Forecasting of Short-Run Exchange Rates: A Box-Jenkins Approach

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Abstract

Short-run forecasting of exchange rate has been a recent debate in economic theory. This paper tries to find out an extensive view whether the exchange rate can be treated as a model for short-run forecasting purpose. The study focuses on forecasting the daily exchange rate movements of Bangladesh for the period of January 1 to May 31,2005 using the Box-Jenkins four steps approach. The results found that residuals from the OLS regression are white noise error term, which implies that this model is good for estimating the short-run exchange rate of Bangladesh. It points out that daily exchange rate fluctuations in Bangladesh during the forecasted period are almost 2.5 percent from the mean value. This has the implication that the fluctuations in exchange rate movements are not highly volatile. The model may be used as tool of forecasting the movements of exchange rate (Taka/$US) in Bangladesh.

Key Words: Forecasting exchange rates, Stationarity, Autocorrelogram, ARIMA, Box-Jenkins etc.

1. Introduction

The concept of exchange rate has been a hotly debated issue and remains perhaps one of the most important questions in international finance. Since the international business environment is one in which there is no universal medium of exchange, exchange rates are a matter of necessity for interna-

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tional trade. As a result, when transactions are denominated in foreign currencies two basic needs arise. First, there is the need for translation. That is, the transaction which is stated in terms of a foreign currency must be re-expressed or restated in terms of the local currency before it can be recorded in the local accounting records. Second, settlement of the transaction requires conversion. This means that when payment is due, a sufficient amount of the local currency must be exchanged for the stated amount of foreign currency so that payment can be made. At present, both translation and conversion of foreign currency involve the use of exchange rates. Therefore, in order to gain a more thorough understanding of foreign currency translation, it is important to examine the nature of exchange rates. The question which is the concern issue for this study by knowing its above criteria is whether the exchange rate has the predictive influence in the short?

Therefore, exchange rate has become an instrumental tool in restoring the external balance of any country. The changes in exchange rate have significant impact on international trade. Bangladesh is a developing country having good trade relationship with many countries across the world. Among them USA is the major trading partner for Bangladesh. USA has become the major export market for Bangladeshi garments products. The US dollar is the dominance currency in the global market. In Bangladesh there is no exception to this. Most of the activities in foreign exchange market are accounted for in $US, i.e., the majority of foreign transactions are taking place in $US. The Bangladeshi taka always depreciates against the $US dollar and this has a negative impact on the international trade. Import, export as well as different monetary issues are related to the exchange rate stability. Under this circumstance it would be very interesting to study in this paper to forecast the daily exchange rate of Bangladesh over a short run period.

2. The Objective of the Study

As mentioned earlier exchange rate between Bangladeshi taka and USA dollar has been selected for the study since most of the activities in foreign exchange in Bangladesh market are accounted for in $US. The major objective of the study:

i. To make forecasting of time series exchange rate of Bangladesh

ii. To determine whether the model is good for forecasting the short run exchange rate

3. Literature Review

There are various theoretical models like Bilson(1978a,1978b) Dornbusch(1976) Frenkel(1976,1979) in forecasting exchange rate. These models are tested empirically and often characterized by low explanatory power, incorrect signs of coefficients and insignificant magnitudes.

Meese and Rogoff(1983a,1983b,1988) showed that the performance of many structural and time series models is no better than that of a simple random walk model. Other economists like finn(1986), Boothe and Glassman(1987), or Van Aarle et al.(200) have shown a high degree of interest in exchange rate forecasting using various time series models.

While forecasting the Australian dollar-US dollar exchange rate Hoque and Latiff(1993) used vector error correction models, unrestricted vector autoregressions and stochastically restricted VAR models. They conclude on the supremacy of the stochastically restricted VAR model over the unrestricted VAR and of the vector error correction models over the other two.

Liu et al.(1994) concluded on the higher forecasting abilities of both stochastically and deterministically restricted models when compared to unrestricted ones. This result came from the study of the exchange rate of the US dollar against the Japanese yen and the Canadian dollar and the Deutsche mark.

Similar conclusion like Meesee and Rogoff(1983) was drawn by Cuaresma and Hiouskova(2004) that there exists difficulties in more sophisticated time series models (in this case VAR, VEC, BVAR, BVEC and restricted VAR models in different specifications) in outperforming the naÔve forecasts of the random walk for for exchange rates.

In Bangladesh, it is not a long time since the floating exchange rate has been established. This is why, before researching other developments, this paper will focus on the unified approach proposed by Box and Jenkins (1970, revised 1976) for formulating time series models.

4. Econometric Methodology

Before forecasting a time series model, it is indispensable to ascertain whether the exchange rate is a stationary or non-stationary series. If it holds true for non-stationary series, it will be apparently complicated to represent the time series over past and future intervals of the time by the estimated model. Therefore, firstly, it is essential to testify the series- whether it is stationary or non-stationary. To do this, first we need to know the concept of autocorrelation function.

4.1 A portrayal of Time Series Analysis: The Autocorrelation Function

The autocorrelation function proves extremely useful, because it provides a partial description of the process for modeling purposes. The autocorrelation function tells us how much correlation there is (and by implication how much interdependency there is) between the neighboring data points in the series Y_t. We define the autocorrelation with lag K as:

$$\rho_K = \frac{E\,|(y_1-\mu_y)\ (y_{t+h}-\mu_y)|}{\sqrt{E\,|(y_1-\mu_y)^2\ (y_{t+h}-\mu_y)^2|}} = \frac{Cov(y_1 + y_{t+h})}{\sigma_y\ \sigma_{t+h}} \quad \ldots\ldots (1)$$

For a stationary process, the variance at time t in the denominator of equation (1) is the same as the variance at time t+k; thus, the denominator is just the variance of the stochastic process. Hence,

$$\rho_K = \frac{E\,|(y_1-\mu_y)(y_{t+h}-\mu_y)|}{\sigma_y^2} \quad \ldots\ldots (2)$$

It should be noted that the numerator in equation (2) is the covariance between y_t and y_{t+k}. so that:

$$\rho_K = \frac{\gamma_k}{\gamma_0} \quad \ldots\ldots (3)$$

and thus $\rho_0 = 1$ for any stochastic process and the stochastic process is simply:

$$\gamma_1 = \varepsilon_1 \quad \ldots\ldots (4)$$

ε_1 is an independently distributed random variable with zero mean. Then it is easy to see from equation (2) that the autocorrelation function for this process is given by $\rho_0 = 1$, $\rho_K = 0$, for $k > 0$

Then the process in equation (4) is called white noise, and the series is a stationary and therefore the model can be used for forecasting.

However, this does not mean that we cannot use non-stationary series in time series analysis. If the series is non-stationary, then it is needed to transform it to a stationary series using a differencing method. Because many of the non-stationary time series have the desirable property that if they are differentiated one or more times, the resulting series will be stationary. Such a nonstationary series is termed homogeneous.

4.2 The Technique of Formulating Time Series Model

The model to be used in this paper in forecasting the exchange rate of Bangladesh is Autoregressive Integrated Moving Average Models that consists of the following models:

4.2.1 Autoregressive Models

In the autoregressive model, the process is described completely by a weighted sum of its past values and a random disturbance term.. In the autoregressive process of order ρ, the current observation y is generated by a weighted average of the past observations going back ρ periods, together with a random disturbance in the current period. We denote this process as AR(ρ) and write its equation as:

$$\gamma_1 = \phi_1 \gamma_{\tau-1} + \ldots\ldots\ldots \phi_1, \gamma_1 = \rho + \delta + e_1$$

where δ is a constant term which relates to the mean of the stochastic process (Pindyk: 1998).

4.2.2 Moving Average Models

In the moving average process of order q each observation y is generated by a weighted average of random disturbances going back q periods. We denote this process as MA(q) and write its equation as:

$$\gamma_1 = \mu = \varepsilon_t - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} \ldots\ldots\ldots \theta_q \varepsilon \theta_{t-q}$$

Where, the parameters $\phi_1, \phi_2 \ldots\ldots \phi_q$ may be positive or negative (Pindyk: 1998).

In both moving average and autoregressive models, the random disturbances are assumed to be independently distributed across time,i.e, generated by a white noise process

4.2.3 Autoregressive Moving Average Model

The logical extension of the models presented above is the mixed autoregressive moving average process of order (p,q). We denote this process as ARMA (p, q) and represented it by:

$$\gamma_t = \phi\gamma_{t-1} + \phi\gamma_{t-2} + \ldots\ldots\ \phi\gamma_{t-p} + \delta + \varepsilon_t - \theta_1\, \varepsilon_{t-1} - \ldots\ldots\ \theta_q\, \varepsilon_{t-q}$$

In this regard, it is assumed that the process is stationary, so that its mean is constant over time (Pindyk: 1998).

4.2.4 Autoregressive Integrated Moving Average Model

This model is for those non-stationary series that can be transformed into stationary series by differencing them one or more times and d is the number of times.

It is to be noted that y is an integrated autoregressive moving average process of order *(p, d, q)* or simply ARIMA *(p, d, q)* [Pindyk: 1998].

Stationary Series ARIMA: $\phi\ (\beta)\gamma_t = \delta + \theta\ (\beta) + \varepsilon_t$

Non-stationary Series ARIMA: $\phi\ (\beta)\ \Delta^d\ \gamma_t = \delta + \theta\ (\beta) + \varepsilon_t$

Where,

$\phi\ (B)=1-\phi_1(B) - \phi_2\ B^2 - \ldots\ldots\ldots .\phi_p B_p$

$\theta(B)=1-\theta(B) - \theta_2 B^2 - \ldots\ldots\ldots -\theta_q B^q$

This model to be used in this paper.

Therefore, it is indispensable to search out the number of order (p, d, q) and apply it for forecasting the exchange rate of Bangladesh against US dollar (i.e., Taka/US$).

5. Data Sources and Descriptive Statistics

The data of the daily exchange rate between the currency of Bangladesh (i.e., Taka) and USA (i.e., US$) has been used in this study which was taken from the International Financial Statistics (IFS) Database system, maintained by the International Monetary Fund (IMF). The crude data for the daily exchange rate from January 2005 to May 31, 2005 has been demonstrated in appendix 01.

From the following descriptive statistic and histogram stat, the overall pattern of daily exchange rate between Bangladesh and USA cane be observed.

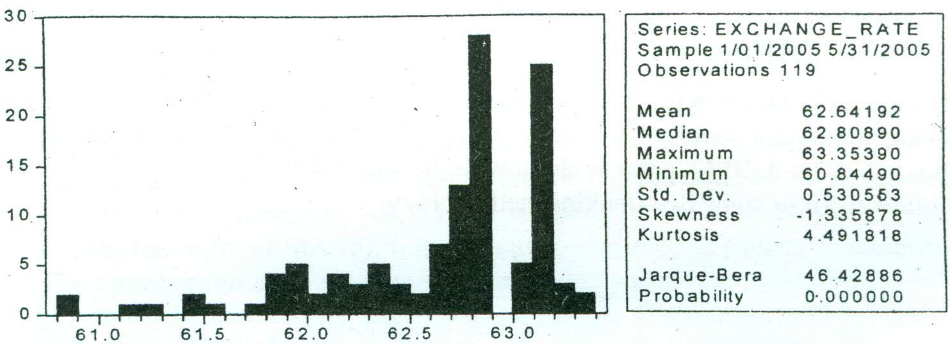


Figure 1 Daily Exchange Rate of Bangladesh (Taka/US$) for the period of January 1- May 31, 2005

From the above descriptive statistics we can understand the daily exchange rate distribution pattern. The mean and median is very close to each other.

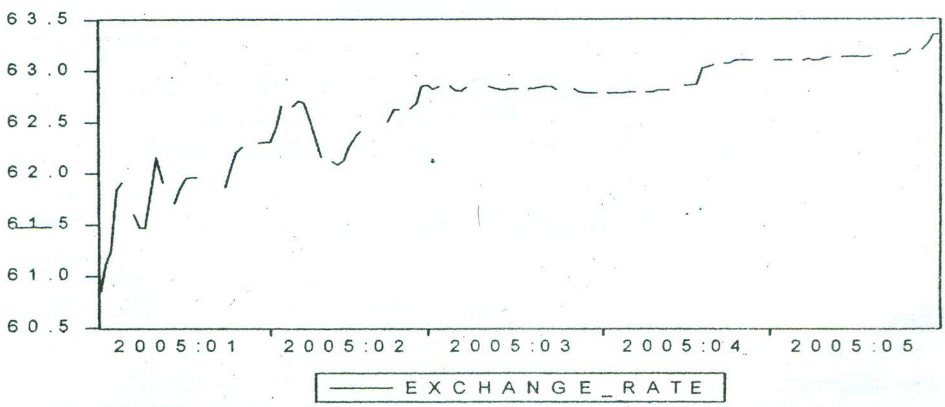


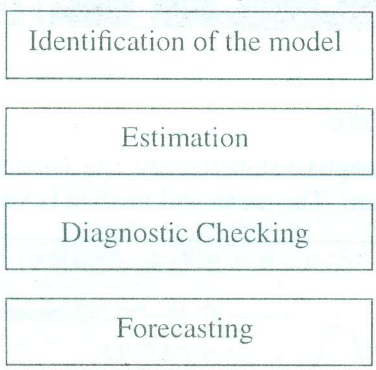
Figure 2 Daily Exchange Rate of Bangladesh (Taka/US$) for the period of January 1- May 31, 2005

The above figure demonstrates that the daily exchange rate of Bangladesh against US$ is more volatile from the January to mid February, i.e. there is reasonable ups and downs during the first two months. After that the exchange rate increases at a decreasing rate allowing us to believe that during this time period, the currency of Bangladesh (i.e., Taka) has been depreciated continuously against US dollar. In final, it can be said that the average trend of exchange rate in the context of Bangladesh in opposition to US currency is upward sloping, which shows that the currency of Bangladesh has been becoming weaker in comparison to $US.

6. Model Estimation and Hypothesis Testing

6.1 BOX-JENKINS: A Four Steps Procedure

In order to know whether the time series of daily exchange rate of Bangladesh is a purely AR process or a purely MA processor an ARMA process or an ARIMA process along with the value of p, d and q, we need to follow the four steps Box-Jenkins methodology.



The Box-Jenkins Methodology

6.1.1 Identification

First, it is crucial to testify the stationarity of the exchange rate (Taka/US$), using the method of correlogram. It is to be called that correlogram displays the autocorrelation and partial correlation functions of the specified series together with the Q-statistics and p-values associated with each lag. This result is depicted in appendix 2 (i.e., correlogram of exchange rate of Bangladesh currency against US$).

From the pattern of the correlogram, it can be seen that the exchange rate (Taka/US$) in non-stationary, because the autocorrelation is statistically significant till 8 lagged values and the partial correlation is significant till the first lagged value. This is eventually the process that is described in the section 4.1 (i.e., characterizing the autocorrelation function). After that, for transforming this non-stationary series into stationary series, the correlogram of first difference had been obtained initially with 36 lags, which is portrayed in appendix 3. At this stage, this research has been seen that the series has got the shape of stationarity.

From this process, it is clear that the number of difference is one, i.e., d in the ARIMA is 1. To find the order of AR (p) and MA (q), we can examine the pattern of the correlogram. From the correlogram representation (i.e., appendix 2), it is apparent that the pattern of Autocorrelation (AC) is declining exponentially, and partial autocorrelation (PAC) has only one statistically significant spike. Therefore we can determine that the order of AR (p) is one. Therefore, for estimation, AR (1) will be used. On the other hand, in determining the order of MA (q), it is obvious to observe the pattern of the PAC. The correlogram shows that there is only one significant spike, hence MA (1) should be used for the purpose of estimation. Therefore, from the above discussion, the bottom line is that the original time series is ARIMA (1,1,1) and as the daily data set is not continuous it is not possible to make estimation by using MA (1) command in eviews program and therefore, ARIMA (1,1,0) can be used for estimation purpose.

6.1.2 Estimation

Having identified the value of p, d, and q, the next stage is to estimate the parameters of autoregressive and moving average terms in the model. From the last section it is found that the model has already identified the exchange rate time series in Bangladesh as ARIMA (1,1,0) which will be estimated using the method of Ordinary Least Square (OLS). The details estimated results are given in appendix.

Variable	Coefficient	t-Statistic
C	0.022662	1.594823
D(EXCHANGE_RATE(-1))	0.317125	2.644276
R-square	0.092012	

The above regression states that the lag variable has significant influence in determining movements of exchange rat. It is statistically different from zero.

6.1.3 Diagnostic Checking

Before using this model for forecasting, it is inevitable to determine whether the residuals of the estimated results are white noise or not. For this purpose the residuals of the estimated results had been obtained (this result output has been presented in appendix 2). This calculation has indicated that the calculated Q-statistic at 32 lagged period is 9.9390. Hence,

χ^2 (k– p – q) Test: The degrees of freedom (32 – 1) = 31

At 5% level of Significance

$Q_{calculated} = 9.9390$

$Q_{critical} = 43.7729$

$Q_{calculated} < Q_{critical}$. It implies that the error term of the estimated results is a white noise. As a result, there is no correlation between error terms in the model. Hence the above estimated results can be used for forecasting purpose.

6.1.4 Forecasting

For the purpose of forecasting the exchange rate (Taka/US$) the latest 2 months daily observations have been selected, i.e. the daily exchange rate for the period of 5th April 2005 to 31st May 2005. The result has been depicted in the below Figure.

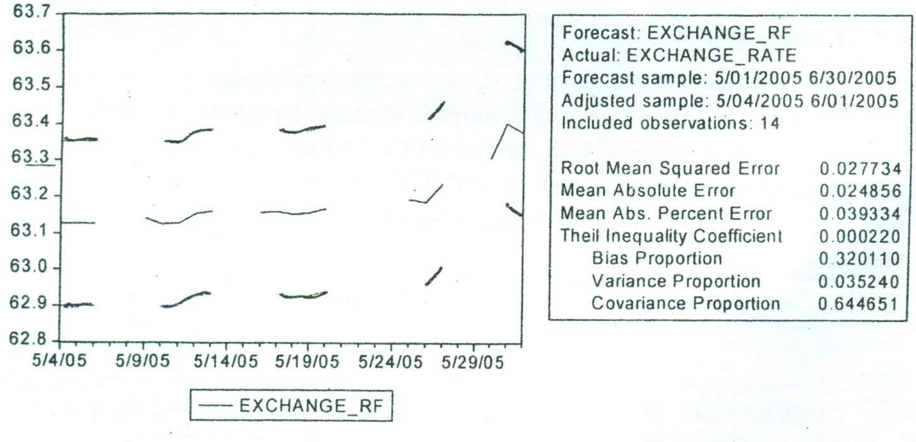


Figure 3 The forecast of Exchange Rate (Taka/$US)

The above ex post forecasted result shows that the daily exchange rate fluctuations in Bangladesh during the forecasted period are almost 2.5% from its mean value. This indicates that fluctuations are not highly volatile. Our objective is to predict future exchange rate of a time series subject to as little error as possible. For this reason we consider the optimum forecast to be that forecast which has the minimum mean square forecast error. The result of mean percent error, root mean square error as well as Theil Inequality Coefficient is all very low. By considering the above values this model seems to be good for forecasting the exchange rate of Bangladesh in the short run period. Now if we take a look at the following diagram to see the actual and the forecasted value during this forecasted period, we can observe real situation of the daily exchange rate forecasting.

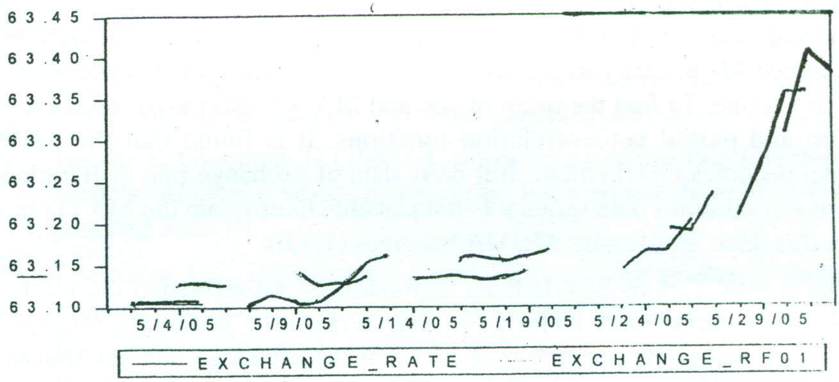


Figure 4 Daily Exchange Rate (Taka/$US) -The Actual vs Forecast

The above figure of ex post forecast of exchange rate (Taka/$US) for the period of April to May 2005 implies that the direction of both actual and forecasted value is more or less same. The pattern shows that the forecasted value of daily exchange rate is above the actual value over the forecast period. It over predicts the daily exchange rate but with a little deviation from the actual value. The trend of both actual and forecasted line indicates the daily exchange rate remains almost stable until May 20 and after that it reflects an upward trend (with a steeper slope) until the end of May. It could be seen that Bangladeshi taka depreciates against the $US over the forecasted period. It is to be noted that the forecasted line shows a declining trend of exchange rate from 30th May onward. On the other hand, actual line indicates upward trend. The forecasted value does not capture the accurate the pattern from the end period onward. After comparing these two line we can conclude that this model may be used for forecasting short run exchange rate of Bangladesh. The gap in the lines in above graph indicates that the data series of daily exchange rate of Bangladesh is not a continuous one. Thatís why there exist gap in the lines.

An evaluation of this model as a forecasting tool is somewhat difficult given the volatility of exchange rates. What we can see, the ARIMA model captures trends but fails to predict the accurate results in certain periods.

7. Interpretation of Results and Conclusion

This paper focuses on forecasting the daily exchange rate movements of Bangladesh for the period of January1 to May 31, 2005. In forecasting the exchange rate the study uses the Box–Jenkins four steps procedures. In first part we tested stationarirty of time series by using the autocorrelation function. Stationarity is found at first difference level. That means the number of difference (d) in order to transform the non stationary time series into stationary is one. To find the order of AR and MA we again used the autocorrelation and partial autocorrelation functions. It is found that the ARIMA model becomes (1,1,1) order. But daily data of exchange rate of Bangladesh is not a continuous data series it is not possible to estimate the MA (1) model with this data. Thatís why ARIMA becomes (1,1,0).

In the second part of Box-Jenkins methodology we estimated the model by using the original OLS method (as time series now stationary series). The results show that the coefficient of one-year lag exchange rate has significant impact on exchange rate movements. This can be supported from the statistical result. It is statistically significant. The r^2 value is very low but this does not mean that specification is poor one. It is desirable in case of time series model that r^2 is usually very low. In this situation e we cannot measure the fit of the model by only seeing r^2 value.

In third steps (diagnostic part) study found that residuals from the OLS regression are white noise error term, which implies that this model is good for estimating the short- run exchange rate of Bangladesh.

Having found this model fit for forecasting, in the last part study made ex post forecasting of exchange rate. The results found that the daily exchange rate fluctuations in Bangladesh during the forecasted period are almost 2.5% from its mean value. This indicates that there exists fluctuations in exchange rate movements but fluctuations are not highly volatile. The model may be used as a tool of forecasting the movements of exchange rate (Taka/$Us) in Bangladesh.

8. Limitation of this Research and the Possible Extensions

The paper focuses on time series model of forecasting daily exchange rate of Bangladesh. Although the predicted results show a consistent pattern with the actual value of exchange rate in the short run, the exchange rate between Bangladesh and USA cannot be only predicted by considering past information itself. There may other information that should be included. The exchange rate prediction is very difficult in the sense that it depends lot on the changing demand and supply of US dollar in foreign exchange market. This is because exchange rate can be affected by the economic variables and non-economic variables including political unrest factors in a country like Bangladesh where political unrest is in its extreme form.

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Appendix : 1

Data on Daily Exchange Rate of Bangladesh

Date	Exchange Rate (Taka/$US)	Date	Exchange Rate (Taka/$US)
1/1/2005	60.84490	1/2/2005	60.84490
1/3/2005	61.11490	1/4/2005	61.24740
1/5/2005	61.84590	1/6/2005	61.90790
1/7/2005	–	1/8/2005	61.59790
1/9/2005	61.46890	1/10/2005	61.46790
1/11/2005	61.85290	1/12/2005	62.15290
1/13/2005	61.90790	1/14/2005	–
1/15/2005	61.70790	1/16/2005	61.83540
1/17/2005	61.95400	1/18/2005	61.95700
1/19/2005	61.95700	1/20/2005	–
1/21/2005	–	1/22/2005	–
1/23/2005	–	1/24/2005	61.85950
1/25/2005	62.05950	1/26/2005	62.20950
1/27/2005	62.25980	1/28/2005	–
1/29/2005	–	1/30/2005	62.30230
1/31/2005	62.30480	2/1/2005	62.30730
2/2/2005	62.45520	2/3/2005	62.65770
2/4/2005	–	2/5/2005	62.65020
2/6/2005	62.70430	2/7/2005	62.68930
2/8/2005	62.52710	2/9/2005	62.35460
2/10/2005	62.15460	2/11/2005	–
2/12/2005	62.11210	2/13/2005	62.08460
2/14/2005	62.12460	2/15/2005	62.25460
2/16/2005	62.35710	2/17/2005	62.40710
2/18/2005	–	2/19/2005	62.40210
2/20/2005	–	2/21/2005	–
2/22/2005	62.50210	2/23/2005	62.62460
2/24/2005	62.62460	2/25/2005	–
2/26/2005	62.62610	2/27/2005	62.68360
2/28/2005	62.84360	3/1/2005	62.86110

Date	Exchange Rate (Taka/$US)	Date	Exchange Rate (Taka/$US)
3/2/2005	62.82100	3/3/2005	62.84600
3/4/2005	–	3/5/2005	62.84850
3/6/2005	62.80600	3/7/2005	62.80100
3/8/2005	62.83600	3/9/2005	–
3/10/2005	62.84600		
3/11/2005	–	3/12/2005	62.84700
3/13/2005	62.82700	3/14/2005	62.81700
3/15/2005	62.81700	3/16/2005	62.82700
3/17/2005	62.82700	3/18/2005	–
3/19/2005	62.82700	3/20/2005	62.82700
3/21/2005	62.83700	3/22/2005	62.84700
3/23/2005	62.84600	3/24/2005	62.81700
3/25/2005	–	3/26/2005	–
3/27/2005	62.81900	3/28/2005	62.78900
3/29/2005	62.78600	3/30/2005	62.78700
3/31/2005	62.78700	4/1/2005	–
4/2/2005	62.78700	4/3/2005	62.78700
4/4/2005	62.78700	4/5/2005	62.78600
4/6/2005	62.78900	4/7/2005	62.79030
4/8/2005	–	4/9/2005	62.79230
4/10/2005	62.79130	4/11/2005	62.80790
4/12/2005	62.80890	4/13/2005	62.80890
4/14/2005	–	4/15/2005	–
4/16/2005	62.85500	4/17/2005	62.86100
4/18/2005	62.86110	4/19/2005	63.02310
4/20/2005	63.03310	4/21/2005	63.05410
4/22/2005	–	4/23/2005	63.07410
4/24/2005	63.07370	4/25/2005	63.10370
4/26/2005	63.10370	4/27/2005	63.10400
4/28/2005	63.10400	4/29/2005	–
4/30/2005	63.10400	5/1/2005	–
5/2/2005	63.10400	5/3/2005	63.10400
5/4/2005	63.10400	5/5/2005	63.10400
5/6/2005	–	5/7/2005	63.10400
5/8/2005	63.11400	5/9/2005	63.10450
5/10/2005	63.10450	5/11/2005	63.12450

Date	Exchange Rate (Taka/$US)	Date	Exchange Rate (Taka/$US)
5/12/2005	63.13450	5/13/2005	–
5/14/2005	63.13450	5/15/2005	63.13450
5/16/2005	63.13550	5/17/2005	63.13050
5/18/2005	63.13250	5/19/2005	63.14150
5/20/2005	–	5/21/2005	63.14150
5/22/2005	–	5/23/2005	63.14150
5/24/2005	63.16350	5/25/2005	63.16350
5/26/2005	63.20150	5/27/2005	–
5/28/2005	63.20350	5/29/2005	63.26190
5/30/2005	63.35190	5/31/2005	63.35390

Appendix 2

Ordinary Least Square Results

Dependent Variable	: D(EXCHANGE_RATE)
Method	: Least Squares
Date	: 06/20/05 Time : 20:33
Sample(adjusted)	: 1/03/2005 5/31/2005
Included observations	: 71
Excluded observations	: 78 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.022662	0.014210	1.594823	0.1153
D(EXCHANGE_RATE(-1))	0.317125	0.119929	2.644276	0.0101

R-squared	0.092012	Mean dependent var	0.035659
Adjusted R-squared	0.078853	S.D. dependent var	0.117055
S.E. of regression	0.112345	Akaike info criterion	-1.506724
Sum squared resid	0.870873	Schwarz criterion	-1.442987
Log likelihood	55.48870	F-statistic	6.992195
Durbin-Watson stat	2.289022	Prob(F-statistic)	0.010127