Forecasting aggregate and disaggregate energy consumption using arima models: A literature survey

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Abstract

The paper is aimed at contributing to the body of knowledge that exist in the area of energy forecasting by reviewing relevant empirical works on energy forecasting using ARIMA models. This paper is relevant in the face of frequent power outage and the dependence on external economies for energy supply. The study is based on secondary data obtained from electronic journals through archival studies. In all 10 articles were selected through purposive sampling method and were analysis using content analysis method. The results indicate that future energy consumption is expected to increase in economies in which these forecasts have been done. Hence, energy use must be efficient to avoid energy crisis in future. Future research should look at review of works on forecasting in a comparative manner comparing other models that have been used in forecasting energy demand. The paper is limited by the use of only secondary data. Errors in

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variables and omissions may not be known by the researchers. The findings may also lack external validity since the sample size is small and was selected by non probability sample.

1 Introduction

Forecasting of energy consumption for both domestic and non-domestic purposes is of national interest for short run and long run economic policies. The intractable energy crisis in many economies including Ghana has made the forecasting of energy consumption relevant and as such the need to get appropriate forecasting model is very crucial (Mohamed and Bodger, 2005). The consumption of energy has been increasing over the years due to factors such as population growth and technology development which aim at improving the well being of citizens. Ghana like other developing economies over the years has been faced with energy crisis at the domestics and industrial levels with cases of total blackout in the country.

In addition to this, there have been a lot of energy shortages resulting in long queues at filling stations without any acceptable reasons to the citizens. There has been many lights offs without any information of it happening. This has lead to the destruction of people's electrical appliances resulting in law suit and threat of law suits.

In view of these the researcher provides a review of empirical results on energy consumption forecasting in order to enrich our understanding of the theoretical models in the forecasting of energy consumption using ARIMA models.

Future researches will consult the paper in their studies since the paper provides results on empirical works. Policy makers, economist, energy experts will also find the paper useful in planning for the economy's energy consumption. This may help ensure sufficient energy supply in future. To the knowledge of the researchers few empirical reviews has been done on the topic and hence, the paper fills in the literature gap. The review also includes current research works on the topic.

The global objective is to contribute the body of knowledge in the area of energy demand forecasting by reviewing empirical research works on energy forecasting based on arima model. Specifically the research examines whether economies will face future energy consumption increase and whether arima

models are efficient in forecasting energy consumption.

The research provides answer to research questions such as what is the nature of energy consumption in future and why. By asking this question the researchers will want to find out if future energy consumptions will increase and why as well as variables responsible for such increase? This is done by reviewing empirical works bases on ARIMA models. According to Ediger and Akar (2007) the use of ARIMA models can efficiently be used for forecasting of energy demand in emerging economies.

The assumption underlying the paper is that future energy use will increase in developed and developing economies, since well being of human depend on energy used at the domestic and non-domestic levels.

The intention with the paper is to present findings from literature on ARIMA forecasting of energy consumption. Hence, the paper is based on secondary sources of data; text books; journals and conference papers. Data were obtained through archival study of these sources. The sources were selected for study using purposive sample method. In all 10 research papers well reviewed.

The paper is not without limitations. Since the findings are based on secondary sources of data errors in the use of secondary data may affect the findings of the paper. If data has been massage the researchers may not know. Also errors of omission may not been known by the researchers. In addition if data has been manufactured the researchers may not been in known.

The paper does not include researchers own empirical works. The paper does not proposed model for forecasting. The rest of the paper looks at the literature review, methodology, findings, conclusions and recommendations.

2   Literature Review

2.1 Forecasting Energy Consumption Using ARIMA Model (Theoretical model)

The forecasting of energy consumption can be done based on Autoregressive Integrated Moving Average (ARIMA) models. There are other models uses in forecasting energy consumption in economies. Some of the other models are multiple regression models, and artificial neural network models.

There are four steps involved in this model and these steps have been explained by Ajith and Baikunth (2001) as model identification, parameter estimation, model diagnostics, and forecast verification and reasonableness. The steps are discussed by Ajith and Baikunth (2001) as;

➢ Model identification: "Using graphs, statistics, autocorrelation function, partial autocorrelation functions, transformations, etc. achieve stationary and tentatively identify patterns and model components".

➢ Parameter estimation: "Determine the model coefficients through the method of least squares, maximum likelihood methods and other techniques".

➢ Model diagnostics: "Determine if the model is valid. If valid, then use the model; otherwise repeat identification, estimation, and diagnostic steps".

➢ Forecast verification and reasonableness. "Having estimated an ARIMA model, it is necessary to revisit the question of identification to see if the selected model can be improved. Several statistical techniques and confidence intervals determine the validity of forecasts and track model performance to detect out of control situations."

The ARIMA Model

In an empirical estimation the ARIMA model for forecasting energy consumption can be specified as in equation (1) following Mucuk and Uysal (2009).

$$Y_t = u + \theta_1 Y_{t-1} + \theta_2 Y_{t-2}, ..., \theta_p Y_{t-p}$$

$$u_t + \Phi_1 \varepsilon_{t-1} + \Phi_2 \varepsilon_{t-2}, ..., \Phi_q \varepsilon_{t-q} \qquad (1)$$

where θ and Φ are the coefficients of the ARIMA, respectively.

2.2 Empirical Review on Forecasting of Energy Consumption

Many models have been used to forecast energy consumption empirically. In some economies energy consumptions has been increasing while in other economies energy consumption has been going done. According to Ajith and Baikunth (2001) if energy consumption is more than production energy crisis may occur. This means to prevent future energy crisis production should not lag behind energy consumption.

Wang and Meng (2012) predicted energy consumption of Hebei province from 2009 to 2013. The results demonstrate that the energy consumption in Hebei province will continue to increase for the next 5 years. The writers reported that in 2013 the energy consumption will increase to 28856.26 million tons of standard coal, at the average annual growth rate of nearly 2.8% during the period of 2009 to 2013. They recommended policies measures, such as energy taxes, investments in improved energy efficiency, or changes in output composition must be considered explicitly.

Ahmad and Latif (2011) forecasted electricity demand for Selangor. The data set used in the study is electricity generated data every week for one of the electricity substation in the vicinity of Selangor from January 2009 to February 2011. It was established that expected electricity generation increased over the study period. This means energy consumption will increase over the years and policy on efficient energy usage must be put in place.

In a study by Albayrak (2010) ARIMA model was used to forecast primary energy production consumption in Turkey for the period 1923-2006. The forecasted values for the period 2007 to 2015 indicated annual increase rates of 10% for total energy consumption, 11% for street illumination, 11% for

government, 12% for residential consumption, 8% for consumption per capita, 7% for installed capacity per capita, and 9% for installed capacity.

The results also revealed that the average annual rate of total primary energy consumption will increase between 5% and 7%. The researcher indicated that:

> If Turkey continues to rely on external source of energy consumption without increase in the investment of infrastructure and also diversify energy source to use domestic source there may be energy crisis in future. The increase in energy consumption in Turkey has occurred as a result of the increase in population the researcher explained. Population growth is the main determinant of energy consumption increase.

The study by Albayrak (2010) did not assess the stationarity properties of the series and the result may be spurious and unreliable. Future empirical works must examine the stationarity features of the time series data.

Mucuk and Uysal (2009) forecasted energy demand for Turkey for the period 2007-2015 using annual data from 1970-2006. The study was bases on ARIMA model. The analysis shows that energy demand which was 97.995 TOE in 2006, will reach 119.472 TOE in 2015 by increasing at a rate of 22%. The researchers indicated that their forecasted values "are below the official forecasts of the Ministry of Energy and Natural Resources, but the estimated values are similar to the forecasts of Ediger and Akar (2007)".

Erdogdu (2007) used ARIMA model to forecast net electricity consumption in Turkey and indicated that the electric energy demand of Turkey will continue to increase at an annual average rate of 3.3% and will turn out to be 158.15 TWh in 2012.

In US Al-Fattah (2006) study developed a forecast Model for U.S. Natural Gas and established that gas production rate will maintain a production plateau of 18.7 Tcf/yr from 2005to 2008 after which gas production will increase gradually from 19.0 Tcf/yr in 2010 to reach 22.5 Tcf/yr in 2025.
The researcher predict that U.S. gas production will have an average annual rate of increase of 0.5% from 2005 to 2015 after which the average annual rate of change of production will increase to 1.2% for the period of 2015 to 2025. The forecasts also show that U.S. gas depletion rate will increase from 10.6%/yr in 2005 to 13.4%/yr in 2025.

The researcher states that while the reserves discovery rate increases, U.S. gas proved reserves are predicted to increase from 197 Tcf in 2005 to 215 Tcf in 2010, and that the gas proved reserves will increase at an annual rate of 1.3% and are expected to reach 263 Tcf in 2025. The forecast was for the period 1918-97; 1998-2004.

Ediger, Akar, and Uğurlu, (2006) developed a decision support system for forecasting fossil fuel production by applying a regression, ARIMA and SARIMA method to the historical data from 1950 to 2003 in a comparative manner.

The analysis established the fossil fuel supply and demand relation and the fossil fuel gap, and that the gap between the fossil fuel supply and demand will grow reaching 69 mtoe in 2010, 82.6 mtoe in 2020, and 103.4 mtoe in 2030. In other words, the percentage of fossil fuel consumption that will be met by the indigenous fossil fuel production will decrease to 18.64% in 2010, 15.52% in 2020, and 6.19%in 2030. This ratio falls from 80% to 19% throughout the period from 1950 to 2003, respectively.

Their findings according to the researches show that the fossil fuel production peak has already been reached; indicating the total fossil fuel production of the country will diminish and theoretically will end in 2038. According to the researchers production is expected to end in 2019 for hard coal, in 2024 for natural gas, in 2029 for oil and 2031 for asphaltite. They indicated that the gap between the fossil fuel consumption and production is growing enormously and it reaches in 2030 to approximately twice of what it is in 2000. According to the researchers:

> This gap shows clearly that the dependence on imports is increasing and it will be filled with the imported fossil fuels, mostly in the form of oil and natural gas. Therefore, there seems to be two pathways for Turkey to follow for decreasing the fossil fuel gap in the future.

The researchers proposed policy options to manage energy consumption to ensure economic growth. They indicated that:

> On the demand side, policy programs should be prepared and decisively Implemented to increase the energy productivity by substituting more efficient energy sources, by using energy more efficiently, and by switching from heavy industry to light industry and further to services in addition to energy conservation programs. On the supply side, production of domestic fossil fuel sources should be increased by employing more efficient methods and techniques if the reserve estimations are correct and by increasing reserves with the help of new discoveries.

3   Findings

Based on the review of the literature on forecasting of energy consumption the following findings are provided.

*Whenever the production of goods and services lag behind energy usage energy crisis occur. Energy supply should meet it usage for an economies not to suffer energy crisis.

*Energy consumption will increase in future. This means more energy will be need in future for productive activities in order to ensure well being of citizens.

*There is the need to manage energy usage given the limited energy resources in economies. Since energy resources are limited efficient usage of energy is very important.

*Diversification of energy sources help avoid energy crisis in an economy. Economies should not relay on only one source of energy supply. More energy sources should be exploited to meet demand.

*Investment in energy infrastructure ensures adequate energy supply. More resources should be spent on energy infrastructure facilities in order to supply enough energy for domestic and non-domestic use.

*Most economies over rely on external sources of energy consumption and this may lead to energy crisis. Domestic energy production should be taken serious so that energy can be produced domestically.

*Most economies do not use efficient energy sources to ensure sufficient energy supply.

*Most economies also do not embark on efficient use of energy use to ensure adequate energy supply.

*Economies use heavy industry and should switch to light industry and further to services to ensure sufficient energy consumption.

*Economies are not embarking on energy conservation programmes which are needed to avoid energy crisis in an economy.

*More research to ensures the discovery of more energy sources in order to ensure adequate supply of energy is not embark on by some economies.

*Variables such as population, income, energy prices, trade, stock index, and temperature influence future consumption of energy.

*Arima models are robust and efficient in forecasting energy consumption especially in linear models. Also it is the most commonly used model since it is simple to use in forecasting especially in linear models.

4   Conclusions and Policy Implications

This paper presented a review of ARIMA models used in forecasting energy consumption. Based on these findings and the review of the empirical works the conclusion is that ARIMA models are efficient and robust in forecasting energy consumption and must be used in developed and developing economies in forecasting energy consumption and other macroeconomic variables. Energy consumption will increase as population, temperature and income increase. Improvement in stock index will also increase energy consumption. Decrease in energy prices and taxes will also increase energy consumption.

Based on the review, findings and conclusions it is recommended that population, price of energy, income/output, and temperature should all be incorporated when modeling energy demand and they should arguably be considered in future energy policy decisions in economies.

To ensure sustainable energy consumption in economies; there is the need to increase investment in domestic energy infrastructural facilities; diversify domestic energy supply; reduce reliance on external energy supply; substitution of more efficient energy sources for less efficient energy sources; efficient use of energy; switching from heavy industry to light industry; and investment in research. Also energy tax must be introduced to reduce consumption and also to increase revenue for domestic investment in energy infrastructure.

Energy Prices should be increased to reduce energy consumption and also to motivate efficient use of energy. These policies must be implemented after the causal relationship between energy consumption and economic growth has been established so that growth is not impaired.

Future research should through archival study examine comparatively the robustness (better prediction power) of ARIMA models in relation to other models such as multiple regressions, artificial neural networks, and cognitive mapping.

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