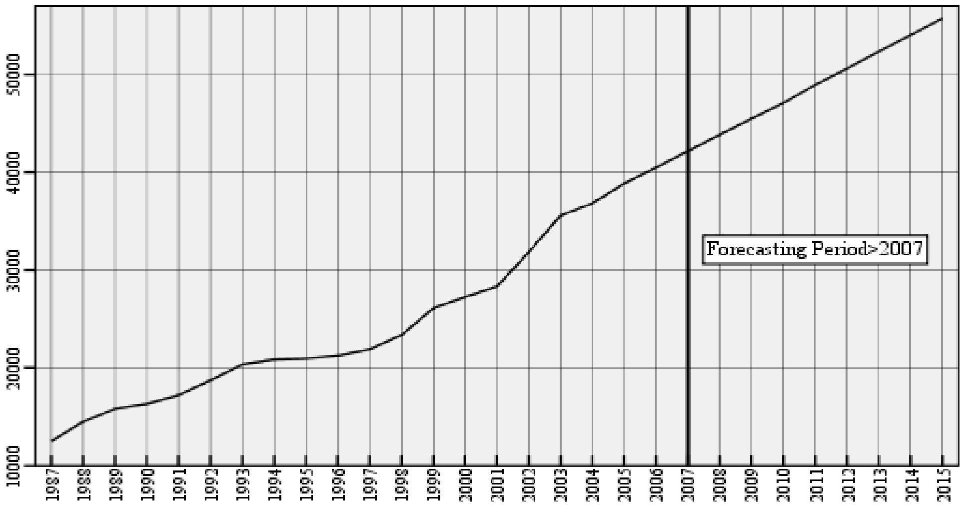


Figure 4: Observed and Forecasted ICPC (W) and CPC (KWh)

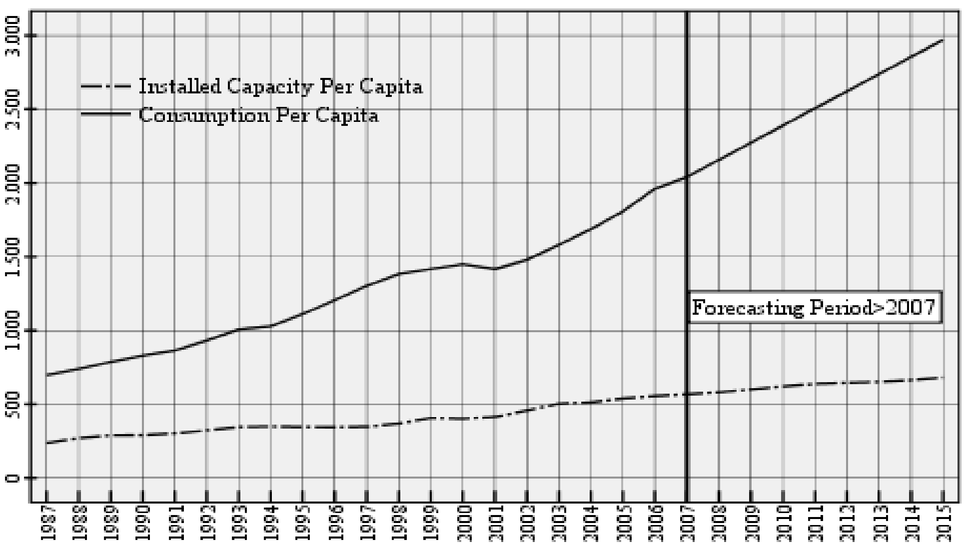


Figure 5: Ratio of Energy Production to Total Production

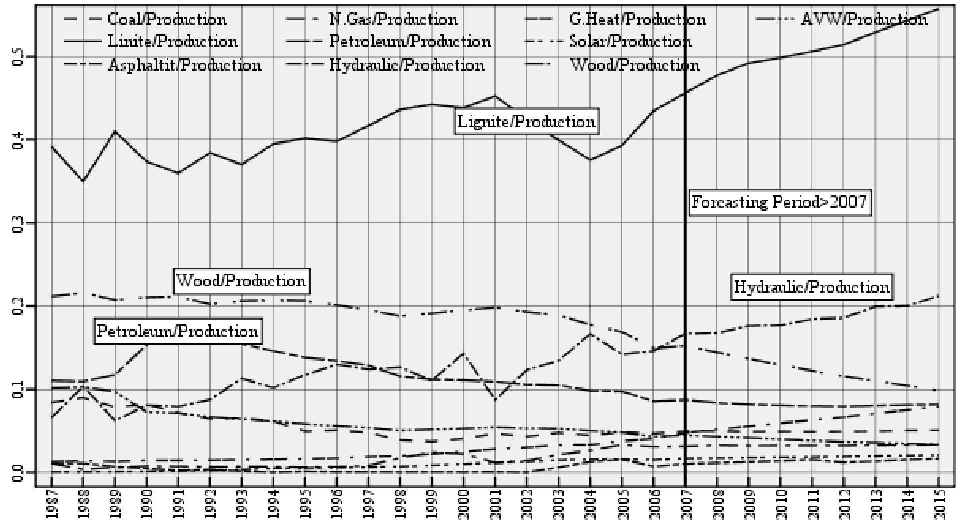


Figure 6: Ratio of Energy Consumption to Total Consumption

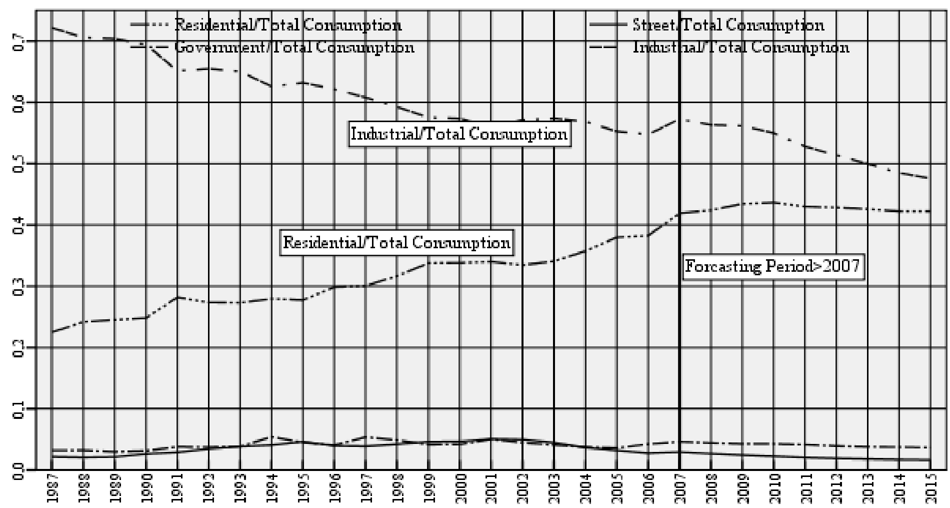
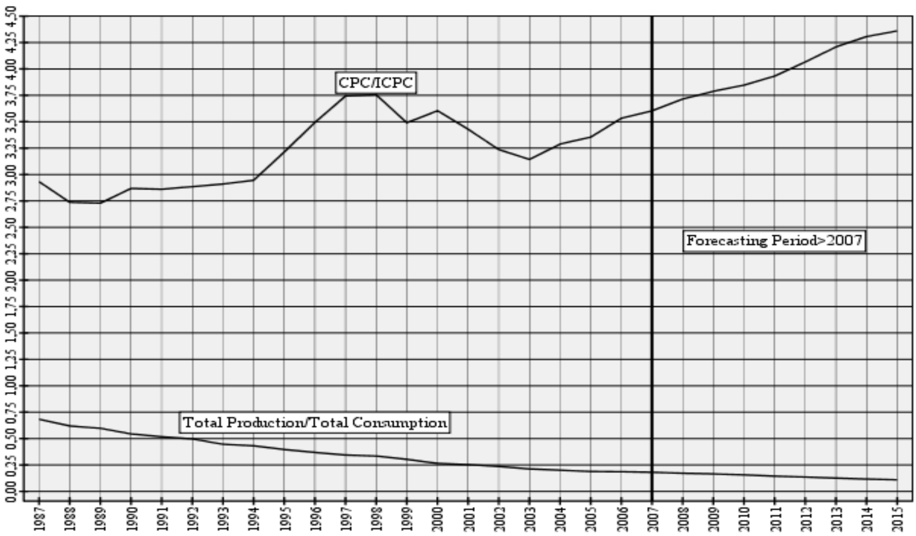


Figure 5 shows the ratios of energy production series to the total production and Figure 6 shows the ratios of energy consumption series to the total consumption. Figure 7 displays CPC/ICPC and total production/total consumptions ratios. As seen in the Table 7, energy production structure in Turkey changed dramatically. The energy rate produced from wood is first reduced from 34.2% in 1945-1980 to 23.5 in 1981-1990. In 1991-2006, it decreased to 19.3% and expected to decrease to 12.4% in 2007-2015. In the same periods, animal and vegetable wastes (AVW) rates are 17.9%, 12%, 5.5% and 3.9% respectively. The other rates of production and consumption series tendencies are shown in the Table 7, Figure 5, Figure 6 and Figure 7.

Figure 7: CPC/ICPC and Total Production/Total Consumption



Forecasting primary energy production and consumption markets are very important for effective implementation of energy policies. More precise forecasts of energy consumption and production are vital when consumption growth rates are greater than production growth rates as in the case of Turkey. Projection for energy markets of Turkey is obtained officially from MAED simulation models. Table 8 compares the results from this study with most recent official projections based on two different scenarios and Erdoğdu (2007) projections. As seen in the Table 8, the results of the ARIMA forecasting of the total primary energy consumption are compared with the most recent MAED results based on two different scenarios. It is obvious that in the years 2011, 20012, 2013 and 2014 the forecast values almost coincides with the MAED scenario 2 results and with Erdoğdu (2007) for 2005, 2007 and 2008.

Table 8: The Comparison of This Study with Official (MAED) and Erdoğdu (2007) Results

	Projection for net energy consumption				Difference between this study and the others			Differences as a percentage of forecast based on this study		
	Official (MAED)									
Year	Scenario-1	Scenario-2	Erdoğdu (2007)	This Study	Scenario-1	Scenario-2	Erdoğdu	Scenario-1	Scenario-2	Erdoğdu
2005	124048	124048	129311	130263	6215	6215	952	0,05	0,05	0,01
2006	137064	131715	132631	143071	6007	11356	10440	0,04	0,08	0,07
2007	148174	140053	138134	137966	-10208	-2087	-168	-0,07	-0,02	0,00
2008	160373	148933	146365	146819	-13554	-2114	454	-0,09	-0,01	0,00
2009	173660	158374	145144	153812	-19848	-4562	8668	-0,13	-0,03	0,06
2010	188050	168412	155667	163780	-24270	-4632	8113	-0,15	-0,03	0,05
2011	203574	179020	156010	177577	-25997	-1443	21567	-0,15	-0,01	0,12
2012	220280	190327	158150	189623	-30657	-704	31473	-0,16	0,00	0,17
2013	237840	202332	168210	202413	-35427	81	34203	-0,18	0,00	0,17
2014	256644	215073	160090	216102	-40542	1029	56012	-0,19	0,00	0,26
2015	NA	NA	NA	228082	NA	NA	NA	NA	NA	NA

NA: Not Available

The other most outstanding outcome from the comparison is the fact that there is especially a substantial difference between this study and the official projection (MAED) scenario 1 and Erdoğdu (2007) projections in the long term period. If it is supposed that the results of this study are valid for 2011, 2012, 2013 and 2014, scenario 1 overestimate the primary energy demand by 15%, 16%, 18% and 19%, on the other hand Erdoğdu (2007) underestimate the primary energy demand by 12%, 17%, 17% and 26% respectively. However, especially for the long-term ARIMA forecast gives an underestimation when compared with the MAED results and gives an over estimates when compared with Erdoğdu (2007) results. But the results of this study are almost coinciding with the MAED scenario 2. To put in a different way, MAED based on scenario 1 over predict the primary energy demand by 25.997, 30.657, 35.427 and 40.542, Erdoğdu (2007) underestimates the primary energy demand by 21.567, 31.473, 34.203, 56.012 units respectively.

There is one important point to keep in mind while evaluating and using these results. First of all, forecasting, especially in primary energy market, is considered more an art than a science. Therefore, some variations are to be expected depending on the model's assumptions. Like any other models, ARIMA modeling is based on some assumptions. There is a direct link between the accuracy of the forecast and the validity underlying assumptions. The main assumption behind ARIMA forecasting technique is that the current trend in primary energy consumption will more or less repeat in the future.

4. Conclusion

Univariate Box-Jenkins time series analysis provides an alternative approach for modeling primary energy production and consumption markets. Based on 19 different data sets, best ARIMA results were obtained. The *R*-squares values for historical data are almost close to 1 except asphaltit production series. Asphaltit production data has a highly irregular time series. Consequently, none of the method that has been utilized gave good results for this series. ARIMA model was found to be more representative than others were. However, since its production values are proportionally small, it does not affect the overall picture.

Table 6 demonstrates that the primary net energy consumption will increase 5%, while the primary energy production will expected to increase to 0% on average per year in the next decade. This is a signal for an energy crisis in the near feature of Turkey. It has been recently noted that three major problems of the Turkish energy system are: (1) dependency on imported energy sources, (2) denomination of energy consumption by fossil fuels, and (3) low energy efficiencies than other countries (Ediger et al., 2006).

Energy is one of the most important strategic factors for developing countries. Turkey mainly has six major primary energy sources. In 1991-2006, they are lignite (40.8%), wood (19.3%), petroleum (12.5%), hydraulic (12.1%), AVW (5.5%) and coal (5%) respectively as seen in the Table 7. There are several other primary energy sources such as asphaltit, natural gas, geothermal and solar energy. Turkey mainly depends on imported energy sources similar to the European countries. Along with, the European countries use Turkey as a bridge to transport energy sources by using the pipelines between them and Turkey's neighbors having rich petroleum and natural resources. This is an important advantage for Turkish energy policy if it is managed efficiently.

Turkey has an advantage of having almost all energy resources and renewable resources such as wind energy, solar power, and geothermal energy existing in the country. Turkey's main renewable energy source is AVW, but it is expected to decrease in the future as the options of oil, gas, coal or electrical heating and cooking become available. Furthermore, Turkey can not use nuclear energy yet for energy production but it is envisaged that three nuclear energy centrals will be completed until 2015. As a result, nuclear energy production will become an alternative energy source in recent years.

Efficiency and environmental aspects of the energy should also be considered in determining the best mix of the country. Therefore, great emphasis should be given also on the utilization of other domestic energy sources, including renewable energy sources such as hydropower, wind, geothermal, and solar, for which the country has a significant potential. Diversification will certainly increase the energy security of Turkey, which seems to be one of the most significant aspects of the Turkish energy system. Therefore, the proper energy management model is very important for the future of Turkey. Turkey must give importance to hydroelectric and nuclear plants due to their lower cost with comparison to other sources.

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