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Forecast Model for Transmission of Natural Gas of Loopline and Mainline: A Time Series Analysis using Box Jenkins Approach

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Abstract

Suitable forecast model for Natural Gas Transmission System of Loopline and Natural Gas Transmission System of Mainline has been finalized. Using Box-Jenkins Approach (1976), Auto-Regressive Integrated Moving Average (ARIMA) model has been produced. Box-Jenkins Approach (1976) included Stationarity of the series, estimation of correlogram for identification of order of ARIMA models and selection of most adequate and appropriate model by applying diagnostics checks. Later on, by comparing values of Schwarz Information Criterion (SIC), Akaike Information Criterion (AIC), Root Mean Square Error (RMSC), Theil Inequality Coefficient (TIC) and Standard Error (S.E.) of Regression for each model, forecast model is finalized. In the end, forecasts have been made using selected models and compared these forecast values with the actual values for 2010 in order to check the accuracy of the model.

Keywords

Box-Jenkins (1976) approach, ARIMA model, Time series forecasting, Transmission of natural gas of loopline, Transmission of natural gas of mainline

1. Introduction

The transportation of natural gas is a difficult task use to be performed by natural gas industries. In transportation situation, natural gas has to be move from one place or location to another.

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Different types of transportation resources might be practice to transfer natural gas but transferring of large quantity of natural gas through pipelines is considered to be the most reasonable, economical and safe way. Furthermore, improvement in repairing techniques of pipelines makes it famous and comfortable to use at world-wide level from last few decades.

Natural gas has three forms of pipelines, namely; gathering system, distribution system and interstate pipeline system. In order to transfer gas from well to purification plant, we use gathering system. This type of pipeline has small diameter. Furthermore, there are two types of pipeline namely; intrastate and interstate. Interstate pipeline is that by which we transfer natural gas across the national borders while intrastate pipeline is that which carry natural gas within the national boundary. Interstate pipeline are normally from 24 to 36 inches in diameter. Transmission pipeline can be as small as of 0.5 inches in diameter and over all such pipelines are from 6 to 48 inches in diameter. In transmission system, there are two types of lines; Mainline and Loopline. Mainline pipes are those which are 16 inches to 48 inches in diameter. There is another pipeline, which is called lateral pipelines, this pipeline delivers gas to or from the mainline, and it is six inch to sixteen inches in diameter. Pipelines are normally called line-pipe. It is made up of carbon steel material; on the other hand, distribution pipes are made up of plastic.

Nathan (2013) discussed political analysis of pipeline projects. He inspected the security concerns, role of different players, their positions, goals and strategies as well. According to him, India is not gifted with considerable resources of natural gas due to which it must has to communicate with neighboring regions as they are giving rise to projects, namely, Turkmenistan–Afghanistan–Pakistan–India, Iran–Pakistan–India and Myanmar–Bangladesh–India. Growth of natural gas in both the countries would depend on import of gas but cooperation has not been appearing in India and Pakistan, exploration tasks and success of their projects depends on cooperation between these two countries (Sen, 2000).

Turkmenistan, Afghanistan, Pakistan and India signed an agreement with Asian Development Bank (ADB) on December 11th, 2010, namely; Tapi Gas Project, in order to overcome their shortfalls. In 2010, Pakistan signed agreement entitled Indo-Pak-Iran pipeline Project with Iran regarding pipeline, then in the mid of 2010, Iran completed pipeline project. If this project will be completed on time in 2014 (which is not possible according to present political situations) than it will help us to recover from our shortfall of natural gas, although, shortfall will still exist but that will be less than today's.

Indo-Pak-Iran pipeline is economically beneficial for Indian energy demand as well as Indian policy makers are making efforts to concentrate on Import of natural gas. But for this purpose, pipeline would have to pass through Pakistan land and India is not ready to accept the role of Pakistan in their project as in case of military fight Pakistan can stop their gas supply. These three countries did not share goals so the project has not been come to reality. Aim of India in this pipeline project is high but its economic interests in this pipeline project are not according to the political, economic and strategically goals of Iran and Pakistan, due to which this project is in delay (Pandian, 2005).

Demand for natural gas is increasing day by day due to which care for transmission system and forecast of transmission system is also required so that transmission network can be extended, and improved. Villada et al. (2013) discussed transportation structure and suggest that satisfactory development of structure of supply of gas can pay to raise the safety. Han and Weng (2010) showed their work in which for safe functioning of supply system of natural gas (as there is always a chance of accident in such cases), for pipeline network of natural gas, they used method of Integrated Quantitative Risk Analysis. In this technique, they worked on probability assessment of accidents, analyzed previous results (included both of outside and inside gas pipeline) and evaluated risks. And in result, for pipeline network of natural gas, this method or technique considered to be applicable. According to Azeadeh et al. (2010), growth and preparation of natural gas transmission network includes schemes with serious planning at the background. Improvement in the planning and application of pipeline network can considerably donate to the financial effectiveness of gas supply system. Ma et al. (2013) believed that demand of natural gas pipeline is increasing day by day and side by side as the demand is increasing security problem of pipelines is also important to concentrate on. Risk calculation and managing for pipeline network is the effective technique to promise its safety running. He outlined the pipeline maximum length and studies gas network accident probability and accident consequence. Simonoff et al. (2010) investigated Risk measures and scenario to know about the relation between reasons and happening features with consequences of failures of pipeline. Risk management actually reduces pipeline incidents. It was found in conclusion that for risk management, the important feature of incidents can be different and may depend on the incident which includes the model of type of distribution or transmission pipeline. This method helps the decision makers to give ways in order to get good know-how regarding cost consequence measures which depends on reasons and type of incident. Shah (2004) believed that transmission network extension planning is a key to improve distribution, storage and production so that increasing demands can be forecast further.

ARIMA modeling in Box-Jenkins (1976) methodology/approach can be useful to shape forecast model and forecast model can be used to estimate upcoming values. We choose the ARIMA model for predicting and forecasting purpose (Olajide et al. 2012; Faisal 2012). Among others Jenkins and Watt (1968), Yule (1926, 1927), Bartlett (1964), Quenoulli (1949), Ljunge and Bos (1978) have also emphasized the use of ARIMA models in this regard.

The objective of this study is to estimate the forecast model for Transmission System of Natural Gas, Loopline and Mainline, in Punjab (Pakistan). It is essential to have such forecast models which have implementable capability so that it can be observed that what will be the goal to attain related to issue of short fall.

2. Research Methodology and Data Description:

Source of data is Bureau of Statistics, Punjab. Data has been compiled by all volumes of the publication namely; Punjab Development Statistics by Bureau of Statistics, Punjab. Yearly data of Punjab (Pakistan) on Natural Gas Transmission System (in kilometer) of Loopline and Mainline has been taken. This data is of Sui Northern Gas Pipeline Company, Ltd. It is annual data and includes years; 1979-1980 to 2009-2010.

Different methods can be used for forecasting in time series; $ARIMA\ (p, d, q)$ model using Box Jenkins Approach (1976) has been used for this purpose in order to have a final forecast model.

2.1 Auto-regressive Moving Average $ARMA(p, q)$ Model: If Auto-regressive (AR) and Moving Average (MA) are not separately suitable for forecasting and modeling than a combination of it called Auto-Regressive Moving Average Model or mixed model can be used. This model with q Moving Average terms and p Auto-Regressive terms can be given as:

$$Y_t = \phi_1 Y_{t-1} + \cdots + \phi_p Y_{t-p} + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \cdots + \theta_q \varepsilon_{t-q}$$

Furthermore,
If $q = 0$ then $ARMA(p, q) = AR(p)$
If $p = 0$ then $ARMA(p, q) = MA(p)$

2.2 Auto-Regressive Integrated Moving Average $ARIMA(p, d, q)$ Model: When time series is not Stationary and data is not seasonal then difference transformation can be used to convert the non-Stationary data into Stationary in order to proceed for model building and forecasting. If Y_t is changed into $\Delta^d Y_t$ by taking first, second or higher order difference and if aim is to build model for such data then $ARMA(p, q)$ will be changed into $ARIMA\ (p, d, q)$ model; d is the order of difference. The objective was to estimate such a model which can be interpreted when sample data will be generated. If this model is used for forecasting then it should assume that the structure of model is constant over time and particularly over future time period. This ARIMA model was then used for forecasting of data. $ARIMA\ (p, d, q)$ was given as:

$$\Delta^d Y_t = \phi_1 Y_{t-1} + \cdots + \phi_p Y_{t-p} + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \cdots + \theta_q \varepsilon_{t-q}$$

2.3 Box-Jenkins Approach (1976): Box-Jenkins Approach (1976) for model building and forecasting has three steps.

2.3.1 Identification of Order: In this initial step, identification of values p, d, q which is orders of ARIMA model is required. In objective approach, Augmented Dickey-Fuller (Unit Root) Test (1979) is useful to test the Stationarity. And as far as subjective approach is concern, there is time plot (line graph) or correlogram by examining Autocorrelation (AC) and Partial Autocorrelation (PAC) at different lags. If series is not Stationary, then we make it Stationary by using commonly used “difference” transformation and again apply the above methods for checking Stationarity.

2.3.2 Model Estimation: After finding the suitable values of p, d, q from correlogram, we estimate models by using different combinations of defined orders of $MA(q)$ and $AR(p)$. Eviews has been used for this purpose. In estimating one combination, when all the AR and MA terms using in that combination shows significant result then that combination will be finalized as a model to proceed further.

2.3.3 Diagnostic Checks: Different diagnostic checks are used to see whether the selected model is adequate or not. Diagnostic checks include; Analyze the actual values and fitted values (graphically) of estimated model. Check that process is Stationary and invertible or not. Correlogram of residuals and squared residuals are used for checking for constant variance and autocorrelation, respectively. In both the cases, Q-stat of residuals and squared residuals also been inspected as well. Normality test is that in which it is determine that whether the residuals of the model is following Normal Distribution or not. Anderson- Darling test has been used for this purpose. Breusch-Godfrey Serial correlation Lagrange Multiplier (LM) Test used to test autocorrelation among the residual terms. This test is used especially when higher order differences exist. Auto-Regressive Conditional Heteroscedasticity (ARCH) Test used to test about the homoscedasticity of residual terms.

2.4 Forecasting: In this step, forecast model is finalized using final estimated ARIMA models which were analyzed and finalized through diagnostic checks mentioned above.

Forecast model is used to finalize on the bases of Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC) and Standard Error (S.E.) of Regression. Furthermore, In order to know that how well our forecast is for particular model as compare to other models, forecast evaluation criteria (graphical) is used. Static forecast method has been used using Eviews software. It calculates series of one-step ahead forecasts using actual values. In this, we used to analyze Root Mean Square Error (RMSE) and Theil's Inequality Coefficient (TIC) and graphical look as well.

2.5 Summary of Adequate, Good or Best Fitted Model: Main points in order to get an adequate and best fitted forecast model as compared to all the other models generated from the same time series data.

- Time series data should be Stationary.
- Statistically significant coefficients of AR and/or MA terms.
- Stationarity and invertibilty property.
- No autocorrelation and constant variance result should be attained using different diagnostic checks.
- Residuals should be normal.
- Smaller value of AIC, S.E of regression and SIC as compare to other models of the same series.
- Smaller values of RMSE and TIC.

3. Result and Discussion

Final forecast models AR(8) AR(9) MA(10) at 1st difference and MA(3) MA(5) at 2nd difference for Transmission System of Loopline and Transmission System of Mainline, respectively, has been finalized which gave closer forecast values when compared to actual ones so these are considered to be suitable forecast models for their corresponding time series (data set). The analysis and interpretation of the data has been carried out in order to obtain suitable forecast model (ARIMA model) using Box Jenkins Approach (1976). Two data sets for this purpose are as:

- Natural Gas Transmission System of Loopline.
- Natural Gas Transmission System of Mainline.

Eviews and Minitab software package for the analysis purpose have been used. Detail of this analysis is given as follows:

3.1 Test for Stationarity: The time plot at actual data is not Stationary for Natural Gas Transmission System of Loopline and Mainline. So, Figures 1 and 2 shows that by using "1st difference" transformation for Transmission System of Loopline and "2nd difference" transformation for Transmission System of Mainline series become Stationary. Then with the help of correlogram, Figures 3 and 4, it has been realized the same as its spikes are not showing any pattern which means series or data becomes Stationary. In Tables 1 and 2, Augmented Dickey-Fuller (Unit Root) Test (1979) is showing that p-value is smaller than α 1% which illustrations that null hypothesis of Unit Root test i.e., series is non-Stationary or series has Unit Root, is rejected.

3.2 Identification of ARIMA model: In correlogram, spikes of AR and MA which are outside the bounds or at the bounds are used to be chosen from AC and PAC lags, respectively, in order to proceed for estimation of models. From different combinations of selected AR and MA orders, different models (by using least square method) is use to obtain, and by going through the process of different diagnostic checks, models are finalized to proceed for selection of forecast model. Summary of selected spikes of AR and MA (selected from AC and PAC lags), selected models and final forecast model is shown in Table 3.

We have selected models by analyzing p-value for MA terms and AR terms at their respective orders. Tables 4 and 5 shows that estimated models are statistically significant i.e., smaller than α 1%. So that's why these models have been selected. Tables 4 and 5 gave the models which was estimated and considered as the final forecast models at the end.

3.3 Diagnostic Checks: Diagnostic check includes graph of actual and fitted values, ARMA structure, correlogram of residuals and squared residuals, normality test for residuals, LM Test and ARCH Test.

- In graph of actual and fitted values, actual and fitted value must follow each other.
- ARMA structure is used to get information about the invertibility and Stationarity condition of AR and MA terms respectively. In ARMA structure, if all the MA roots and AR roots for the models are lying inside and at the unit circle then it means that process is invertible and Stationary, respectively.
- Correlogram of residuals gives information about whether residuals have constant variance or not, side by side, p-values of Q-statistics have been checked for autocorrelation. If spikes are outside the bound then it means residual terms do not have constant variance and on the other-hand if spikes are inside the bounds or at the bound then it shows that residual terms have constant variance and are purely random. p-values of Q-stat must be greater than α 1%, it will mean that no autocorrelation exists.
- Correlogram of squared residuals gives information about whether residuals have autocorrelation or not, side by side, p-values of Q-statistics have been checked for autocorrelation. If spikes are outside the bounds then squared residual term has autocorrelation, on the other hand, p-values of Q-stat must be greater than α 1%, it will mean that no autocorrelation exists.
- Anderson-Darling test has been used to check the normality of residuals for all the models. For normality checking of residuals, p-value of Anderson-Darling Test is use to check. If p-value less than 1% which mean null hypothesis i.e. residuals follows normal distribution, is rejected.
- Breusch-Godfrey Serial Correlation LM test is used to check that whether residuals have autocorrelation or not. p-value of F-statistics must be greater than α 1% then it is use to conclude that there is no autocorrelation exists.
- Autoregressive Conditional Heteroscedastic (ARCH) test is used to check that whether residuals have constant variance or not. p-value of F-statistics must be greater than α 1% so it can conclude that there is

homoscedasticity in residual terms which means there is no ARCH effect and residuals have constant variance.

Summary of the all estimated models is given in Tables 6 and 7. This Table shows that which model satisfied the diagnostic check and finally after fulfilling all diagnostic checks which model is considered as final.

Table 6 shows that by using Diagnostics Checks ARIMA(9,1,10) and AR(8) AR(9) MA(10) has been finalized for Natural Gas Transmission System of Loopline series as all the diagnostic checks has been fulfilled for these two models. Similarly, for Natural Gas Transmission System of Mainline series AR(3) MA(3) MA(5) and MA(3) MA(5) models were selected (Table 7).

3.4. Forecast Model: After selection of models through diagnostic checks, last step is to finalize the single model which can be used for forecast purpose. Graphically, forecast evaluation is use to be observed. If forecast values are within the bounds than that model can be consider as final forecast model. Additionally, Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC), Standard Error (S.E.) of Regression, Root Mean Square Error (RMSE) and Theil Inequality Coefficient (TIC) of selected models are used to examine as well. The model having smallest values of these terms as compare to other models is considered as final forecast model. Tables 8 and 9 is showing the summary that which model has the smallest value as compare to other selected models.

Table 8 shows that all the conditions are fulfill for AR(8) AR(9) MA(10) for Natural Gas Transmission System of Loopline. So this model with be the final forecast model for estimating Consumption of Natural Gas, given as:

$$\Delta Y_t = c + \phi_8 \Delta Y_{t-8} + \phi_9 \Delta Y_{t-9} + \theta_{10} \varepsilon_{t-10}$$

$$\Delta Y_t = 79.81375 - 0.340989 \Delta Y_{t-8} - 0.502295 \Delta Y_{t-9} + 0.952779 \varepsilon_{t-10}$$

The coefficients of the model have been picked from Table 4.

Similarly, Table 9 shows that values of AIC, SIC and Standard Error of Regression are smaller for MA(3) M(5) and values of Root Mean Square Error and Theil Inequality Coefficient are smaller for AR(3) MA(3) MA(5). In such situation, MA(3) MA(5) is a model which will be considered as the final forecast model for estimating Transmission System of Natural Gas for Mainline, given as:

$$\Delta^2 Y_t = c + \theta_3 \varepsilon_{t-3} + \theta_5 \varepsilon_{t-5}$$

$$\Delta^2 Y_t = 0.464192 - 0.507983 \varepsilon_{t-3} - 0.482058 \varepsilon_{t-5}$$

The coefficients of the model have been picked from Table 5.

The results of the diagnostic checks and graphical forecast evaluation for the final forecast model of Natural Gas Transmission System of Loopline has been shown in Figures 5-10 and Tables 10-11.

The actual Transmission of Natural Gas of Loopline for year 2009-2010 is given as 2809 kilometer, on the other hand the forecast value of Transmission of Natural Gas of Loopline with the help of the above given model for year 2009-2010 is 2932.16 kilometer. By comparing these two values it is clear that as values are close to each other so it can be said that our estimated forecast model is adequate one.

The results of the diagnostic checks and graphical forecast evaluation for the final forecast model of Transmission System of Natural Gas (Mainline) has been shown in Figures 11-15, Tables 12-13 and Figure 16.

The actual Transmission of Natural Gas of Mainline for year 2009-2010 is given as 3022 kilometer, on the other hand the forecast value of Transmission of Natural Gas of Mainline with the help of the above given model for year 2009-2010 is 3056.15 kilometer. By comparing these two values it is clear that as values are close to each other so we can say that our estimated forecast model is adequate one.

4. Conclusion

In this research work, our interest was to select a suitable and an adequate forecast model among various selected ARIMA models which shows high power for prediction or forecasting.

Among various selected ARIMA model, with the help of diagnostic checks, the best forecast model for each of two data sets has been selected. Forecast model selected for Transmission of Natural Gas (Loopline) is AR(8) AR(9) MA(10) at 1^{st} difference. Forecast model selected for Transmission of Natural Gas (Mainline) is MA(3) MA(5) at 2^{nd} difference. By using these models, forecast values for year 2010 has been estimated and then compared with the actual values for year 2010.

According to comparison between forecast and actual value, we come to say that AR(8) AR(9) MA(10) at 1st difference and MA(3) MA(5) at 2nd difference for Transmission of Natural Gas (Loopline) and Transmission of Natural Gas (Mainline), respectively, are the models which gave closer values as compared to actual ones so these are considered to be suitable forecast model for their corresponding time series (data set) and can be used for practical application.

Table 1: Augmented Dickey-Fuller (Unit Root) Test for Transmission System of Loopline at 1st difference

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.456241	0.0007
Test critical values:	1% level	-4.323979	
	5% level	-3.580623	
	10% level	-3.225334	

*MacKinnon (1996) one-sided p-values.

Table 2: Augmented Dickey-Fuller (Unit Root) Test for Transmission System of Mainline at 2nd difference

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-8.083888	0.0000
Test critical values:	1% level	-4.339330	
	5% level	-3.587527	
	10% level	-3.229230	

*MacKinnon (1996) one-sided p-values.

Table 3: Selected Spikes, Models and Forecast Model

Data Type	Identification of models using Correlogram	Models selected	Models Finalized using Diagnostic Checks	Forecast Model
Natural Gas Transmission System of Loopline	MA(5) MA(9) MA(10) AR(5) AR(8) and AR(9)	ARIMA(9,1,10), ARIMA(0,1,10), AR(8) AR(9) MA(10), MA(5) MA(10), ARIMA(0,1,9) and ARIMA(9,1,9)	ARIMA(9,1,10) AR(8) AR(9) MA(10)	AR(8) AR(9) MA(10)
Natural Gas Transmission System of Mainline	MA(1), MA(3), MA(4), MA(5), MA(6), MA(9), AR(1), AR(3) and AR(5)	ARIMA(3,2,3), AR(3) MA(3) MA(5), ARIMA(0,2,1), MA(3) MA(5), MA(4) MA(6), ARIMA(0,2,6) and ARIMA(0,2,9)	MA(3) MA(5) and AR(3) MA(3) MA(5)	MA(3) MA(5)

Table 4: Estimated AR(8) AR(9) MA(10) for Transmission System of Loopline at 1st difference

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	79.81375	7.929535	10.06538	0.0000
AR(8)	-0.340989	0.112755	-3.024145	0.0081
AR(9)	-0.502295	0.112582	-4.461600	0.0004
MA(10)	0.952779	0.032623	29.20614	0.0000

R-squared	0.894133	Mean dependent var	84.50000
Adjusted R-squared	0.874283	S.D. dependent var	119.3193
S.E. of regression	42.30665	Akaike info criterion	10.50462
Sum squared resid	28637.64	Schwarz criterion	10.70377
Log likelihood	-101.0462	Hannan-Quinn criter.	10.54350
F-statistic	45.04418	Durbin-Watson stat	2.213352
Prob(F-statistic)	0.000000		

Table 5: Estimated MA(3) MA(5) for Transmission System of Mainline at 2nd difference

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.464192	12.92663	0.035910	0.9716
MA(3)	-0.507983	0.161004	-3.155094	0.0041
MA(5)	-0.482058	0.161101	-2.992272	0.0062
R-squared	0.204148	Mean dependent var		1.607143
Adjusted R-squared	0.140479	S.D. dependent var		230.2531
S.E. of regression	213.4684	Akaike info criterion		13.66581
Sum squared resid	1139219.	Schwarz criterion		13.80855
Log likelihood	-188.3214	Hannan-Quinn criter.		13.70945
F-statistic	3.206428	Durbin-Watson stat		2.722448
Prob(F-statistic)	0.057598			

Table 6: Diagnostic check Summary for Transmission System of Loopline

Category		**ARIMA(9,1,10)**	**ARIMA(0,1,10)**	**AR(8) AR(9) MA(10)**	**MA(5) MA(10)**	**ARIMA(0,1,9)**	**ARIMA(9,1,9)**
Time Plot	1st						
Correlogram	MA(5) MA(9) MA(10) AR(5) AR(8) and AR(9)						
Unit Root Test	1st						
Graph of Actual, Fitted and Residuals		√	√	√	√	√	√
ARMA Structure		√	√	√	√	√	√
Correlogram of Residuals		√		√			√
P-value of Q-stat		√	√	√	√	√	
Correlogram of Squared Residuals		√	√	√	√	√	√
P-value of Q-stat		√	√	√	√	√	√
Normality Test		√	√	√	√	√	√
LM Test		√	√	√	√	√	√
ARCH Test		√	√	√	√	√	√

Table 7: Diagnostic check Summary for Transmission System of Mainline

Category		ARIMA(3,2,3)	AR(3) MA(3) MA(5)	ARIMA(0,2,1)	MA(3) MA(5)	MA(4) MA(6)	ARIMA(0,2,6)	ARIMA(0,2,9)
Time Plot	2^{nd}							
Correlogram	MA(1) MA(3) MA(6) AR(1) AR(3) AR(6)							
Unit Root Test	2^{nd}							
Graph of Actual, Fitted and Residuals			√	√	√			
ARMA Structure		√	√	√	√	√	√	√
Correlogram of Residuals		√	√	√	√	√	√	√
P-value of Q-stat		√	√	√	√	√	√	
Correlogram of Squared Residuals		√	√	√	√	√	√	√
P-value of Q-stat		√	√	√	√	√	√	√
Normality Test		√	√		√	√	√	√
LM Test		√	√	√	√	√	√	√
ARCH Test		√	√	√	√	√	√	√

Table 8: Summary for final Forecast Model for Transmission System of Loopline

Category	ARIMA(9,1,10)	AR(8) AR(9) MA(10)
Forecast Graph Evaluation	√	√
AIC		√
SIC		√
Standard Error of Regression		√
Root Mean Square Error		√
Theil Inequality Coeffeicent		√

Table 9: Summary for final Forecast Model for Transmission System of Mainline

Category	**AR(3) MA(3) MA(5)**	**MA(3) MA(5)**
Forecast Evaluation Graph	√	√
AIC		√
SIC		√
Standard Error of Regression		√
Root Mean Square Error	√	
Theil Inequality Coeffeicent	√	

Table 10: Breusch-Godfrey Serial Correlation LM Test for AR(8) AR(9) MA(10) of Natural Gas Transmission System of Loopline

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	1.020039	Prob. F(4,12)	0.4357
Obs*R-squared	5.064007	Prob. Chi-Square(4)	0.2808

Table 11: Autoregressive Conditional Hetroscedasticity (ARCH) Test for AR(8) AR(9) MA(10) of Natural Gas Transmission System of Loopline

Heteroskedasticity Test: ARCH

F-statistic	0.167768	Prob. F(4,11)	0.9504
Obs*R-squared	0.919980	Prob. Chi-Square(4)	0.9217

Table 12: Breusch-Godfrey Serial Correlation LM Test for MA(3) MA(5) of Natural Gas Transmission System of Mainline

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	2.826345	Prob. F(4,21)	0.0508
Obs*R-squared	9.778902	Prob. Chi-Square(4)	0.0443

Table 13: Autoregressive Conditional Hetroscedasticity (ARCH) for MA(3) MA(5) of Natural Gas Transmission System of Mainline

Heteroskedasticity Test: ARCH

F-statistic	0.500900	Prob. F(4,19)	0.7354
Obs*R-squared	2.289437	Prob. Chi-Square(4)	0.6827

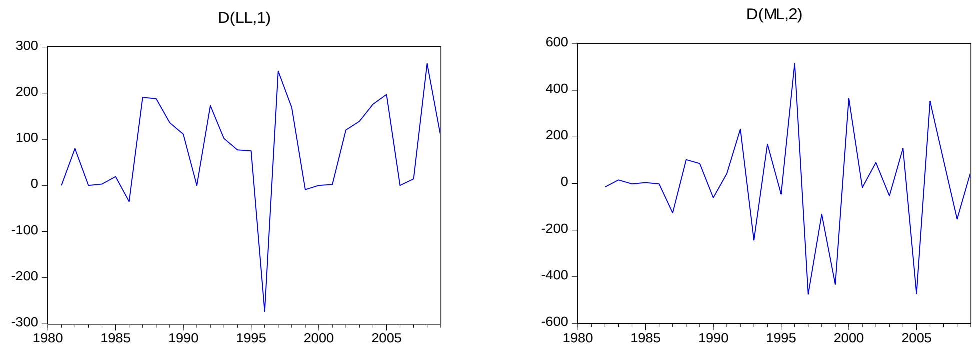
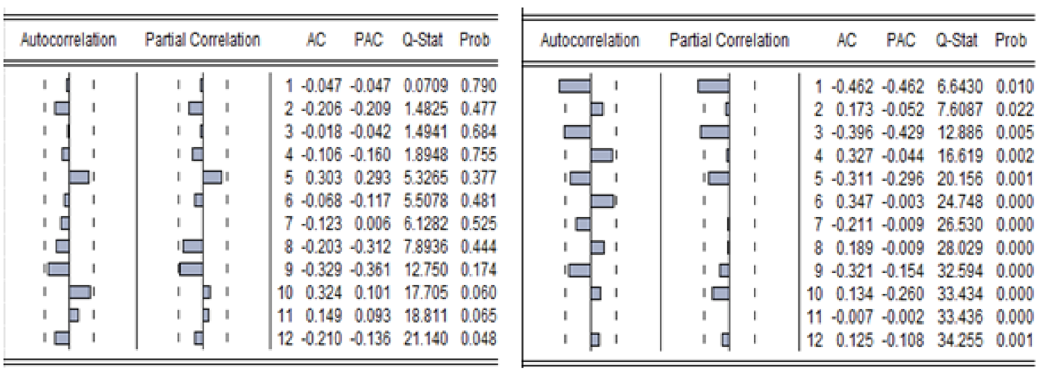


Figure 1-2: Time plots for Transmission System of Loopline and Mainline series at 1st and 2nd difference, respectively.



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.047	-0.047	0.0709	0.790
		2	-0.206	-0.209	1.4825	0.477
		3	-0.018	-0.042	1.4941	0.684
		4	-0.106	-0.160	1.8948	0.755
		5	0.303	0.293	5.3265	0.377
		6	-0.068	-0.117	5.5078	0.481
		7	-0.123	0.006	6.1282	0.525
		8	-0.203	-0.312	7.8936	0.444
		9	-0.329	-0.361	12.750	0.174
		10	0.324	0.101	17.705	0.060
		11	0.149	0.093	18.811	0.065
		12	-0.210	-0.136	21.140	0.048

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.462	-0.462	6.6430	0.010
		2	0.173	-0.052	7.6087	0.022
		3	-0.396	-0.429	12.886	0.005
		4	0.327	-0.044	16.619	0.002
		5	-0.311	-0.296	20.156	0.001
		6	0.347	-0.003	24.748	0.000
		7	-0.211	-0.009	26.530	0.000
		8	0.189	-0.009	28.029	0.000
		9	-0.321	-0.154	32.594	0.000
		10	0.134	-0.260	33.434	0.000
		11	-0.007	-0.002	33.436	0.000
		12	0.125	-0.108	34.255	0.001

Figure 3-4: Correlogram for Transmission System of Loopline and Mainline series at 1st and 2nd difference, respectively.

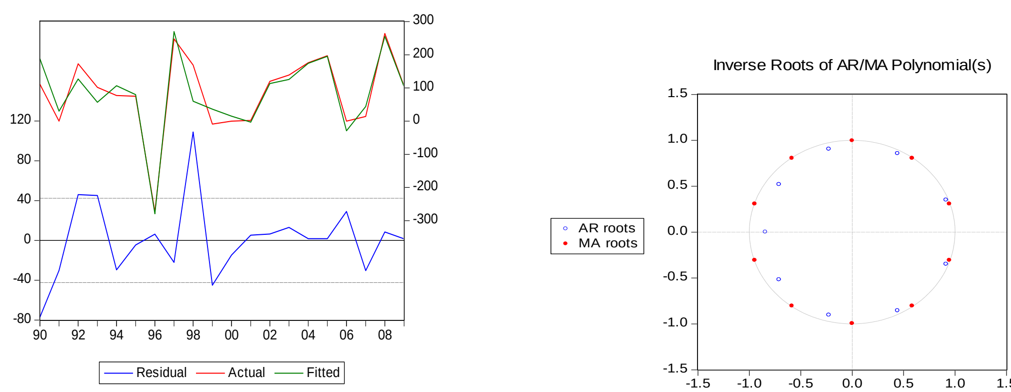
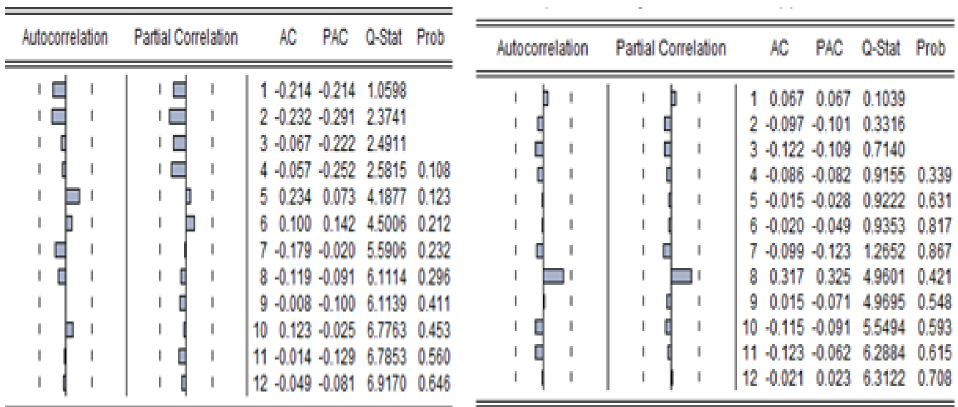


Figure 5-6: Graph of Actual, Fitted, Residual values and ARMA structure for AR(8) AR(9) MA(10) of Natural Gas Transmission System of Loopline



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.214	-0.214	1.0598	
		2	-0.232	-0.291	2.3741	
		3	-0.067	-0.222	2.4911	
		4	-0.057	-0.252	2.5815	0.108
		5	0.234	0.073	4.1877	0.123
		6	0.100	0.142	4.5006	0.212
		7	-0.179	-0.020	5.5906	0.232
		8	-0.119	-0.091	6.1114	0.296
		9	-0.008	-0.100	6.1139	0.411
		10	0.123	-0.025	6.7763	0.453
		11	-0.014	-0.129	6.7853	0.560
		12	-0.049	-0.081	6.9170	0.646

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.067	0.067	0.1039	
		2	-0.097	-0.101	0.3316	
		3	-0.122	-0.109	0.7140	
		4	-0.086	-0.082	0.9155	0.339
		5	-0.015	-0.028	0.9222	0.631
		6	-0.020	-0.049	0.9353	0.817
		7	-0.099	-0.123	1.2652	0.867
		8	0.317	0.325	4.9601	0.421
		9	0.015	-0.071	4.9695	0.548
		10	-0.115	-0.091	5.5494	0.593
		11	-0.123	-0.062	6.2884	0.615
		12	-0.021	0.023	6.3122	0.708

Figure 7-8: Graph of Correlogram of Residuals and Correlogram of Squared Residuals for AR(8) AR(9) MA(10) of Natural Gas Transmission System of Loopline

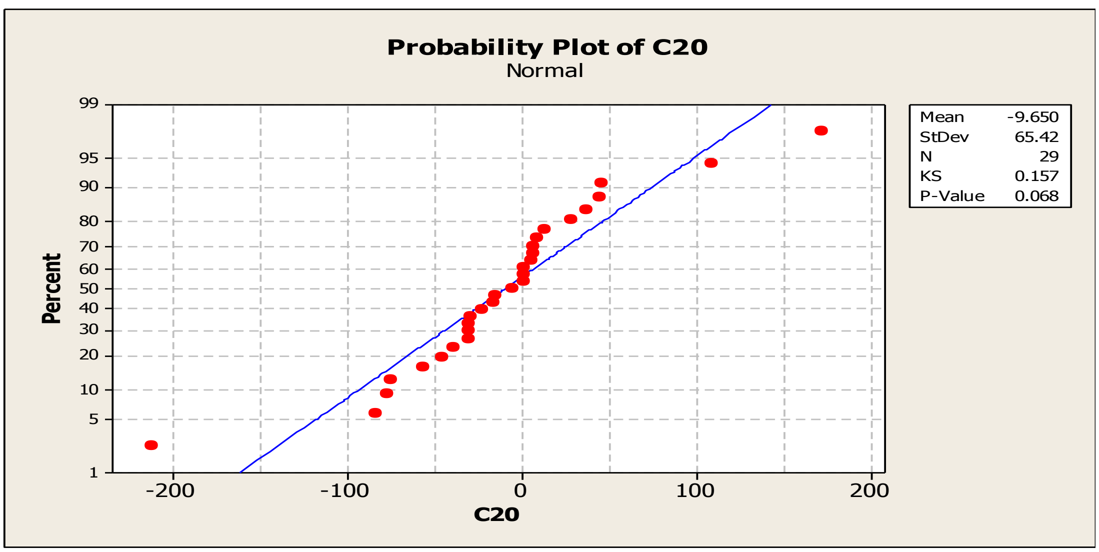


Figure 9: Normality test for AR(8) AR(9) MA(10) of Natural Gas Transmission System of Loopline

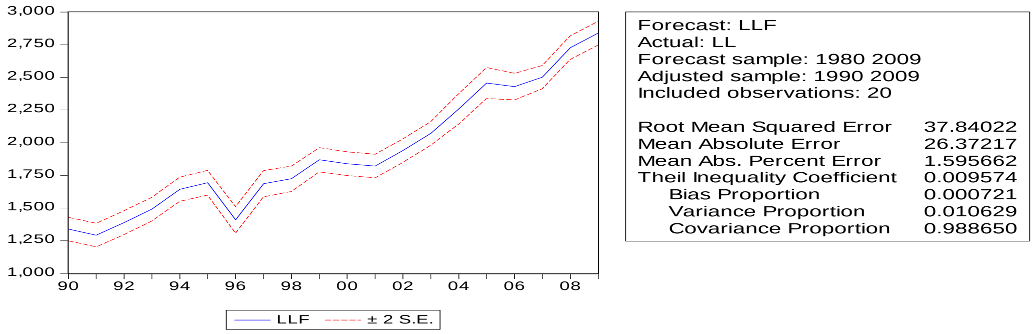


Figure 10: Graphical Forecast Evaluation for AR(8) AR(9) MA(10) of Natural Gas Transmission System of Loopline

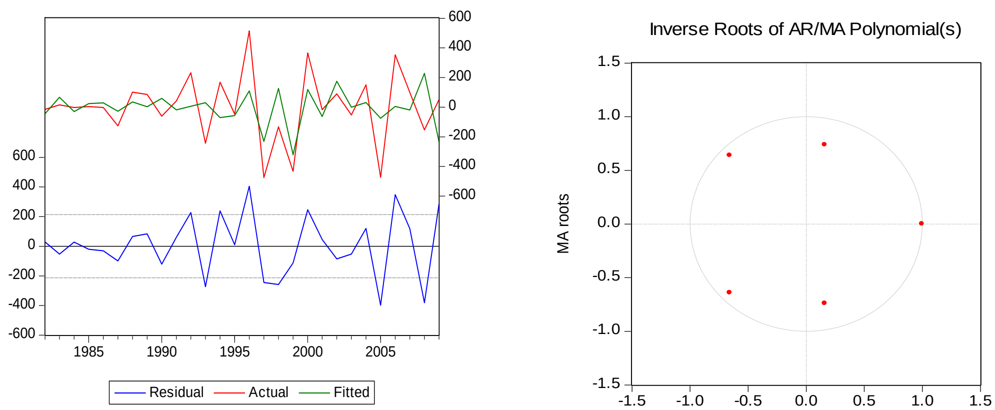
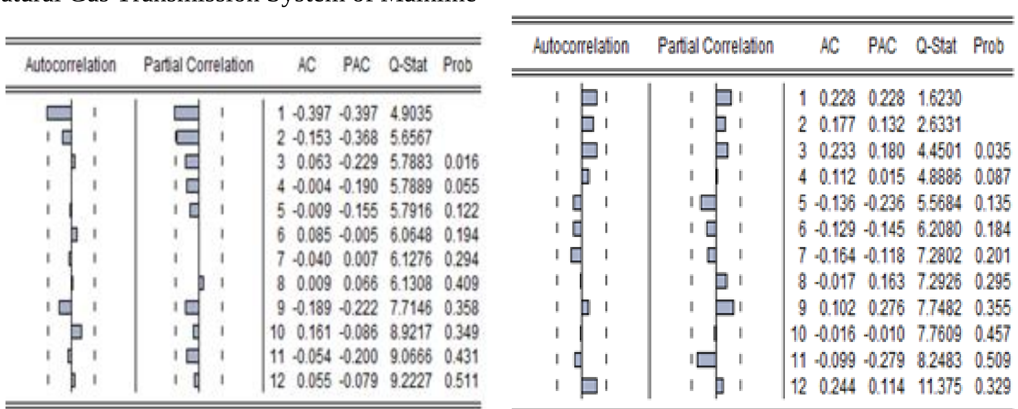


Figure 11-12: Graph of Actual, Fitted, Residual values and ARMA structure for MA(3) MA(5) of Natural Gas Transmission System of Mainline



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.397	-0.397	4.9035	
		2	-0.153	-0.368	5.6567	
		3	0.063	-0.229	5.7883	0.016
		4	-0.004	-0.190	5.7889	0.055
		5	-0.009	-0.155	5.7916	0.122
		6	0.085	-0.005	6.0648	0.194
		7	-0.040	0.007	6.1276	0.294
		8	0.009	0.066	6.1308	0.409
		9	-0.189	-0.222	7.7146	0.358
		10	0.161	-0.086	8.9217	0.349
		11	-0.054	-0.200	9.0666	0.431
		12	0.055	-0.079	9.2227	0.511

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.228	0.228	1.6230	
		2	0.177	0.132	2.6331	
		3	0.233	0.180	4.4501	0.035
		4	0.112	0.015	4.8886	0.087
		5	-0.136	-0.236	5.5684	0.135
		6	-0.129	-0.145	6.2080	0.184
		7	-0.164	-0.118	7.2802	0.201
		8	-0.017	0.163	7.2926	0.295
		9	0.102	0.276	7.7482	0.355
		10	-0.016	-0.010	7.7609	0.457
		11	-0.099	-0.279	8.2483	0.509
		12	0.244	0.114	11.375	0.329

Figure 13-14: of Correlogram of Residuals and Correlogram of Squared Residuals for MA(3) MA(5) of Natural Gas Transmission System of Mainline

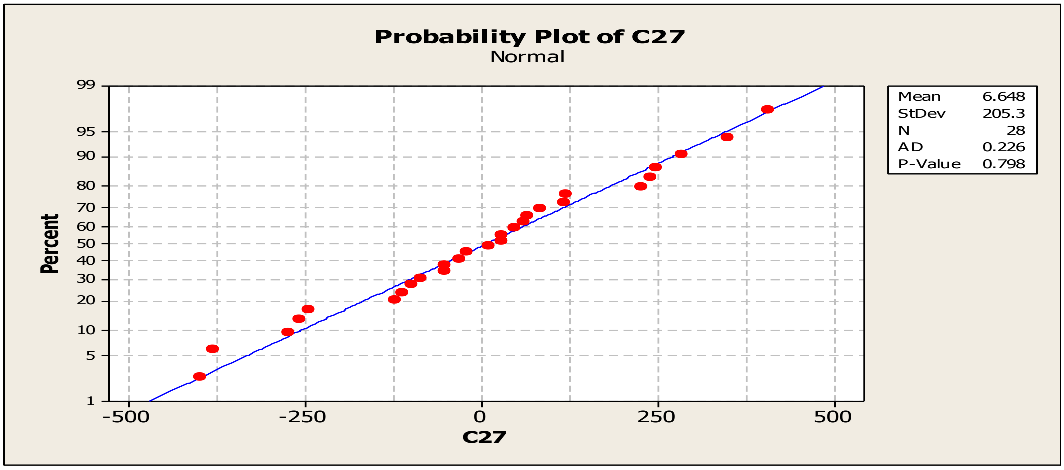


Figure 15: Normality test for MA(3) MA(5) of Natural Gas Transmission System of Mainline

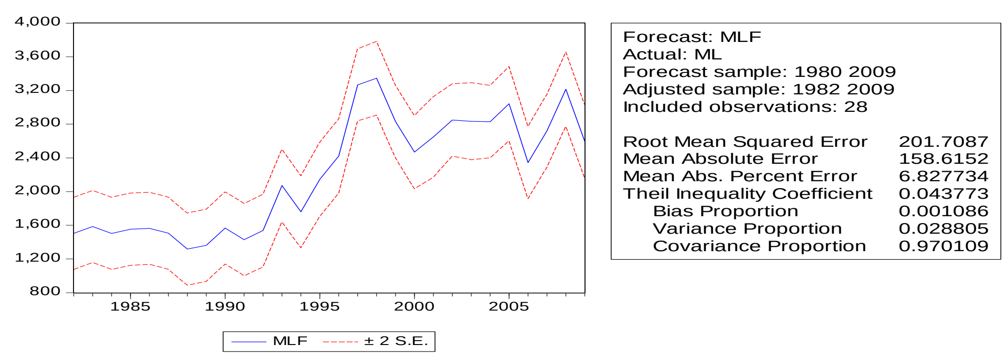


Figure 16: Graphical Forecast Evaluation for MA(3) MA(5) of Natural Gas Transmission System of Mainline

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