CHAPTER - I

INTRODUCTION

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CHAPTER-I
INTRODUCTION

This introductory chapter provides a glimpse of the works presented in the thesis. For convenience the chapter is divided into some sections. Section 1.1 introduces the background and depicts the main problem undertaken in the study. In section 1.2 relevant literature and previous works are briefly reviewed. The main objectives of the study are presented in section 1.3. The data used in the study and their sources are given in section 1.4. Methodologies adopted for selection of the best predictive models in the study are briefly discussed in section 1.5. The organisation of the contents of the whole study is mentioned in section 1.6. Section 1.7 deals with the findings of the study in a nutshell. Finally, the policy which may be implemented from the findings of the study is outlined in section 1.8.

1.1. BACKGROUND OF THE STUDY

Energy is an important element of the socio-economic political world in which we live. We must pay due attention to the energy factor while planning for the future because the energy system shadows very closely the economic system (Hutber 1984; p.2). Again, given similar economic characteristics and profiling the same energy scenario, Ebohon (1996; p.447) shows that energy plays a key role in economic development for developing countries. Bangladesh Government has been making plans every five-year for its future development since its independence. In all of the earlier plans the authority gave emphasis to minimize the gap between the production and the consumption of gas and electricity. In the plans, the authority had to provide some estimated figures of the consumption of energy for the next five-year of planning for convenience of production and supply planning. They do not mention any method used for estimation/prediction purposes. It has transpired that there always remained a significant gap between their prediction and the actual consumption.

Presently oil, gas, power and mineral resources' condition in Bangladesh is very weak and their per capita consumption is very low. The government is considering natural gas and power as two of the important elements for its economy. That is why three of the important objectives regarding gas and power sectors considered in Fourth Five Year Plans (1990-91 to 1994-95) of Bangladesh were i) to improve the total gas system ii) to reduce the present gap between production and consumption of gas and iii) to encourage production and efficient use of electricity.

Hence, it is clear from the above discussion that future socio-economic development of a developing country like Bangladesh partially depends on the future consumption pattern of energy system. Moreover, presently, the demand of natural gas and power is increasing with respect to its supply. So, the Government of Bangladesh is in a position to take intensive care for improving the supply of energy, subject to its availability. Eventually, the question like ' supply to what extent ?' has to be faced by the planners for proper planning. The answer to such a question lies in searching the best predictive model(s) by which future energy consumption can be predicted efficiently. This study is an effort in that direction.

1.2. REVIEW OF LITERATURE

The work on the energy consumption in Bangladesh, focussing particularly on modelling and forecasting aspects, is rather scarce.

Paul and Haque (1995) performed a work on the modelling and forecasting the total gas consumption in Bangladesh using ARIMA methodology. They verified the fitness of three pre-selected ARIMA models. Although primarily they considered AME, MAPE, RMSE and SBC criteria for model selection, finally they selected the model on the basis of MAPE only. They showed that ARIMA(1,1,1) model outperformed the gas consumption in Bangladesh. Paul (1994) worked with the problem of finding characteristics of the sector wise gas consumption and total electricity consumption. The work focussed on growth types of modelling and determining the factors which affect the aforesaid energy consumption. The selection was made depending on the value of R^2 and it was found that the cubic model fitted the selected energy consumption rather well. In the present study, the fitness of ARIMA models and growth models to the total gas and electricity consumption is also restudied using some latest tools for the selection of models. The selected models are then compared with ANN models with respect to their predictive performances.

Some other available works on 'non-modelling' aspect of energy consumption in Bangladesh and elsewhere are reported here.

Zahir (1993) worked with non-oil sector energy consumption with the view to identifying the potentials for developing non-oil energy resources in OIC member countries using some suitable coefficients and indices. Hossain (1985) worked with the planning and development aspect of the gas sector in Bangladesh. No analytical research on modelling and forecasting the electricity consumption has yet been performed.

Besides these, considering the extensive use of the forecasting of energy consumption, different types of empirical works on gas and electricity consumption in different countries are undertaken by some authors. Some of the very recent works are the following:

Ebohon (1996) made an effort to observe the exact relationship between energy and other factors of production, such as GDP and GNP in order to see whether energy complemented or substituted the considered factors of production in Nigeria and Tanzania. He used multiple regression analysis for this purpose and showed that the relationship between energy and economic factors was complementary. Wilson et al.(1994) worked with the energy efficiency aspect in Australia. They defined the energy efficiency as the ratio of value produced to the energy consumption after allowing for the effects of changes in relative sizes of sectors which had different intensities. They showed that energy efficiency in Australia was improved by around 10% in total energy consumption and 9% in final energy consumption between 1973-74 and 1990-91. Quanguo *et al.* (1994) compared China's present and past energy consumption using some tables. They found that both of coal production in the composition of energy consumption and the utilization efficiency of energy in China were low. They also found that serious environmental pollution was caused by coal consumption and per unit energy consumption in China was higher than some developed/advanced countries. Finally, they recommended some strategy and policies for energy consumption in China. Eden (1993) studied present and future energy condition in the world in general. He outlined two scenarios for energy and electricity consumption for the year 2050. He showed that the growth in energy demand had been much greater in developing countries than in industrial countries, particularly, since 1973. Per capita demand in developing countries increased by more than 50% since that time and total demand in this group had more than doubled. On an average, per capita electricity consumption was 0.4 MWH/A in the developing countries. In a targeted growth by the year 2050, per capita use in DEVC would increase more than five folds to 2.3 MWH. The continuing growth of population in the DEVC coupled with substantial growth in per capita use of electricity, led to fairly high growth rates for total electricity demand of the order of 4.1% per annum and 3.5% per annum for targeted efficiency. These were about half the recent historical growth rates for DEVC. Lee *et al.*(1992) worked on short-term electric load forecasting in Korea applying ANN models. For this purpose he applied the back-propagation learning algorithm in two different approaches, *viz.* static and dynamic. He showed that performance of dynamic approach was better than static approach in the sense that dynamic approach used much less number of neurones and weights, trained faster and gave better results. Testing the results using historical utility load data, they showed that the use of ANN model in short term forecasting was satisfactory. Ho *et al.*(1992) proposed a multi layer NN with an adaptive learning algorithm for short term electricity demand in Taiwan. Effectiveness of their proposed algorithm was demonstrated performing load forecast and compared with that of conventional algorithms. They showed that accurate load forecast could be achieved by their proposed adaptive learning algorithm in a very efficient way. Engel *et al.*(1992) formulated some univariate linear regression forecasting equations for hourly peak electricity demand in Michigan. They compared performances of the models using some criteria. They showed that univariate linear regression with one day lag was simply a more sophisticated rule of the thumb for forecasting daily system peak.

Some other works are as follows:

Ayyash *et al.*(1985) studied the electricity consumption in Kuwait. Mashayekhi (1985) worked on the residential and commercial gas sector of Pakistan. Lyness (1984) worked on the gas demand in Great Britain. Rhys (1984) worked on electricity demand in England and Wales. Skinner (1984) worked on the electricity demand in England. Beirlein *et al.*(1981) studied the consumption of electricity and natural gas in the North Eastern United States.

Besides these, some available empirical studies on the comparative aspect of forecasting performance of econometric models are as follows:

Ferrer *et. al.*(1997) investigated the forecasting ability of unobserved component models compared to the univariate ARIMA approach for five types of monthly automobile sales in Spain. Accuracy of forecasting ability was assessed by comparing some measures of forecasting performance based on out-of-sample predictions. They showed that the performance of ARIMA approach was fair by most of the performance criteria. Jamal and Abdullah (1996) developed an econometric model of sinusoidal type to forecast the electricity consumption and to study the impact of ambient temperature on consumption in the Eastern Province of Saudi Arabia. They compared the results of this model with that of simple linear regression and quadratic models. They showed that simple regression model gave better results followed by sinusoidal and the quadratic model. Kohzadi *et. al.* (1996) compared the predictive performance of ANN technique with ARIMA types of models using data of live cattle and wheat price. They used AME, MAPE and MSE criteria for comparison of prediction accuracy. They also performed turning point test suggested by Cumby and Modest (1981). Nizami and Garni (1995) performed a comparative study on the predictive performance of ANN technique with that of regression technique. They used chi-sqaure (goodness of fit) criterion for comparison of prediction performance. Chiang *et. al.* (1996) defined and developed a back-propagation neural network and compared its predictive performance with that of linear and non-linear regression techniques. They used net asset value of mutual fund data for their study. For comparison they used MAPE Criterion only. They showed that the neural network significantly outperformed regression models in the situation with limited data availability. Leshno and Spector (1996) verified the predictive performance of ANN technique in comparison with classical multivariate discriminate analysis (MDA) using data of bank bankruptcy in New York. For comparison purposes they used type I, type II and total error of the selected models. Chakrabarty *et. al.*(1992) compared the performance of multivariate neural network technique with ARMA model using the data of monthly flour prices in the Buffalo, Minneapolis and Kansas Cities. They used MSE and coefficient of variation criteria for comparison. Tang *et. al.* (1991) compared neural networks and Box-Jenkins models, using international airline passenger traffic, domestic car sales and foreign car sales in the USA. They concluded that Box-Jenkins models outperformed the neural net models in short-term forecasting. On the other hand, neural net models outperformed the Box-Jenkins models in the long run.

All of the above authors showed that ANN techniques performed better for prediction than the traditional models considered in their respective study.

In this study, attempt is made to compare the predictive performance of three types of models, *viz.* growth types of models, ARIMA types of models and the ANN techniques using as many as seven criteria. The best models of each of three types are selected analytically. Predictive performances of these three types of models to the log-transformed data are also compared.

1.3. OBJECTIVE OF THE STUDY

The literature reviewed above indicates that no notable initiative has yet been undertaken to forecast the energy consumption in Bangladesh. The basic objective of the present investigation is to fill this outstanding gap and it is hoped that the forecasts will be useful for future energy planning. The detailed objectives are:

i) to find the characteristics and structural models of the gas and power consumption,

ii) to determine analytically what types of available econometric models fit best to the gas and power consumption in Bangladesh,

iii) to develop an ANN type of model which fits gas and power consumption adequately,

iv) to compare the predictive performances of the models on the basis of available statistical/econometric criteria,

v) to select the most predictive model by comparative study, and finally,

vi) to predict the energy consumption by the selected model(s).

1.4. DATA USED IN THE STUDY

To achieve the above objective, yearly data of gas consumption (GC) in 10^6 cft in Bangladesh for the years 1970-71 to 1992-93 and that of electricity consumption (EC) in MKWH for the years 1976-77 to 1992-93 (available as on December 1995) are collected from annual reports of Bangladesh Gas, Oil and Mineral Corporation(BOGMC) 1993-94, different issues of Statistical Year Book of Bangladesh and annual reports of the Bangladesh Power Development Board (BPDB) 1993-94. Data regarding some other correlated factors such as annual gas production (GP), annual petroleum and petroleum products consumption (PETC), annual gross domestic products (GDP) and annual populations (POP) are also collected from different issues of Statistical Year Book of Bangladesh.

1.5. METHODOLOGY

In order to proceed with the modelling and forecasting of the gas and electricity consumption in Bangladesh, latest devices of econometric methods are employed, because, it is already well established that econometric methods are the best methods of forecasting future patterns of a series. For example, Armstrong (1978; p.552) stated '.....econometric methods provide more accurate short range forecasts than other methods'. He performed a survey of the experts' opinion on accuracy of econometric predictions and found that 35% of the respondents viewed econometric methods as 'significantly' accurate, whereas 62% viewed such methods as somewhat accurate. Brown (1970; p.441) asserted that econometric methods were originally designed for short-range forecasting. Worswick (1974; p.118) also stated that econometric methods in short range forecasting were more fairly generally recognized. Again, in favour of the application of econometric methods for energy forecasting, Rhys (1984; p.28) stated that econometric methods represented a major intellectual advance over simple trend projections; they provided a means to explain and measure trends in total energy use or electricity uses in terms of cause and effect. Philips (1984) used and recommended econometric methodology as the predominant methodology for energy forecasts.

Hence from the above fact it is clear that the use of econometric methods for modelling and forecasting the energy consumption in Bangladesh is quite justified. The step-wise methodology employed in this study is discussed below in brief. It must be mentioned here that we have followed the same methodology for gas and electricity consumption separately.

Step I. ***Salient features and structural relationship of energy consumption***

In this step, statistical properties, such as average consumption, standard deviation of consumption and growth rate of energy consumptions are observed. Energy efficiency defined by Wilson *et. al.*(1994; p.287) is also observed. Correlation coefficients of energy consumptions with some related factors are computed to examine their interrelationship. Structural relationship of energy consumption with other related factors are also estimated through multivariate regression analysis in order to identify the factors responsible for variations in energy consumptions. For this purpose the models with appropriate regressors are selected by two methods. Firstly, applying step-wise regression analysis considering all possible combination of regressors. In this case the final models with appropriate regressors are selected comparing values of the criteria like adjusted R^2 (Johnston 1991; p.177), mean square error (MSE), C_p (Mallows 1973; p.662, Montogomery and Peck 1992; p.271), PC (Amamiya 1976; p.7), PRESS (Allen 1974; p.126). Secondly, more influential factors are selected using factor analysis (Srivastava and Carter, 1983). At this stage all regression models are fitted using SPSSPC+ software.

However, the structural models are estimated using the total set of data with the view to determining the factors which affect the energy consumption. These methods are not used for forecasting purposes. Although some analysts, for example, Engel *et.al.* (1992), Jamal and Abdullah (1996), showed that structural models sometimes gave better model for prediction for out-of-sample data, these were very difficult to use in predicting future data. Difficulties of using structural models for prediction purposes were also mentioned by some other analysts, such as Ma (1989; p.394), Messe and Rogoff (1983; p.3), etc. Moreover, Hall (1994, p.21) stated that the advantage of using univariate models in forecasting was that spurious correlation between variables would not give misleading forecast and provided a very simple and robust approach to forecasting.

Due to the above-mentioned limitations of using structural model for forecasting, we prefer to investigate the fitness of univariate/time-dependent models including a comparison of their forecasting performances.

Step II. *Partition of data in different periods*

The available consumption data set for gas and electricity is split into two parts. The first part is the observation set, commonly known as estimation period and the second part is the prediction set, commonly known as validation period. The first part is used for model fitting and the second part is used to verify the prediction performance of fitted models. The consumption figure for second half is predicted using the models fitted with data in estimation period. This type of post-sampling study for model fitting and prediction was advocated by some econometricians, for example, Cooper and Weeks (1986), Montogomery and Peck (1992) and also used by Nizami and Garni (1995), among others.

Thus, for gas consumption data the period 1970-71 to 1988-89 is considered as the estimation period and that of the period 1989-90 to 1992-93 is considered as validation period. Similarly, for electricity consumption data the period 1976-77 to 1990-91 is considered as estimation period and that of the period 1991-92 to 1992-93 is considered as validation period. Accuracy of the models are also compared on the basis of their performances in total period.

Step III. ***Application of growth models***

In this step, fitness of ten types of time-dependent regression models, commonly known as growth models, to the energy consumption using data in estimation period are investigated. The types considered in this study are linear, logarithmic, inverse, quadratic, cubic, compound, power, S, growth and exponential. Primarily three of the more outperformed models are selected on the basis of the values of adjusted R^2. The consumption figures for these three models are predicted for validation period. Then, the most predictive model or the best of these three models are selected comparing values against absolute mean error (AME), root mean square error (RMSE), mean absolute percent error (MAPE) in all the three periods.

It is to be noted here that Kennedy (1985, p.210) suggested the use of log-transformation of a series for better ARIMA model and Lachtermacher and Fuller (1995, p.391) showed that some type of Box and Cox (1964) transformation improved the performance of neural network models. So, fitness of all the three types of models, viz., growth models, ARIMA models and ANN models, to the untransformed series and to the log-transformed series are studied separately. In this step fitness of all of the above-mentioned ten models to the log-transformed series are also investigated. The variable, untransformed or transformed, for which the model is to be selected is determined using the two statistics viz. r^2 and T, proposed by Sclove (1970, p.394 equations 7 and 8 for T). However, in this study results obtained from both types of series are reported for the convenience of use.

Step IV. *Application of autoregressive integrated moving average (ARIMA) model*

In this step Box and Jenkins' (1976) models or popularly known as ARIMA(p,d,q) types of models are fitted to the untransformed and log-transformed energy consumption using data in estimation period. Detail of this ARIMA methodology is available in text books (for example, among others Box and Jenkins 1976, Pankratz 1986; Pindick and Rubinfeld 1986; Hall 1994). For fitting and selecting the tentatively adequate models, three steps described by Box and Jenkins (1976, p.19) are followed. In this case too ten forms of ARIMA models are fitted to each of all types of series. These forms are chosen observing the nature of autocorrelation function (acf) and partial autocorrelation function (pacf) plots of original series, differenced series and error series. Thus in this study, the proper order of autoregression is determined comparing the values of C_p Criterion (Mallows 1973, p.662), $\phi(p)$ criterion (Hannan and Quinn 1979; p.191), the corrected Akaike Information Criterion (Hurvich and Tsai 1989, p. 300), Schwarz Information Criterion (Schwarz 1978; p.463) for all the models. The appropriate degree of differencing in order to make the series stationary, is determined using the $\delta(p,d,q)$ criterion (Koreisha and Pukkila 1993; p.401, equation

4). In addition to comparing values of these criteria, the nature of acf and pacf plots are also observed. The order of moving average is determined by observing the acf and pacf plots. Analysis in the fitting stage is performed using the software SPSSPC+.

In this case too, three of the closely better performed models are selected for comparison. Using these three models the consumption figures are predicted for validation period. Thus, the most predictive ARIMA type of model is finally selected comparing the values of these three models against AME, RMSE and MAPE in all the three periods. The predictive performance of this finally selected model is compared with the models selected in steps III and V.

Step V. *Application of artificial neural networks (ANN) technique*

An artificial neural network (ANN) is a comparatively recent development in the field of pattern recognition and general function estimation which is becoming increasingly popular in varied fields of human enquiry. The main developments in this field are done by cognitive scientists and recently the models' usefulness as an answer to the statistical regression problem and time series forecasting problems is being looked into by many authors.

Literature on this technique is available in many text books, among others Carpenter *et al.*(1987), Kohonen (1989), Aleksander and Morton (1990), Kosko(1994). The programming of this technique in C++ language is also available in Rao and Rao (1996). The applications of this technique, particularly in forecasting the time series data, are also available. For example Kohzadi et. al.(1996), Chiang *et. al.*(1996), Nizami and Garni(1995), Leshno and Spector (1994), Ho and Yang(1992), Chakrabarty *et.al.*(1992), Tang *et.al.*(1991) among others.

In this case about ten forms of models with varied numbers of hidden layers in a single input layer are trained using the data in estimation period for untransformed and transformed series separately and the values of MAPE and RMSE are observed in each case. Output of three more adequately fitted models are reported. The consumption figures for validation period are predicted using these three forms. Then the final model is selected on the basis of the values of AME, RMSE and MAPE in all the three periods. The predictive performance of this finally selected model is compared with the models selected in steps III and IV.

Step VI. *Comparison of forecasting performances and selection of final model*

It is mentioned in section 1.2 that some comparative studies on the predictive performance of different types of models have been performed by some authors. Most of them used AME, MAPE and RMSE criteria for comparison purposes. Pair wise predictive performance comparison has also been carried out. In this study, in order to select the best predictive model from three types of analytically selected models in steps III, IV and V, predictive performances of them are compared in two stages using some additional criteria.

Thus, in the first stage, tests of equal accuracy of the predictive performance of pair wise models are undertaken. For this purpose the non-parametric test statistics like sign tests, Wilcoxon's signed rank test and MGN test are employed. These tests are proposed by Diebold and Mariano (1995). In addition, the tests of encompassing-in-forecasts are also applied to test the hypothesis that model i encompass model j, against the two alternatives - either model i encompasses model j or model j encompasses model i. This type of test is proposed by Chong and Hendry (1986) and applied by Hallman and Kamstra (1989) and Donaldson and Kamstra(1996).

In the second stage, predictive performances of selected models are compared considering individual performance using values of some statistical/econometric criteria computed for each of the three periods. The criteria considered in this study are R^2, AME (absolute mean error), RMSE (root mean square error), MAPE (mean absolute percent error), SAPE ('smoothed' absolute percent error), Chi-square, Theil's U (Theil 1961, p.32; Leitch and Tanner 1991, p.581) and PC (prediction criteria) (Amamiya 1976; p.7).

The predicted values obtained by different types of selected models along with the observed values are also reported at the appropriate place.

After the above mentioned analytical modelling and forecasting performance comparison, the best predictive model for each of untransformed and transformed data series is selected and recommended for efficient prediction of gas and power consumption in Bangladesh.

1.6. ORGANIZATION OF THE CONTENTS

The contents are organized in different chapters. Each chapter is a combination of different sections and subsections. Chapters are mainly comprised of different steps of methodology separately. The main contents of different chapters are as follows:

Chapter II constitutes with the analysis and results of the step I, *i.e.* it discusses the salient features and structural relationship of energy consumption. Chapter III consists of the analysis and results of step III, *i.e.* this chapter focuses on the application of growth models to the untransformed and transformed energy consumption data. In addition logic of transformation is also discussed in this chapter. Chapter IV contains the analysis and results of step IV, *i.e.* it contains the application of ARIMA methods to the untransformed and transformed energy consumption. Chapter V deals with the analysis and results of step V, *i.e.* this chapter discusses the application of ANN technique to the untransformed and transformed energy consumption. Chapter VI contains the analysis and results of step VI, *i.e.* this chapter discusses the analysis of the comparison of predictive performance of different selected models. Each chapter contains a summary of the results obtained. Finally, Chapter VII contains concluding remarks including suggestions for further study and an epilogue.

1.7. FINDINGS OF THE STUDY

For succintness, the findings of the study obtained from the analysis discussed in methodology section are presented here.

i) Average gas consumption (GC) in Bangladesh is 73646.261 X 10^6 cft. per annum and that of the consumption of electricity (EC) is 2844.47 MKWH, gas consumption efficiency in Bangladesh is 91.68%.

ii) There exists strong correlation of gas consumption with GP, EC, PETC, POP and GDP. Similarly, electricity consumption is strongly correlated with GC, PETC, POP and GDP.

iii) Step-wise regression analysis for selecting the subset of regressors using the selection criteria like MSE, $\bar{R}^2$, C_p, PC, PRESS shows that {GP, EC} are so far the best subset regressors for expressing the gas consumption by linear regression model. The same type of analysis shows that {GC, PETC} are the best subset regressors for electricity consumption.

iv) Factor analysis by maximum likelihood method extracts the same two factors GP and EC as step-wise regression analysis for gas consumption which together explains 95.64% of total variation. Similarly in case of electricity consumption, factor analysis extracts the same two factors GC and PETC as in step-wise regression which together explains 93.27% of total variation.

v) Finally, regression model GC = -3400.31 + 0.89 GP + 23.22 EC is selected for gas consumption and regression model EC = 1672.84 + 0.359 GC - 1.215 PETC is selected for electricity consumption in Bangladesh.

vi) Investigation toward the fitness of as many as ten types of growth models to the gas consumption data are performed. The models are fitted to the data of observed period. The validations of models are verified using data of validation period. The performances of three well-performed models (on the basis of R^2) are compared on the basis of the values of criteria like Adjusted value of R^2, AME in three periods, MAPE in three periods and RMSE in three periods.

vii) Quadratic model is found to outfit all other models, with respect to the criteria, to the untransformed gas consumption.

viii) Predictive performance of the quadratic growth model is the best for log-transformed gas consumption too.

ix) Untransformed and log-transformed electricity consumption can also be best predicted by quadratic type of growth model.

x) Log-transformed series of both gas and electricity consumption is preferable to the untransformed series as dependent variable in order to fit quadratic models.

xi) Gas consumption data (untransformed and transformed) and electricity consumption data (untransformed and transformed) are non-stationary. In order to fit ARIMA models to these data they are made stationary by differencing. The degrees of differencing is determined by observing the nature of acf and pacf plots of differenced series and employing the criterion suggested by Koreisha and Pukkila (1993).

xii) The order of autoregression is determined by employing Mallows (1973) criterion, Schwarz (1978) criterion, Hannan and Quinn (1973) criterion and Hurvich and Tsai (1989) criterion. In this case too, nature of acf and pacf plots of original series (transformed and untransformed) are observed.

xiii) Ten types of tentatively selected ARIMA models (obviously, on the basis of the criteria mentioned above) with varied values of p,d,q are estimated and their validities are tested using AME, MAPE and RMSE in all the estimation, validation and total periods. Thus as far as the criteria selected for diagnostic checks are concerned, it is found that ARIMA(1,2,1) model out perform other models for untransformed gas consumption series and the same type of ARIMA model is also found to adequately fit the log-transformed gas consumption series.

xiv) ARIMA(1,2,1) model is selected as the best ARIMA model for untransformed electricity consumption data series, while, in case of log-transformed electricity consumption, ARIMA(1,1,1) model is found to outperform other types of ARIMA models.

xv) The untransformed gas consumption data is preferable to the log-transformed data for ARIMA modelling, and in the case of electricity consumption data, no such conclusion can be drawn.

xvi)ANN model with a single hidden layer consisting of a single neuron has been selected as the best ANN model for both of the untransformed and transformed gas consumption. The input layer containing a single neuron corresponding to the time period and the output layer containing a single neuron corresponding to the annual gas consumption figure.

xvii) Again, ANN model with a single hidden layer consisting of two neurons in each layer has been found to best suit the untransformed electricity consumption, while, ANN model with a single hidden layer containing a single neuron has been selected as the best ANN model for log-transformed electricity consumption.

The main findings of this study towards comparison of the predictive performances of the selected three types of models and selection of the best model produces the following results.

xviii) Tests of encompassing-in-forecasts for untransformed gas consumption show that none of the three competing models encompasses any one of the other two. MGN and WSR test for pair wise equal accuracy comparison indicate that there is significant difference between forecast accuracy of ARIMA and ANN models. On the other hand, no significant difference between the prediction accuracy of the growth and ANN models, and growth and ARIMA models are found by pair wise equal accuracy tests. Again, forecasting performance of ANN model supersedes other two models by maximum criteria of individual predictive performance comparison. So, ANN model is selected as the best predictive model for untransformed gas consumption followed by quadratic model and ARIMA model.

xix) Interpretation of the results of pair wise forecast accuracy tests and individual prediction performance tests for log-transformed gas consumption is the same as that of untransformed series. Thus, in this case too, ANN model is selected as the best predictive model for log-transformed gas consumption followed by quadratic model and ARIMA model.

xx) For untransformed electricity consumption, tests of encompassing-in-forecasts show no significant difference between the predictive accuracy of three competing models. The sign test, WSR test and MGN test reveal that predictive performance of ANN model significantly differs from that of growth and ARIMA models. While no significant difference is found in predictive accuracy of growth and ARIMA models. Neither of the growth and ARIMA models uniquely outperforms either by individual predictive performance accuracy tests. However, the values of the most of the criteria are in favour of better performance of the growth model. So growth model is considered as the best predictive model for untransformed electricity consumption.

xxi) It is found by the tests of encompassing-in-forecasts and pair wise accuracy comparison tests that there are no significant difference between predictive performances of three types of selected models for log-transformed electricity consumption. Individual predictive performance accuracy also reveals that predictive accuracy of all the three models are almost the same. In this case too predictive performance of growth model is a little bit better so far as the values of the criteria are concerned. Hence, growth model is selected as the best predictive model for log-transformed electricity consumption followed by ANN model and ARIMA type of model.

1.8. POLICY IMPLICATIONS

Forecasting and policy evaluation are very closely related in a feedback system. In general, the need for forecasts arises from the fact that the planners need to have a clear view about the future behaviour of the factor(s) of interest. Knowledge about this behaviour pattern is essential for effective economic planning. Energy sector is perhaps the most significant one that needs a thorough management. Hence, modelling energy consumption (in Bangladesh) assumes an extremely important role towards reducing the energy wastage and thereby furthering economic progress. It is expected that the models selected in this study will be helpful for policy makers as well as the concerned authority in efficient energy management in Bangladesh.