A Comparison of DecisionMakingModels and ElectricityEnergyDemandForecasting for Turkey

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Abstract

Turkey is rapidly growing with a 73 million young and confident people. So, energy requirements have been rising with increasing population for twenty years in Turkey. The development a country and people living of standards is directly related to the energy utilization rate. Authors and researchers claimed that, the Turkish economy is currently the fastest growing economies among the European Union. In addition, there are a lot of and different studies that were published recently on forecasting of Turkey's electricity demand. But the aim of this study is to compare forecasting models each other with error estimations and estimate future demand. This study is a proposition of a new approach by comparing grey prediction and multiple regression models with Model of Analysis of the Energy Demand (MAED). Turkish Ministry of Energy and Natural Resources carry out MAED. In this study, electricity energy consumption in Turkey is forecasting with grey prediction and multiple regression models from 1970 to 2010. In this model, we used total export, total import, population and GDP data unlike than Akay and Atak (2007). This study also explores new approach by using more data and suggestions regarding to electricity consumption. As a result, proposed approaches estimates have more accurate results than MAED model in the comparison of electricity consumption.

Keywords: Turkey's electricity consumption forecasting; Grey prediction; Multiple regression

1. Introduction

Energy consumption in Turkey has increased dramatically for ten years because of its increasing population and economic development. Turkey is a central country because of between Europe and Central Asian Regions. In 2011, Turkey's population was 73 million, 24% over the 1989 level (Turkstat, 2012). Energy is one of the most significant development priorities for Turkey. Energy, particularly electricity, is essential for improving quality of live and developing as social and economic like European Countries. Electricity energy is producing with various sources like oil, natural gas, hydro, coal and biofuels. Oil and natural gas reserves are extremely limited (Tunç et al., 2006).Figure 1 shows energy production for Turkey between 1970 and 2009. Especially, hydro energy sources began to use in recent years.

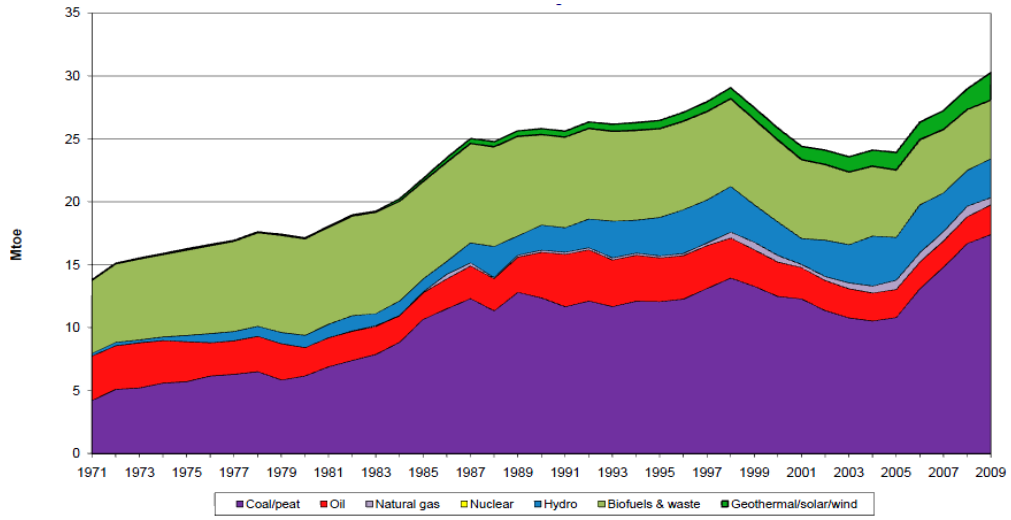

Figure 1: Turkey's Energy Production (Source: OECD/IEA, 2011)

Electricity energy is a vital input for social, economic and technical development of Turkey like the other countries. Projections for Turkey demonstrate positive results from the use of energy, especially for electricity, and identify key areas for improvement by 2023 (ESMAP Report, 2011). In Turkey, energy consumption projections are made by Ministry of Energy and Natural Resources of Turkey (MENR). MENR has carried out energy forecasting studies by using Model for Analysis of Energy Demand (MAED) simulation technique since 1984. MAED performs higher values than real results because of too much data observed (Hamzaçebi, 2007). That is a handicap of this technique. This paper does not claim our methods are the best. We just try to present different technique which is able to apply for estimating electricity consumption.

Actually, there are many studies related electricity forecasting with models. So, the purpose of this study is to compare models each other according to proximity of the actual values. In this paper, Grey prediction (GP) is presented to predict the Turkey's electricity consumption. GP approach is used because of high prediction accuracy, requirement of little computational effort and applicability in case of limited data situations. In this respect, the present study attempts to forecast the consumption of electricity between 2003 and 2010 by using multiple regression and GP models. The variables in the case study of Turkey for estimation of consumption values are introduced. Then actual data is compared with MAED, regression and GP models.

In the following sections; literature is reviewed in section two. Brief information about Turkey's electricity consumption is given in section three. In the fourth section, multiple regression and GP approaches are introduced shortly. Data analysis, performance evaluation and results of electricity demand forecasting are presented in section five. Finally, the section six has conclusion and recommendations.

2. Literature Review

In the literature, there are studies related to long time electricity energy consumption estimate. In recent studies neural networks, econometric models, regression models, and grey models (GM) are the most commonly used techniques in energy forecasting studies for different countries (Suganthi and Samuel, 2012). Egelioglu et al. (2001) used multiple regression analysis to investigate the relationship between energy consumption with the

price of electricity, the number of customers and the number of tourists is determined in N. Cyprus. Al-Ghandoor et al. (2008) are developed empirical multivariate regression modelto predict the electricity requirement of Jordon's industrial sector. Electrical power demand is affected by capacity utilization and industrial production outputs. Azadeh et al. (2008) present an artificial neural network (ANN) model for annual electricity consumption in industrial sectors with high energy. ANOVA variance analysis shows the advantages of ANN approach. Tso and Yau (2007) compare the accuracy of regression analysis, decision trees, and neural networks in predicting electricity energy consumption in Hong Kong.

Some studies are related to GM. Hsu and Chen (2003) used improved GM to forecast energy demand for Taiwan. Energy demand is influenced GDP, fuel price, the vehicle kilometers of travel and the number of motor vehicles per energy. Pao and Tsai (2011) predict and investigate the relationship between energy consumption with output, income and pollution emission by using GM for Brazil. The causality results show that there is a bidirectional strong causality running between energy consumption, emissions and income. Ma et al. (2007) studied GM to predict Chain's energy production and consumption

Some publications try to compare and combine models each other. For example, Lu et al. (2009) used GM with time series model (ARIMA) for correction. Vehicular energy consumption, CO^2 emission and the amount of motor vehicles are studied in Taiwan. Yao and Chi (2004) compared taguchi method with GM to optimize electricity demand settings. Electricity demand predictor system with PC based was expected to decrease the usage of electricity. Lee and Tong (2011) forecasted energy consumption by using GP model that combines genetic algorithm.

On the other hand, except for the MENR, Some researchers were studied on forecasting of Turkey's energy demand. Öztürk and Ceylan (2005) and Canyurt et al. (2004) utilized genetic algorithm heuristic method for modeling Turkey's future energy demand with import, export, GDP and population, and some economic indicators. Tunç et al. (2006) used multiple regression analysis to predict Turkey's electricity consumption for the period of 2010-2020 and modeled a linear mathematical model to minimize distribution costs for future electrical power supply investment.

Hamzaçebi (2007) studied Turkey's net electricity consumption on sectoral basis by choosing ANN model. ANN model is able to forecast future values of many variables simultaneously and solve nonlinear structures. Yüksek et al. (2006) claimed hydro electric power will satisfy Turkey's electricity demand after 2020.

3. Turkey Electricity Consumption

Today, one of the most important indicators of developing countries is considered to be electricity consumption for individuals because of easy to use, able to convert other types of energy at any time. Electricity energy is used in nearly all kinds of activities, such as: industrial production, lighting, transportation, agriculture, residential, and heating. In parallel with the development and growth of the Turkish economy, increasing population and rising living standards, electric power consumption has shown a steady increase over the years. However the electricity consumption per capita was 207 kwh in 1970, this number becomes 2400 kwh in 2008. But this amount of consumption is still under the world average about 3000 kwh. While the industrial sector has the highest proportion

about consumption of electrical energy, it is followed by use of residential and service in sectoral basis (IEA report, 2009:124)**.**

The Table 1 shows the amount of electrical energy consumed in a few countries for three years. Turkey is the last one among countries in the table, but electricity consumption increases by each year.

Table 1: Electricity Consumption Per Capita (kWh/Capita)

	2006	**2007**	**2008**
World	2659	2752	2782
OECD	8381	8477	8486
USA	13515	13616	13647
Germany	7175	7185	7148
France	7585	7573	7703
England	6192	6142	6067
Turkey	2053	2210	2400

(Source: International Energy Agency (IEA) – World Energy Statistics (2008, 2009 and 2010))

The main goal of this study is to forecast and compare electricity consumption for Turkey using GP, MAED and regression. Although the consumption of electricity is important in one country, the production is vital. Therefore, the electricity consumed must be known which are produced by energy sources. In 2011, the total electricity produced in Turkey was 229.4 billion kwh. This was obtained by natural gas (% 45.4), hydraulic dams (%18.4) and lignite (%6.9). The others are coals, geothermal, thermal, wind and streams. There are potential indigenous sources for 246 billion kilowatt-hours (kWh) per year of electric power generation is estimated in Turkey.

4. Forecasting Methodologies

In order to enhance the predicting accuracy, we introduce two improved techniques that are GP and multiple regression models.

4.1. Grey prediction model

Grey Prediction is an alternative forecasting method for those systems whose structure is uncertain, complex and imperfect information. GP has advantages with higher forecasting accuracy and requiring low data items to make forecasting models when compared with other techniques. GP has been used successfully in many disciplines such as electricity demand, material handling, consumption estimate and results help managers for strategically decision making Hsu and Chen (2003).

In the following, there are GP steps (Akay and Atak, 2007)
Step 1: Original data sequence with n samples defined as
$x^{(0)} = (x^{(0)}(1), x^{(0)}(2), \dots, x^{(0)}(n)$
(1)$x^{(1)} = (x^{(1)}(1), x^{(1)}(2), \dots, x^{(1)}(n)$Accumulated Generation Operation AGO formulation of $x^{(0)}$ is expressed as

(2)

That is:

$$x^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i) \qquad \text{k=2,3,…,n} \qquad (3)$$

Step 2: A first order grey differential equation is establishing to construct the GM (1,1) model

$$\frac{\partial x^{(1)}(k)}{\partial k} + az^{(1)}(k) = b, \qquad (4)$$

Where

$$z^{(1)}(k) = 0.5x^{(1)}(k) + 0.5x^{(1)}(k-1) \qquad \text{k=2,…,n} \qquad (5)$$

K is a time point, a is called development coefficient and b is called driving coefficient. $[a,b]^T$ can be estimated by using least mean square estimation technique coefficient as

$$\begin{bmatrix} a \\ b \end{bmatrix} = [B^T B]^{-1} B^T Y, \qquad (6)$$

Where

$$B = \begin{bmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ \dots & 1 \\ -z^{(1)}(n) & 1 \end{bmatrix}, \quad Y = \begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n) \end{bmatrix}. \qquad (7)$$

Step 3: After computed estimated coefficient a and b, GM(1,1) cumulative equation can be obtained by solving differential equation

$$\hat{x}^{(1)}(k+1) = \left[x^{(1)}(0) - \frac{b}{a}\right] e^{-ak} + \frac{b}{a} \qquad (8)$$

Where $\hat{x}(k)$ denotes AGO prediction of x at time k point. Reduction of the randomness of data makes AGO one of the most important characteristics of grey theory. $\hat{x}^{(0)}(k)$series can be predicted by performing IAGO $\hat{x}^{(1)}\widehat{(k)} - x^{(1)}(k+1)$.

4.2. Multiple regression model

Multiple regression is a practical extension of simple regression model. It allows us to build a model with several independent variables instead of just one variable. The dependent variables that we want to forecast will be $\hat{y}$. The independent variables will be $x_1, x_2, \dots, x_n$. The proper equation would be (Heizer and Render, 2008);

$$\hat{y} = c + b_1 x_1 + b_2 x_2 + \cdots + b_n x_n \qquad (9)$$

The main purpose of the regression analysis is to determine the best fitting coefficients of the model and to find an appropriate mathematical model from the given data (Azadeh et al., 2011).

5. Data Analysis

Various models have been developed in different studies in order to predict electricity consumption on economic indicators. Prediction models, such as MAED, multiple regression and GP, in this study will be compared with each other. The data used for this study is shown in Table 2.

Table 2: Turkey net electricity consumption, export, import, GDP and population between 1970 and 2002

Years	Net electricity consumption (GWh)	Total export (billion $)	Total import (billion $)	GDP ($*10^9)	Population (*000)
1970	7307	588	947	25,306	35464
1971	8289	676	1170	22,636	36245
1972	9527	885	1562	28,651	37054
1973	10530	1317	2086	36,081	37884
1974	11358	1532	3777	49,746	38730
1975	13491	1401	4738	62,226	39585
1976	16078	1960	5128	71,223	40446
1977	17968	1753	5796	81,467	41316
1978	18933	2288	4599	89,073	42206
1979	19663	2261	5069	108,837	43132
1980	20632	2910	7909	90,678	44105
1981	22030	4703	8933	94,641	45130
1982	23586	5746	8842	85,353	46198
1983	24465	5727	9235	81,133	47285
1984	27635	7133	10756	78,824	48360
1985	29708	7958	11343	89,263	49399
1986	32209	7456	11104	100,873	50395
1987	36697	10190	14157	115,096	51349
1988	39721	11662	14335	121,667	52278
1989	43120	11625	15792	142,635	53208
1990	46820	12959	22302	150,68	55120
1991	49283	13593	21047	151,04	56055
1992	53985	14715	22871	159,1	56986
1993	59237	15345	29428	180,42	57913
1994	61401	18106	23270	130,69	58837
1995	67394	21637	35709	169,49	59756
1996	74157	23224	43627	181,48	60671
1997	81885	26261	48559	189,83	61582
1998	87705	26974	45921	269,29	62464
1999	91202	26587	40671	249,75	63364
2000	98296	27775	54503	266,57	64252
2001	97070	31334	41399	196,01	65133
2002	102948	36059	51554	232,53	66008

Seasonality and fluctuations was not observed in data that examined before. Electricity consumption level is decreasing just in the times of crisis as well as they show linear

distribution. Electricity energy consumption data and population were taken from Turkish Statistical Institute (TurkStat). Total export, import and GDP data were taken from Yiğit (2011) paper and TurkStat. Comparison of annual electricity consumption forecasts for 2003 to 2010 using GP and regression models are shown Table 3 and Figure 2 with their signs.

5.1. Performance Criterion

There are four measures used as performance criterion: mean absolute errors (MAE), root mean square errors (RMSE), absolute percentage error (APE) and mean absolute percentage error (MAPE). In decision-making, APE and MAPE used for the comparison of ANN and MAED results and for the best network structure two criteria (MAE and RMSE) results were taken into account. To avoid this problem we will use MAPE performance criteria and its formulation is given below (Hamzaçebi, 2007).

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{e_i}{Y_i}\right)100 \quad (10)$$

Where *ei* shows the differences between forecasted and actual values, Y_i shows the actual values for*i.* year and *n* shows number of years. If the forecast item is measured in thousands, the MAE and RMSE values can be very large (Heizer and Render, 2008:114).

5.2. Grey prediction

GM is one of many forecasting models that used grey prediction. This model which is used in this study helps to find a and b coefficients for GM variables. GP function is created with these coefficients. As a result of the transactions are;
a = -0.069
b = 12791.375
The solution of GM (1,1) cumulative equation is;

$$\hat{x}^{(1)}(k+1) = 192689.25e^{-0.069k} - 185382.25$$

5.3. Multiple regression model

Traditionally, regression analysis has been the most popular modeling technique in predicting energy consumption.It refers to a set of methods by which estimates are made for the model parameters from the knowledge of the values of a given input and output data set. Linear multiple regression model is using to estimate electricity consumption in this section. The model utilize is follows:
$Y = -82674.151 + 0.245X_1 + 0.261X_2 + 12.017X_3 + 2.297X_4$
Where
Y: Annual electricity consumption forecast (dependent)
X_1: Total net export (independent)
X_2: Total net import (independent)
X_3: Gross Domestic Production (GDP) (independent)
X_4: Population (on the middle of the year) (independent)

5.4. Results

The MAED and forecasting results of GP and regression analysis are compared with actual data in Table 3. The last 9 observed data from 2003 to 2010 is used to validate obtained

model. The regression and GP models give better results than MAED model in the comparison of electricity consumption. It shows that, both methods will be effective in order to forecast long term perspective.

Table 3 : Comparison of models with MAPE errors from 2003-2010

Years	Actual	MAED	GM (1,1)	Regression
2003	111766	144363	118227	104259
2004	121142	156015	127173	118549
2005	130263	162520	136758	129127
2006	143071	166892	147027	140518
2007	155135	165427	158030	157090
2008	161948	168604	169819	174512
2009	156894	184403	169451	152049
2010	172051	199928	182984	170212
MAPE error (%)		17.98	4.9	3.1

Figure 2 presented the prediction error values of electricity consumption using two models from 2003 to 2010.

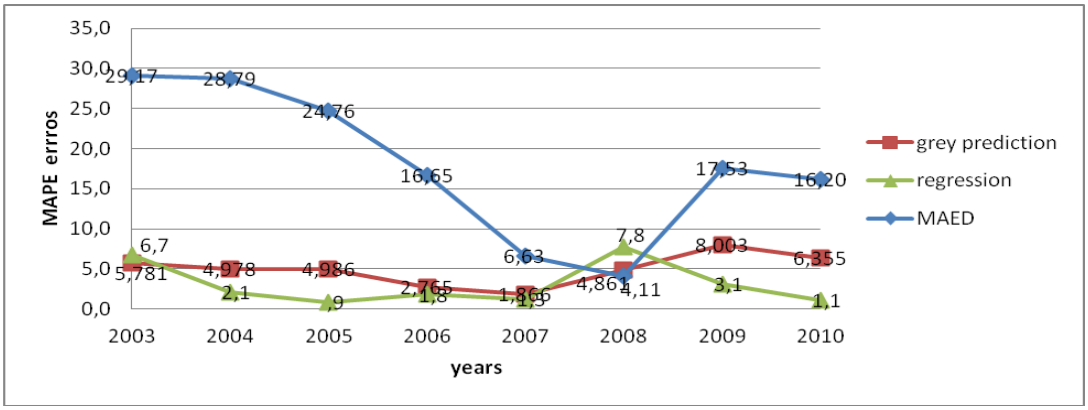

Figure 2: Forecasting errrors of the models period 2003-2010

As it can be deduced from Figure 2, there are big differences between results of models for the period 2003-2010. The reason in those differences is that the MAED model uses many variables, and in case of variability level in them, this brings high error effects on the result. On the other hand, GP uses only consumption data of the last nine years. In this respect, it has both simplicity and not too much prediction inaccuracy, and can be implemented easily.

6. Conclusion

Turkey is developing and growing country respect to its production, management, organization, transportation and so on. The government of Turkey should monitor electricity consumption growth with a focus on demand side initiatives and facilitate sufficient investments. So, forecasting is quite significant for effective application of energy. Accurate forecasts of electricity consumption are vital when demand grows faster.

The aim of this study is to point out the use of sufficient different forecasting types. First of all, this paper focused on forecasting the annual electricity consumption for Turkey, and

secondly, compared estimated errors (MAPE) between MAED, GP and regression models with actual data in the period of 2003-2010. Results have revealed that, GP and regression models perform close findings with %4.9 and %3.1 respectively. But, MAED results are higher than others with %17.98. It shows that, GP and regression methods are effective in order to forecast long term perspective. In addition, it appears that, the original GM(1,1) model is a powerful forecasting model.

In the future, following works may be focus on many areas, namely industrial, residence, transportation and agricultural by using GP, Artificial Neural Networks (ANN) and some meta-heuristic methods such as ant colony optimization, genetic algorithm, annealing simulation and so on.

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