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Future Electricity Demand of the Emerging European Countries and the CIS Countries

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Abstract

Nowadays, one of the leading factors used in the evaluation of a country's economic development is energy consumption. Because of economic growth, demand for energy is also increasing. In this study, the emerging European countries' (the Czech Republic, Poland, Romania, Turkey) and the CIS countries' (Kazakhstan, Russia, Ukraine, Uzbekistan) electricity consumption has been forecasted for five years period (2015-2019). In the study, GM(1,1) Rolling Model, which is developed in the framework of Grey System Theory is used as a mathematical model for real-time forecasting. The results of the study show that there will not be a significant change in electricity demand in this two area during the 2015-2109 period.

***Key Words**: Energy Demand; Electricity Energy; Derivative Markets; Time Series Analysis; GM(1;1) Rolling Model.*

***JEL classification**: Q41; Q47; G17; G23; C22.*

Introduction

Today, one of the leading factors used in the evaluation of a country's economic development is energy consumption. Because of economic growth, demand for energy is also increasing. Therefore, emerging economies are increasing the growing energy needs.

Energy is an essential input for industries, so it is crucial for both developed countries and emerging economies. The oil crises during the 1970s and the anomalous increases in oil prices in 1990s and 2000s confirmed the energy is a key factor for all economies. Consistently growing production in the world has become the need for power, but the paucity of primary energy resources poses an obstacle to the sustainable economic growth (Bayar and Özel, 2014).

Electricity is one of the most important and widely used forms of energy (Meng *et al.* 2014), also is a secondary energy resource obtained from the conversion of the primary energy resources and wind power. Oil and coal have been the inputs mostly used in electricity generation, but the share of nuclear power and natural gas in electricity generation has increased in recent years (Bayar and Özel, 2014).

Because of electricity is a secondary energy source, planners and decision makers need forecasting of electricity demand. Electricity power system planners and demand controllers in ensuring that there would be enough supply of electricity to cope with increasing demand. Thus, accurate demand forecasting can lead to an overall reduction of cost, better budget planning, maintenance scheduling and fuel management (Lepojevic and Andelkovic-Pesic, 2011). Besides, forecasting of electricity demand for end users is essential for planning their future and hedging from the price volatility. So factories and other production facilities, hotels, shopping centers and entertainment centers forecast their electricity demand and invest in derivative markets to stay the electricity prices.

Also, individual and institutional investors invest their funds in derivative markets. They have three objectives for investing in derivative markets; gaining, arbitrage and hedging. These investors need to forecast the future prices of electricity for achieving their aims. Therefore, forecasting is a significant planning tool of particular relevance in the business environment.

This study primarily aims to forecast future electricity demand of the emerging European countries (the Czech Republic, Poland, Romania, Turkey) and the Commonwealth Independent States – CIS (Kazakhstan, Russia, Ukraine, Uzbekistan) for planners, decision makers, end users, and investors using GM(1,1) Rolling Model for the 2015-2019 period. The emerging European countries and the CIS countries are in energy trade and collaboration with its logistics, especially for gas and oil. (Papava *et al.*, 2009; Dodsworth *et al.*, 2002). The CIS countries supply these primary energy sources, and the emerging European countries consume or convert them into electricity energy. This trade is growing but the energy sources are limited, and the suppliers can need their own power sources in next periods. So this is an important question that “What is the electricity demand of these countries in the next years?” The answers to this question are so fruitful for economic and financial decision makers. That is why selected these countries as the case study.

Literature Review

From an economic viewpoint, the supply and demand of electricity energy must be balanced at any given time. Therefore, electricity is essential for economic development, in particular for the industrial sector and a precise forecasting of electrical power consumption is vital for the economies and the business environment (Meng *et al.* 2014). There are various methods used for energy consumption forecastings such as time series models, regression models, and machine learning technologies such as genetic algorithms, support vector machines, artificial intelligence and grey system theory, etc.

Some methods such as ARIMA models, regression analysis, artificial intelligence techniques, etc. can be used for forecasting the energy demand. However, these methods require a sufficient number of data for efficient forecasting. For forecasting problems where an insufficient amount of data are available GM(1,1) is a forecasting model based on the Grey System Theory (GST) has found acceptance and use in energy literature in the recent years. Jiang *et al.* (2014), predicted electricity consumption of New South Wales in 30-minutely basis using GM(1,1) model and Cuckoo Search Algorithm for the January 2013 - June 2013 period. Kazemi *et al.* (2011), used a Markov chain grey model, a GM(1,1) model and a regression model to predict Iran’s energy consumption of industrial sector for the period from 2009 to 2020. Liu (2013), used a GM(1,1) model for predicting power load of Shan Dong Province for 2012 and 2013. Akay and Atak (2006), forecasted Turkey’s electricity demand using GM(1,1) rolling model for the period from 2006 to 2015. Meng *et al.* (2011), predicted the monthly electricity consumption of China using GM(1,1) and RBFNNs for 2005 and 2006. Mostafaei and Koordnoori (2012), developed an improved GM(1,1) model to forecast total energy demand and supply of Iran for the period from 2009 to 2021. Rathnayaka and Seneviratna (2014), used a GM(1,1) model to forecast electricity demand of Sri Lanka for the period from 2011 to 2015. Wang *et al.* (2012), GM(1,1), SFGM(1,1) and APL-SFGM(1,1) models for electricity demand of South Australia for the period from 2002 to 2010. Wang *et al.* (2015), forecasted sold the electricity quantity of Guizhou Province using a GM(1,1) model for 2013 by monthly basis. Zhao *et al.* (2016), developed GM(1,1), Rolling GM(1,1) and Rolling-FOA-GM(1,1) models for forecasting of Inner Mongolia’s electricity consumption for the period from 2001 to 2014. Wu *et al.* (2004), developed a Grey Neural Network Model(1,1) for electricity demand forecasting. Zheng *et al.* (2013), used GM(1,1) and DGM(1,1) models for forecasting a city in

Western China for the January 2010 - July 2010 period. Zheng *et al.* (2014), developed an optimized GM(1,1) model for China's total social electricity consumption for the period from 2007 to 2010. Bianco et al. (2010), developed a GM(1,1) Rolling Model for forecasting Romania's non-residential electricity consumption for the period from 2008 to 2020. It is evident to see that the GM(1,1) model and its derivatives are being used in various forecasting processes under the framework of energy science.

Research and Methods

GM(1,1) Rolling Model

In GST, GM(h,N) refers to a grey model. In a GM(h,N) model, the "GM" refers to Grey Model; the "h" is the degree of the model, and "N" is the number of variables in the model. In this study, the GM(1,1) rolling model used to the estimation of future values of electricity demands. GM(1,1) refers to a first-degree grey model with one variable. The GM(1,1) rolling model is used to find out relations within time series, the model according to these relations and to estimate using this model. The differential equation of the GM(1,1) rolling model includes coefficients that can adjust according to instant changes. That is to say, the GM(1,1) rolling model can make fruitful estimations by adapting new pertinent data into the model. There is a precondition that the data to be used in the GM(1,1) rolling model needs to have a positive value and the time series must be at the same frequency, such as monthly, yearly. The distinctive mark of the GM(1,1) rolling model than the basic GM(1,1) model is a prediction of future trends as iteratively. GM (1,1) rolling model process steps can be expressed in the following equations (Tabaszewski and Cempel, 2015):

Assume that time series of energy consumption denoted as C.

$$C^{(0)} = \{C(1), C(2),..., C(n)\} \tag{1}$$

where $C(k) \geq 0$, $k = 1,2,...,n$ and $n > 4$.

The sequence obtained through Accumulating Generation Operation (AGO) can be shown as in Eq. 2:

$$C^{(0)} = [C^{(1)}(1), C^{(1)}(2),..., C^{(1)}(n)] \tag{2}$$

where $C^{(1)}(k) = \sum_{i=1}^{k} C(i)$.

The first-order grey differential equation can be shown as in Eq 3:

$$\frac{dC^{(1)}}{dt} + aC^{(1)} = b \tag{3}$$

Where a is the development coefficient and b is the grey action quantity.

The prediction model for the grey system can be obtained by solving Eq. 4:

$$\hat{C}^{(1)}(k+1) = \left[C(1) - \frac{b}{a}\right]\exp(-ak) + \frac{b}{a} \tag{4}$$

Where $\hat{C}^{(1)}(k+1)$ represents an estimation of $C^{(1)}$.

The primary form of GM(1,1) rolling model corresponding to the unit t can be expressed as Eq. 5:

$$C(k) + \frac{a}{2}\left(C^{(1)}(k) + C^{(1)}(k-1)\right) = b \tag{5}$$

Optimal a and b are calculated by Least Squares Method.

$$\begin{bmatrix} \hat{a} \\ \hat{b} \end{bmatrix} = \left(Z^T Z\right)^{-1} Z^T Y \quad (6)$$

where

$$Y = \begin{bmatrix} C(2) \\ C(3) \\ \dots \\ C(n) \end{bmatrix}, \quad Z = \begin{bmatrix} -\frac{1}{2}\left(C^{(1)}(2) + C^{(1)}(1)\right) & 1 \\ -\frac{1}{2}\left(C^{(1)}(3) + C^{(1)}(2)\right) & 1 \\ \dots & \dots \\ -\frac{1}{2}\left(C^{(1)}(n) + C^{(1)}(n-1)\right) & 1 \end{bmatrix} \quad (7)$$

Hence, the estimation of C can be calculated by using Eq. 6

$$\hat{C}^{(1)}(k+1) = \hat{C}^{(1)}(k+1) - \hat{C}^{(1)}(k) \quad (8)$$

Data and Model

The data employed in this study includes only one variable (total electricity consumption) for each country on a yearly basis, taken from Enerdata Global Energy Statistical Yearbook 2015. The data set covers from 1991 to 2014 total electricity consumption of the countries. The data are divided into two parts called training data set and test data set. The training data set includes the values during the years from 1991 to 2000, is used to determine the best GM(1,1) rolling model. The test data set includes the values for the years from 2000 to 2014, is used to generalize k and α predictions.

The length of subsequences (k) and the horizontal adjustment coefficient (α) which are relevant factors to develop a successful model have been determined. k and α parameters affect the estimation performance of GM(1,1) rolling model. In the literature, these parameters are used as $k = 4$ and $\alpha = 0.5$. However, different values of these parameters may increase the prediction performance of GM(1,1) rolling model. For this reason, the best value of these parameters is investigated by experiments. This process is called as optimized grey rolling model. k and α are optimized by using Matlab R2015b. Table 1 shows MAPE values of the training process, and the best k and the best α of each model.

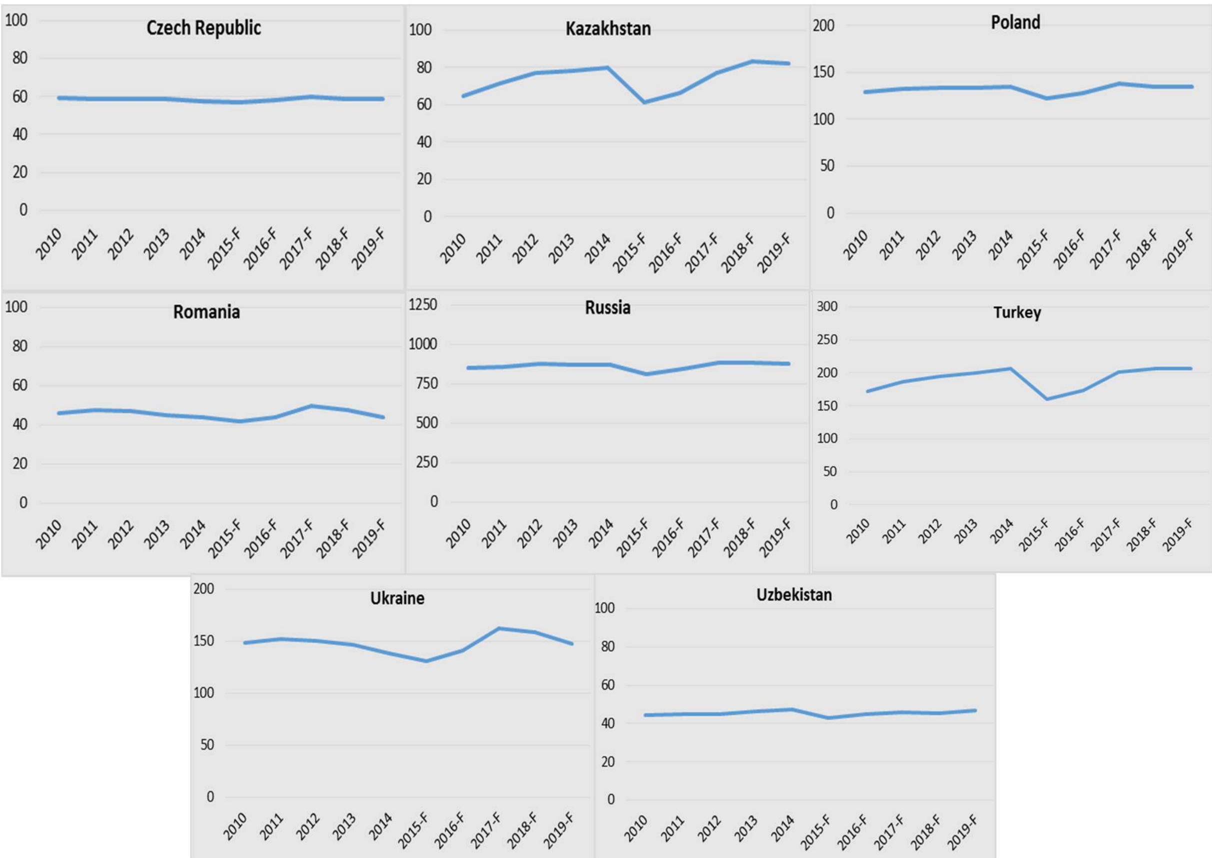
Table 1. Best k and Best α Values of Optimized Grey Rolling Models

Parameters	Czech Republic	Kazakhstan	Poland	Romania	Russia	Turkey	Ukraine	Uzbekistan
MAPE (Training)	3.28	3.98	5.22	2.88	5.86	3.24	5.45	2.97
Best k	4	4	4	4	4	4	4	4
Best α	0.4	0.4	0.4	0.4	0.4	0.5	0.4	0.4

Note: Mean Absolute Percentage Error (MAPE) ≤ 1% means "perfect," MAPE ≤ 5% means "well," MAPE ≤ 10% means "acceptable," MAPE > 10% means "incapable."

Findings

Graph 1 shows that the demand for electricity of the eight countries for the 2010-2014 period. We can see from the charts that the top three economies in electricity demand are Russia, Turkey, and Ukraine. However, Russia's electricity demand is so higher than the other seven countries' demand. Graph 1 also demonstrates that the forecasted values of the 2015-2019 period for the countries. The charts do not move significantly during this time except the year 2015. So we can interpret that trends of charts continue prominently.



Graph 1. *Demand for Electricity Charts of the Countries (Yearly, TWh)*

Table 2 indicates the forecasting results for 5-years electricity demand by each country. According to Table 2, electricity demand generally will decrease for all countries in different percentages but not show a significant change in the 2015-2019 period except the year 2015.

Table 2: Forecasted Electricity Demands of the Countries (2015-2019 Period, TWh)

Years	The Emerging European Countries								The CIS Countries							
	Czech Republic		Poland		Romania		Turkey		Kazakhstan		Russia		Ukraine		Uzbekistan	
2015-F	56.67	↓	122.50	↓	41.76	↓	159.66	↓	61.15	↓	812.13	↓	130.58	↓	43.01	↓
2016-F	57.78	↑	128.39	↑	43.67	↑	173.63	↑	66.12	↑	841.16	↑	140.99	↑	44.88	↑
2017-F	59.78	↑	137.61	↑	49.80	↑	200.63	↑	77.05	↑	884.56	↑	162.14	↑	45.84	↑
2018-F	58.46	↓	135.23	↓	47.63	↓	206.70	↑	83.31	↑	883.66	↓	158.29	↓	45.21	↓
2019-F	58.60	↑	134.63	↓	43.98	↓	206.58	↓	82.11	↓	879.45	↓	147.35	↓	46.72	↑

Table 3. Changes in Electricity Demand of the Countries (2015-2019 Period)

Years	The Emerging European Countries				The CIS Countries			
	Czech Republic	Poland	Romania	Turkey	Kazakhstan	Russia	Ukraine	Uzbekistan
2015-F	-2.29%	-9.26%	-5.09%	-22.87%	-23.56%	-6.97%	-0.32%	-8.49%
2016-F	1.96%	4.81%	4.57%	8.75%	8.13%	3.57%	7.97%	4.35%
2017-F	3.46%	7.18%	14.04%	15.55%	16.53%	5.16%	15.00%	2.14%
2018-F	-2.21%	-1.73%	-4.36%	3.03%	8.12%	-0.10%	-2.37%	-1.37%
2019-F	0.24%	-0.44%	-7.66%	-0.06%	-1.44%	-0.48%	-6.91%	3.34%

Results demonstrate that, in 2015, electricity demand of the countries will decrease sharply and in 2016 and 2017 will increase in various proportions compared to previous year. Especially after 2017, results vary by country. Table 3 and Table 4 show this difference more clearly.

Accordingly Table 3, in 2018, it is only increasing the electricity demand of Kazakhstan and Turkey while other countries have decreasing demand. In 2019, only Czech Republic and Uzbekistan have growing demand, but other countries have declining demand.

It has shown in Table 4, the difference at the end of 2019 compared to 2014. It can be understood from the Table 4; there is no significant change in electricity demand of countries except Ukraine in the next five years.

Table 4: Changes in Electricity Demand at the End of 2019 (compared to 2014, %)

Year	**The Emerging European Countries**				**The CIS Countries**			
	Czech Republic	**Poland**	**Romania**	**Turkey**	**Kazakhstan**	**Russia**	**Ukraine**	**Uzbekistan**
2019-F	1.03%	-0.27%	-0.05%	-0.20%	2.64%	0.74%	12.48%	-0.60%

Results indicate that Czech Republic, Kazakhstan, Russia and Ukraine will show a positive change in electricity demand while Iran, Poland, Romania, Turkey, and Uzbekistan will show a negative change at the end of 2019.

Conclusion

Forecasting of Electricity Demand has a fundamental importance in the energy planning of a country. In this paper, I present an analysis for the emerging European countries and the CIS countries. I developed a GM(1,1) rolling model, which forecasts iteratively, for forecasting electricity demand of these countries for the 2015-2019 period.

The findings of the study show that electricity demand of the CIS countries will increase in next five years except Uzbekistan. Also results indicate that the growth of the electricity demand in this two area will not be significant. When the results are evaluated on the side of the emerging European countries, there is no significant change in electricity demand. The Czech Republic’s electricity demand has an increasing trend about 1% while Poland, Romania, and Turkey have a negligible decreasing trend.

The findings of the study may guide the planning of future plant investments and maintenance operations in these countries. The results can also help in the decision-making process to economy politicians, business professionals, individual and institutional investors. According to the results, in the 2015-2019 period, the decision makers will not see an abnormal increasing electricity demand for these countries. So they can consider these results when planning for the next five year.

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