Forecasting Energy Consumption and CO_2 Emission Using ARIMA in Pakistan

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Abstract: This paper forecasts the energy consumption of Pakistan which is facing a huge and permanent shortfall of electricity. Being a fast developing economy in the current era, water and power development authority has to plan power production project by keeping in mind the future needs of the country. Carbon Dioxide (CO2) emission is a major concern for environmental protection agency for fast developing economies, so we have forecasted CO2 using ARIMA forecasting modeling. Further, we forecasted Energy Consumption as this country is facing a shortfall of almost half of the total electricity consumption using ARIMA.

Keywords: *Forecasting; Energy Consumption; CO2 Emission; ARIMA*

1. Introduction

Energy plays an important role in the development of any economy [1]. Pakistan being the fast-growing economy in the world, having lowest per capita energy consumption and approximately half of the population having no access to adequate electricity [2]. This is not only slowing down the economic growth but also a concern for the basic need of any country's' citizens.

Energy consumption has a strong correlation with economic growth [3] while studying 100 countries it was found by Payne (2010) that there is not a universal direction of energy consumption and economic growth however, there exists a strong correlation between these two variables. Another main study was conducted by [4] which incorporated 100 countries. The author found a strong correlation between economic growth and energy consumption while using GDP growth of countries under study. Further, the author found that this correlation is strong in developed countries as compared to less develop or developing countries. Pakistan is having average electricity demand of 19000 MWs had a short-fall approx. 33% of total energy requirements in April 2017 [5].

Pakistan having 33% shortfall is adversely affecting the economic growth of the country. This effect will be more adverse if the country is declared fast-growing economy. National and international newspapers are ranking the Pakistan in top five fast-growing economies of the world [6]. Literature also suggests that there is a strong relationship between economic growth and CO2 emission in any country [7-11]. Energy consumption plays a vital role in economic development of an economy, and at the same time, rapid economic growth causes CO2 emission which results in environmental destruction. We will be forecasting energy consumption, and in parallel, we will be forecasting CO2 emission as these both are main concerns for the policy makers.

2. Related Work

Extensive researches have been done on forecasting of energy consumption in different countries considering different methodologies, different types of data, different length of the period under study, for example [12-15]. In case of Pakistan relation between energy consumption and economic growth is extensively explored for example [16-19]. Muhammad *et al.* (2011) explored the relationship between trade openness, energy consumption, CO2 emission and economic growth for the period of 1971 to 2009. They used Granger Causality, and bound testing approach for their study and they found a long-run relationship between these variables. Further, they found unidirectional causality from income to CO2 emission, reduction in CO2 due to trade openness in the long-run and CO2 emission is increased when energy consumption is increased.

Working on electricity consumption and real per capita income, Ahmed *et al.*(2013) used Johansen co-integration and Granger Causality test found that electricity consumption per capita, as well as energy consumption per capita, has bidirectional causality with real per capita income. They used the data from 1975 to 2009. Further, they forecasted the energy consumption for next ten years, i.e., from 2009 to 2019 using impulse response function and variance decomposition technique.

Shahbaz *et al.* (2013) in their study using ARDL approach, explored the relationship between natural gas and economic growth in Pakistan by using exports, labor, and capital in their research model. They found that there is a long run relationship between these variables. Using innovative accounting approach they found and any action to reduce usage of natural gas will result in slowing down the economic growth of Pakistan.

One more study of Nasir and Rehman, (2011) policymakers on the relationship of foreign trade, energy consumption, income and CO2 emission. By using data from 1972 to 2008, they found the existence of Environmental Kuznit Curve for Pakistan in long-run while in short run this was denied. They used Johansen

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cointegration approach in their study and concluded the absence of causality from CO2 emission to economic growth but one direction causality from economic growth to energy consumption in case of Pakistan.

Using Cobb-Douglas production function from 1972 to 2011, Shahbaz, et al. [20] found that cointegration between energy consumption (renewable and non-renewable), labor, economic growth, and capital. They employed ARDL boudn testing approach to determine cointegration. VECM Granger causality analysis appraoch was used to conclude feedback hypothesis among econimc growth, energy consumption, capital, andlabor.

In Pakistan, agriculture and industrial sectors are main consumers of energy and at the same time leading sources of CO2 emission. With the passage of time, trees are being sparse in urban areas and reduced agriculture land approximately half in 2009 as compared to 1975 are main sources of CO2 emission. Fast grwoing population and reducing agriculture land are sectors which needed immediate Government consideration to avoid environment and Green House Gases (CHG) issues [21].

Concluding, we hardly find any study to forecast energy consumption and CO2 emission in Pakistan which is the fastest growing Islamic country and top ten fast-growing economies in the World. For a fast-growing country, lack of energy forecasting is an alarming situation for Government, and this may cause severe hurdle in economic growth if not tackled properly. Further, due to lack of such policy implication and less studies on forecasting, it is important and vital to work on energy forecasting.

3. Data and Methodology

3.1 Data

We have used largest available dataset for our forecasting study. For energy consumption we have used, Energy use (kg of oil equivalent per capita) obtained from World Development Indicators WDI [22] as used by Shahbaz and Lean [23]. Annual data for energy consumption is used in our study which covers the period from 1971 to 2014.

We have used largest available dataset for CO2 emission. We have used CO2 emissions kilotons (kt). CO2 emission is measured by emissions are from the burning of fossil fuels and the manufacture of cement. These include CO2 produced during consumption of liquid, solid, gas fuels and gas flaring. Annual CO2 emission data is obtained from World Development Indicators [22] from 1960 to 2013.

Table 1: Summary statistics for key variables

This table reports summary statistics for CO2 emission and Energy Consumption of Pakistan. CO2 emission and Energy consumption data is obtained from [22]. Annual data for CO2 emission is from 1960-2013 and energy consumption is from 1971-2014. CO2 emission is measured in kilotons (kt) while Energy Consumption is measures in (kg of oil equivalent per capita).We do not find any outlier in a data set.

Variable	Mean	Median	S.D	Min	Max	Obs
CO2 Emission	68608.28	51493.85	50498.79	14154.62	163060.489	54
Energy Consumption	405.11	416.83	76.91	285.18	523.76	44

Table 2: Unit Root Test

Results obtained using Augmented Dicky Fuller (ADF) method for variables CO2 Emission and Energy Consumption of Pakistan obtained from World Development Indicators [22]. Annual data for CO2 emission is from 1960-2013 and energy consumption is from 1971-2014. CO2 emission is measured in kilotons (kt) while Energy Consumption is measures in (kg of oil equivalent per capita).Lag length is based on Schwarz Information Criterion (SIC). Critical values are -3.91, -3.42 and -3.13 at 1%, 5% and 10% levels respectively.

Variable Name	At level	At 1st Difference
CO2 Emission	-0.53	-12.81**
log Energy Consumption	4.21	-3.94***

Table 1 describe the summary statistics of key variables under study. We do not find any outlier among variables. CO2 emission has mean value of 68608.28 (kt), maximum value of 163060.489 (kt) while 54 observations are there. Energy consumption has mean value of 405.11 (kg of oil equivalent per capita), maximum value of 523.76 (kg of oil equivalent per capita) with 44 observations.

3.2 Methodology

We used for the first time, Autoregressive, Integrated Moving Average (ARIMA) methodology in the context of Pakistan. ARIMA modeling is developed by Box and Jenkins [24]. We used ARIMA methodology to forecast energy consumption and CO2 emission in context of Pakistan. This methodology has not been used in the context of Pakistan. However, it is being used extensively in domain of rest of countries [25-27]. ARIMA econometric technique state that current values of a variable depend upon own lags of that variable along with current and previous lags of the white noise error term of that variable.

$$y_t = \mu + \varphi_1 y_{t-1} + \varphi_2 y_{t-2} + \cdots + \varphi_p y_{t-p} + \theta_1 u_{t-1} + \theta_2 u_{t-2} + \cdots + \theta_q u_{t-q} + u_t$$

Given below is time series univariate ARMA (p,q) model of variable y with p lags of y_t and q lags white noise error term. In this paper, we took CO2 emission and Energy consumption one by one. When the variable of interest is not stationary at the level, then we take the first difference, and ARMA model accordingly converts into ARIMA model where we show stationary at first difference.

To specify ARIMA model, we have first check data stationarity using augmented Dickey-Fuller (ADF) test which was developed by Dickey and Fuller [28] and found that out data is stationary at first difference rather than level. Figure. 1 shows plots of actual variables while Figure. 2 shows the plot of differenced variables. Using E Views 9.0 software packages for this study, best ARIMA model is selected on the basis of AIC criteria. For this purpose number of models are run by E Views and best model is decided on the basis of AIC or BIC criteria. Unit root test results are given in Table 2; results are showing that our data is stationary at first difference.

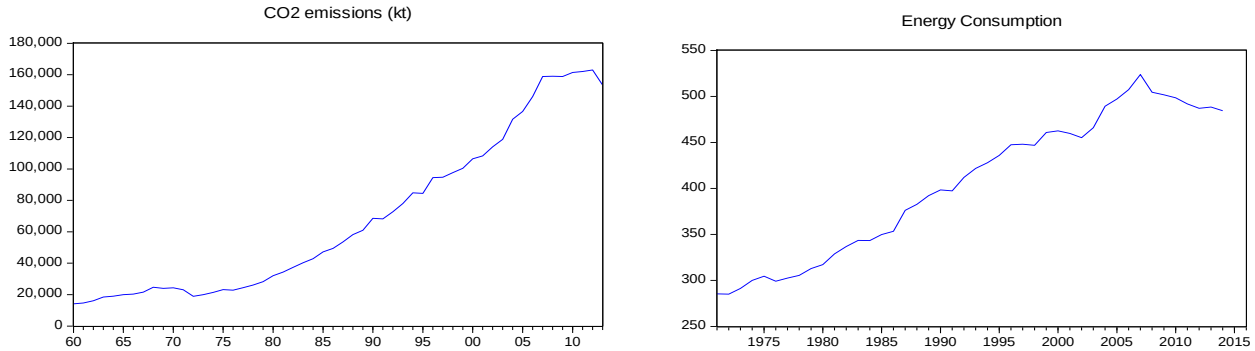

Figure.1 Timer series plot of CO2 emission and Energy Consumption of Pakistan for the period mentioned in Table 1.

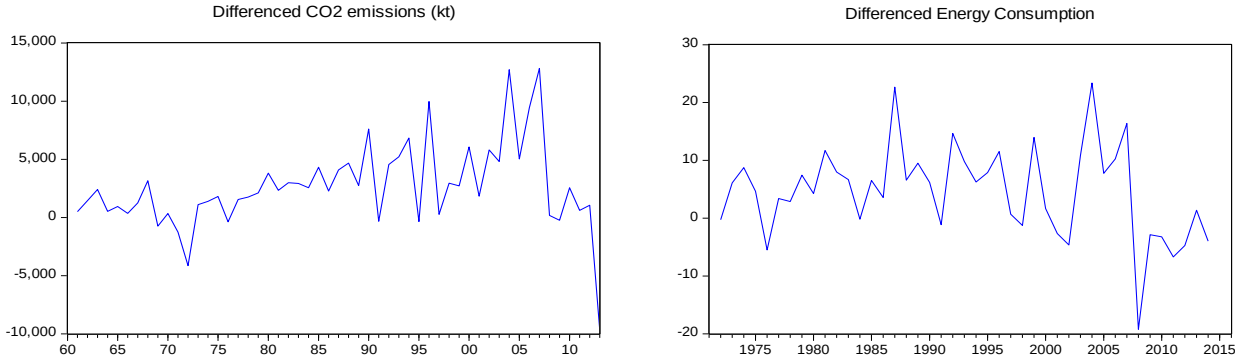

Figure 2 Timer series plot of differenced CO2 emission and differenced Energy Consumption of Pakistan for the period mentioned in Table 1.

4. Empirical Results

The best model for ARIMA forecasting is decided by model fitting using EViews 9. For this purpose, EViews9 runs top 20 models and decides the best one by AIC criterion. Figure.3 and Figure.4 show the ARIMA criteria graph of top 20 models for CO2 emission and Energy Consumption respectively. Table. 3 shows the result of the best model among top 20 ARMA models for CO2 emission and energy consumption. Best ARMA model for CO2 emission is ARIMA (2, 1, 2) and for energy consumption is ARIMA (2, 1, 1).

Table 3: CO2 emission and Energy Consumption forecasting best model

This table presents best model decided by AIC criterion for CO2 emission and energy consumption forecasting. Definitions of all variables are provided in Table 1. *, **, and *** represent significance at the level of 10%, 5% and 1% levels, respectively.

	CO2 emission	**Energy Consumption**
Constant	62279.47	5.925***
	(41060.80)	(0.047)
AR (1)	1.93***	1.99***
	(0.118)	(0.011)
AR (2)	-0.093***	-0.99***
	(-0.118)	(0.0099)
MA(1)	-0.84***	-0.99
	(1.675)	(2558.37)
MA(2)	0.348***	-
	(3.745)	
SIGMASQ	10161701***	-0.0002
	(1894149)	(0.023)
Adjusted R2	0.99	0.99
F-Statistics	2354.95***	1331***
Observation	54	44

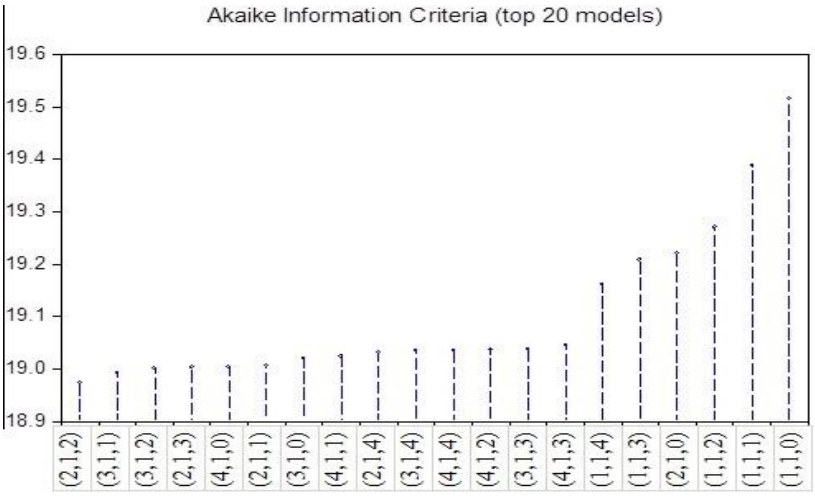

Figure.3 Show the ARIMA criteria graph of top 20 models for CO2 emission

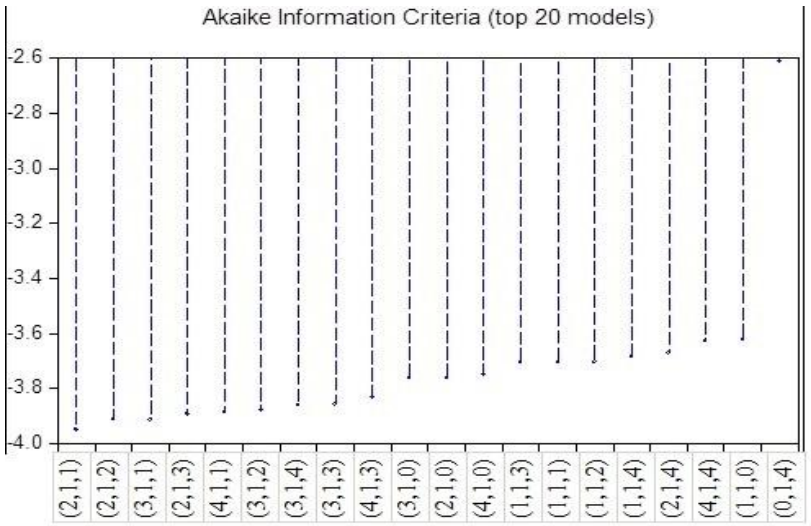

Figure.4.Show the ARIMA criteria graph of top 20 models for Energy Consumption

Discussing Table 3 in detail, in case of CO2 emission, we found that two lags of CO2 emission and two lags of white noise error term are statistically significant in determining the current value of CO2 emission. AR(1) has coefficient of 1.93 while AR(2) has coefficient of -0.093. MA(1) has coefficient of -0.84 while MA(2) has positive coefficient of 0.348.In case of energy consumption, two lags for energy consumption are significant in determining current value of energy consumption of Pakistan. White noise error term is not statistically significant in determining energy consumption. AR(1) has positive coefficient of 1.99 while AR(2) term has negative coefficient of 0.99. MA (1) and MA(2) terms are not statistically significant.

To analyze the forecasted performance, root mean square error (RMSE), Mean Absolute Percent Error (MAPE) and Mean Absolute Error (MAE) are used. Figure III and Figure IV shows the results of above mentioned three error techniques to measure the performance of forecasting model of CO2 emission and Energy Consumption respectively. The value of RMSE is very small and is being used as a benchmark for forecasting analysis in both models of CO2 emission and Energy Consumption. The value of Theil- U is which is between 0 and 1.

5. Conclusion

We forecasted energy consumption and CO2 emission of Pakistan for next ten years. We used ARIMA methodology for said purpose. Our fitted ARIMA models were ARIMA (2, 1, 2) for CO2 emission and ARIMA (2, 1, 1) for energy consumption. Pakistan being fast-growing economy is facing severe shortfall of electricity consumption which is impacting its economy. Further, due to being in top five fast growing economy in last fast years, the CO2 emission is an important factor as Kuznets curve tells us that CO2 emission increases when any economy moves from less developed country to the developing economy and CO2 emission decrease when an economy moves from developing to developed economy. CO2 emission is important for environmental protection agency so that measures may be taken to minimize the losses to the environment and further manufacturing plants resulting in less CO2 emission may be installed and encouraged by the Government.

Crises of energy are of most importance as these crises are the hindrance to growth of economy and at the same time results of forecasting are guidelines for policymakers in developing power production plants to meet the future needs of Pakistan. Our results may be used by

policymakers to help grow this economy in positive direction.

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