Forecasting Exchange Rate of Pakistan

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A dissertation submitted to the Department of Economics, PIDE, at Islamabad in partial fulfillment of the requirement for the degree of Master of Philosophy in Economics

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In the Name of Allah,

The most compassionate, the merciful

Acknowledgement

All praises to Allah, who made me capable of learning, blessed me with the knowledge & intellect and facilitated me with the finest of the mentors all through my academic years.

I feel great pleasure in extending my heartfelt thanks to our worthy supervisor Dr.Wasim Shahid Malik for guiding, supporting, helping, and encouraging me from beginning to end of this research, without his endeavors this research work was not possible.

I would like to express my sincere thanks to Dr.Ejaz Ghani, my head of department for granting me time to complete this project.

My special thanks to Ms.Hafsa Hina for her spectacular interest and cooperation.

I also like to express my great gratitude to all my family members and in laws, my father and my father in law, my husband, and my son for their patience, love and encouragement throughout my studies.

Dedicated To

My mother and my mother-in-law for their love, prayers and encouragement throughout this research

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Abstract

Due to Globalization economies have become more integrated than ever thereby making exchange rate more important for both policy makers and businesses. Pakistan, being an emerging economy, is quite attractive place for foreign portfolio investment. Hence a good understanding and modeling of exchange rate is required for forecasting, in order to make wise decisions regarding international business and economic policies. The general consensus, in this regard, however, is that exchange rate is random walk process.

The present study contributes to the ongoing debate regarding the possibility of correctly forecasting future exchange rate movements. The econometric evidence resulting from this kind of study can suggest which model should be adopted in order to achieve a better forecasting performance contrary to general perception that exchange rate is a random walk process. Our results suggest that exchange rate can reasonably be forecasted if structural breaks are properly modeled. We have used linear and nonlinear model in the form of autoregressive process and threshold autoregressive process, respectively. Quarterly data of Pakistan over the period 1981:Q4 -2011:Q1 have been gathered on nominal exchange rate, real exchange rate, and real effective exchange rate for testing efficiency of linear and nonlinear models to forecast the exchange rates. Our results reveal that nonlinear model can better forecast the nominal and real exchange rates, but in case of real effective exchange rate, linear model is found better.

Chapter 1
Introduction

In addition to the economic factors such as interest rate and inflation, exchange rate is also an important indicator of economic health of a country. It has significant impact on country's level of trade. Hence countries have close eye on exchange rates and manipulate it officially to attain the desired economic targets. Exchange rate is not only considered at macro level, it is equally important at small scale, as it influences the investors' return. Thus knowledge about exchange rate variation and its forecasting technique is necessary for both policy makers and investors.

Exchange rate variation has a significant role in the determination of fundamentals such as prices, interest rate, unemployment, wages and ultimately the output level. However too much variation in exchange rate may not be a healthy sign and may result in macroeconomic destabilization. (Parikh and Williams, 1998).The reasons behind exchange rate volatility and forecasting exchange rate is of utmost importance. Different models and techniques are used by researchers to capture the variation in exchange rates. Our interest however is not only in past exchange rate behavior but we also want to know the future exchange rate behavior; hence forecasting exchange rate has great importance. Therefore forecasting exchange rate is now on top of the research priorities in international finance. Literature still reports the empirical failure, however, in this regard. In empirical research, economic fundamentals based models are found to be inferior to the naïve random walk model. Therefore, in international finance, exchange rate is viewed to be unpredictable especially for short time horizons. In other words exchange rates are thought to follow a random walk process. By random walk it is meant that period-to-period changes in exchange rate are random, and therefore, unpredictable. This means that the tomorrow exchange rate level is as likely to be higher as it is to be lower than its today's level, which means that tomorrow exchange rate level is difficult to predict and the best forecast for tomorrow's exchange rate level is today's exchange rate level.(Moosa)

Currently researchers are also focusing on the non-linear behavior of variables. Froot and Obstfeld (1989) put forward that the traditional view about exchange rate is a linear form of current fundamental is a special case of more general model. They used stochastic calculus techniques where exchange rate is related to the fundamentals linearly as well as nonlinearly. Hence researchers are now testing the use and applicability of non linear models of exchange rate with a special attention to the first moment (see for instance, Diebold and Nason, 1990; Schinasi and Swamy, 1989; Meese and Rose, 1991).Krugman (1988) and Froot and Obstfeld (1989) elaborate that the form of the nonlinearities is fairly obvious. Nonlinearities mainly occur due to three possible reasons. Nonlinearity in exchange rates may be a result of shifts in various regimes; it may be because of time-varying coefficients; or finally it can also be the outcome of some inherent non-linear data generating processes.

Despite the importance of the topic, limited work has been done in this regard with reference to Pakistan. For example, interest rate parity model is used by Khalid (2007) to predict the exchange rate of three Asian countries namely Pakistan, India and China. Rashid (2007) used interest rate parity condition to analyze the exchange rate models. But none of these studies, and to our knowledge, no other study, has focused on non-linear behavior of exchange rate of Pakistan.

This study aims at finding the appropriate methods to model and forecast exchange rate movements in Pakistan. In Pakistan, political and economic factors such as political instability, unstable monetary and fiscal policy and terrorism make exchange rate movements more volatile. Due to such variation in exchange rate, investor is concerned about the future moments; hence forecasting is important. More importantly we hypothesized, in this study that unpredictable nature of exchange rate is due to structural breaks and non-linearity arising due to time varying coefficients. If structural breaks are properly handled and non-linearity is appropriately modeled then exchange rate can reasonably be forecasted. The main objectives to be covered in this study are to estimate the linear and nonlinear models and then to compare their efficiency regarding exchange rate forecasting.

To achieve our objective, we have used two types of autoregressive models; the standard autoregressive (AR) model and the threshold autoregressive (TAR) models. The TAR model is used to capture the nonlinear behavior of exchange rate. We have estimated these both types of models for nominal exchange rate, real exchange rate, and real effective exchange rate using the data over the period 1981:Q4-2011:Q1.On the basis of both models, we have made forecast of three exchange rates for the next six quarters. Finally we have used Mean Square Prediction Error to evaluate the forecast efficiency of two competing models.

The remaining study is arranged as follows: Chapter 2 provides information regarding exchange rate history of Pakistan. Chapter 3 presents the work done in the field of exchange rate in the light of previous literature. Chapter 4 specifies the methodology implied in this study. Chapter 5 presents the estimation results and the forecasting performance of the linear and nonlinear models. Chapter 6 concludes the whole discussion in the light of findings of this study.

Chapter 2

Overview of Pakistan Economy with a Focus on Exchange Rate

The management of exchange rate in Pakistan is the responsibility of State Bank of Pakistan (SBP). State Bank implements different policies regarding exchange rate keeping in view the prevailing situation. Following is the brief history of exchange rate system in Pakistan.

Initially, Pakistani rupee was linked with Pound Sterling but then since 17th September 1971, rupee value is determined in terms of U.S. Dollar. After the separation of East Pakistan in 1971, Pakistan faced the problem of balance of payments; to overcome this problem currency was devalued by 58% and exchange rate was set at Rs 11 per US dollar.

In 1982, again Pakistan was facing the problem of balance of payments, due to the strengthening of US dollar and a decline in remittances from abroad in that year. To deal with these problems Pakistan adopted the system of managed floating exchange rate. In this system rupee value was determined with reference to currencies of major trading partners of Pakistan.

In 1998, after nuclear explosion, Pakistan faced the problem of financial crises due to sanctions by donor countries. A multiple exchange rate system was adopted by authorities to ease the financial crises in Pakistan. This system includes official rate (pegged to U.S. dollar), a Floating Interbank Rate (FIBR), and a composite rate (combines the official and FIBR rates).[1]

On 22nd of July 1998, two-tier exchange rate system was implemented. This act was done to reduce pressure on official reserves and to some extent, save the economy from unfavorable implications of sanctions on Pakistan. On 19th of May 1999 exchange rate was allowed to float within a narrow band. Finally after 20th July 2000, SBP adopted flexible exchange rate system.

Pakistan economy was affected due to 9/11 event; Pakistani currency started appreciating against US dollar due to increase in foreign exchange inflow from abroad. This was partially due to easing of quota restriction from USA and EURO zone on some Pakistani exports, as Pakistan was the main country fighting against terrorism.

By looking at the figure of nominal exchange rate (ER) and real exchange rate (RER) we clearly observe that both exchange rates changed in year 2001.

For more than four years, exchange rate of Pakistan remained stable, after that a significant reduction in its value was recorded; it deprecated against the US dollar by 21 % in 2008.Different combination of factors like trade related outflows, political uncertainty, increase in oil prices affected its value. Rupee revived backs

[1] State Bank of Pakistan (SBP)

some of its value after IMF standby arrangements. The values of exchange rate remain stable about Rs.80-82 per dollar due to revival of inflows from abroad and some import compression. A net deprecation of PAK rupee against the US dollar at around 13.5% was recorded during the period from July 2008 to February 2009.

From the graphs of exchange rates series we can observe the time path of exchange rate and we can see that there are structural breaks in all the three exchange rates.

Figure 2.1: History of Exchange Rates

Figure 2.1.a: Nominal Exchange Rate (ER)

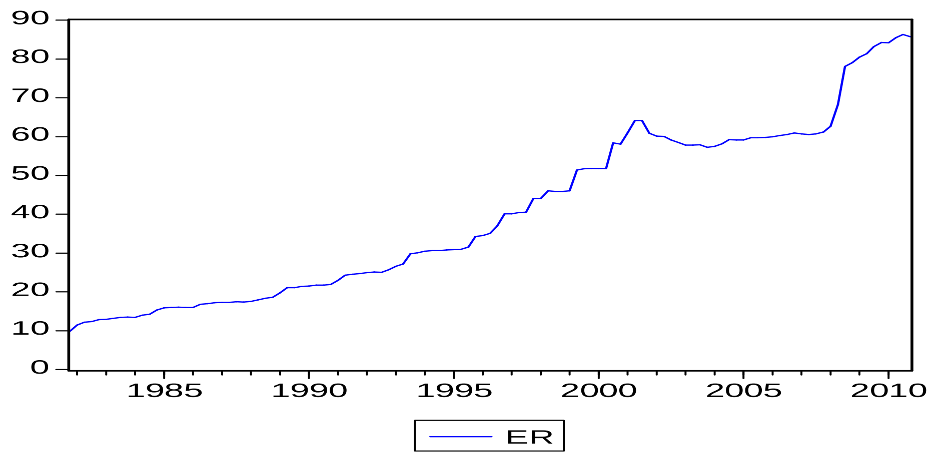


Figure 2.1.b: Real Exchange Rate (RER)

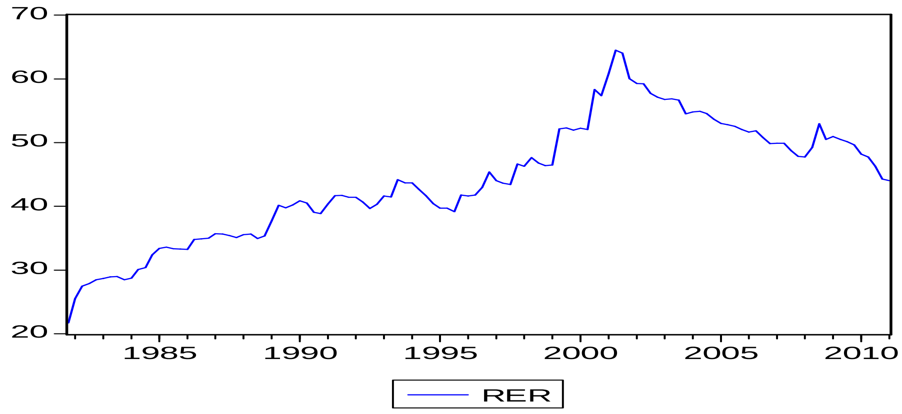
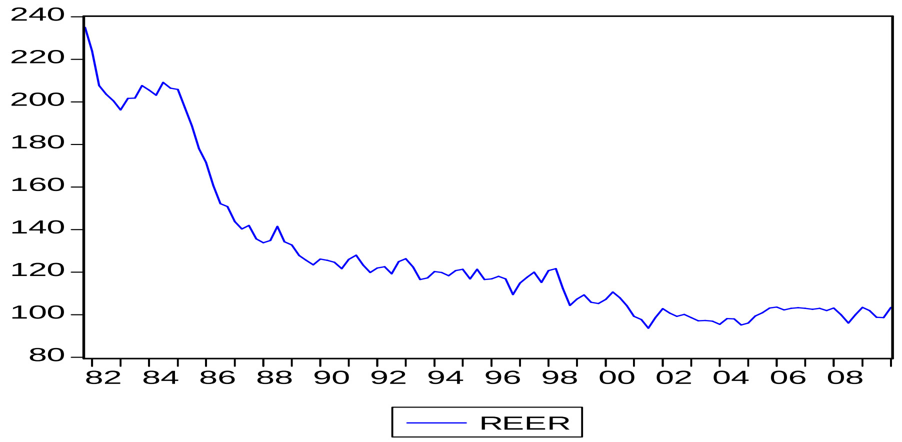


Figure 2.1.c: Real Effective Exchange Rate (REER)



A first structural break in nominal exchange rate is observed in year 2001 and second in year 2008. In real exchange rate, only first structural break is observed at 2001. In 2008, exchange rate jumped but inflation rate, at that time, was also high. So there was no jump in real exchange rate. Finally, in real effective exchange rate, only one structural break occurred at 1985.

Chapter 3

Literature Review

This chapter reviews the empirical literature, and the econometric methodology used by past researchers regarding the issue of nonlinearity and forecasting of exchange rate. As pointed out earlier that nonlinearity in exchange rate is now given special attention in modern research, hence different combination of linear and nonlinear models are discussed here.

3.1 Linear Vs Non Linear Models for Forecasting

A forecast represents a process by which we make expectation about future value of a variable. The most frequent approaches used for exchange rate forecasting are

(a) The fundamental approach.

(b) The technical approach

(a)Fundamental Approach

In this approach fundamental economic variables which determine exchange rate are used, for example interest rate, inflation rate, trade balance, GNP, consumption e.t.c.

(b)Technical Approach

Technical approach is generally based on historical information. In this approach past exchange rates are used for forecasting purposes.

In forecasting different models are used for example the econometric models are based on some economic theory where the dependent variable is related to some independent variable or variables. Econometric models are single equation as well as multi equations models. The multivariate models are based on some underlying theory, these models are based on theory and include monetary model (MM), covered interest parity (CIP), purchasing power parity, Balance of payment (BOP) models e.t.c.

The second category of models is time series forecasting models. These models are entirely based on past history of exchange rate. In these models dependent variable is related to its past values and to random error which may be serially correlated. The most famous class of time series models in forecasting is ARMA.

Modern research is solely focusing on the debate regarding capability of various models to analyze time series data to forecast the exchange rates. Efforts are still on to prove the theoretical and econometric models presently in use, as a good and reliable to analyze and describe empirical data. A vast literature in this regard has been reported by Frankel and Rose (1995) and Meese (1990) covering same debate. However all the literature available so far has been failed to challenge the findings of Meese and Rogoff (1983) that structural macro models in any case cannot do better than the random walk models of exchange rate. They use different time series and fundamentals based models including sticky and flexible price monetary models. The forecasting efficiency of the models are compared with random walk model using the criteria of root mean square.

Monetary fundamentals such as inflation differential, the GDP differential, the short-term interest rate differential and the relative money growth may predict exchange rates out of sample. However their predictive power remains very low especially in the short run. Some evidence has also been found that as the time horizon increases, the models based on these monetary indicators better forecast the exchange rate (Mark, 1995).

Kashif et al (2008) used three alternative models to analyze the daily inter- bank exchange rate of US dollar measured in Pakistan rupees. The forecasting performance of state space model was compared with those of ARIMA and Comprehensive Autoregressive Conditional Heteroscedasticity (GARCH) approach. Four different criteria were applied to analyze the forecasting accuracy. Their study reveals the superiority of State space model over the other two competing models.

Khan et al (2010) conducted a research on factors causing fluctuation in real exchange rate of Pakistan. They applied SVAR (Structure Vector Autoregressive) technique in their study. The data from period 1982-Q1 to 2007-Q1 was taken for the analysis. Their findings suggest that nominal shocks are the key force in variation in real exchange rate. Their results are same to those of Dornbusch (1976) sticky-price model.

Forecasting exchange rate movements is challenging, as they demonstrate high instability, intricacy and noise. Among the traditional forecasting models, no model can forecast with better accuracy than the random walk model. Ever since the Engle (1982) and Bolleslev (1986) have introduced ARCH and GARCH models, they are most commonly applied to financial time series data to measure the volatility and its impacts on other variables.

However it may be a difficult task to use ARCH model in exchange rate as it is directly affected by the structural changes or regime shifts (Lamoureux and Lastrapes, 1990). The ARCH-GARCH models mainly address the issue of volatility; technically speaking conditional variance is function of the returns stochastic process. While this procedure requires stationarity, volatility is usually explained by a linear process but a nonlinear process can also be used to explain the volatility.

It is generally assumed by the tests that have been applied in past that there exist a linear trend in real exchange rates. However upcoming research is increasingly focusing on the point that real exchange rate demonstrate nonlinear trends rather than linear. Probable reasons for non linearity in real exchange rates haves been identified by Taylor et al. (2001). According to them, non linearity in exchange rates may occur due to the transaction costs, shipping costs, tariffs and taxes. Transaction costs associated with the adjustment process in exchange rates generates non linearity in exchange rates (Dumas, 1992;Uppal, 1993; and Sercu, et al, 1995). Another source of non linearity in exchange rates as reported by Coleman (1995) is the expected shipping time or any subsequent positive deviation. Diversity in agents' beliefs and heterogeneity in investors' objectives have also been figured out as the probable source of non linearity in exchange rates (Cerrato and Sarantis, 2006).

Engel and Hamilton (1990) pointed out the incapability of typical single-regime models in determining the exchange rate behavior. They pointed out that random walk models are not a good option when it comes to with - in sample forecast, as compared to regime-switching models.

SETAR (Self-Exciting Threshold Autoregressive) is a special case of TAR (Threshold Autoregressive) models where the threshold variable is considered to be the lagged value of the time series itself. where we also have a delay parameter and it has some positive value.SETAR model is the extension of AR type models. The model is linear in piecewise with respect to threshold variable but not with respect to time. SETAR models are empirically used to explain complex nonlinear phenomena, for example, Asymmetries and jumps phenomenon cannot be captured by linear time series. KrÄager and Kugler (1993) apply the SETAR models on exchange rate.

An extension of TAR models is the STAR Smooth Transition Auto regressive family of models. Closely related to the TAR model, smooth transition autoregressive (STAR) is equally important and useful for forecasting purposes. Terasvirta and Anderson (1992) developed these models for capturing non-linearity over the business cycle. Further the numerical properties and conclusion of their study were examined by Granger and Terasvirta (1993). However the application of these models is still limited. Granger and Terasvirta (1993) used these models to find out the non linear association between GNP growth and leading economic indicators.

In a paper, Engel (1992) used Markov switching model to test the behavior of floating exchange rates of eighteen different currencies, including eleven non-U.S dollar currencies. Estimation is based on monthly and quarterly data from period 1973-1986.The general conclusion is that, the choice of estimation period does not affect the forecasting ability of segmented trend models, but the in sample estimation results of quarterly data seems to produce better results than the in sample results of monthly data. The results reveal that the Markov – switching model does not provide superior forecast of exchange rates. Results obtained from this model generally do not give minimum mean squared error or mean- absolute error as compared to random walk model with drift or without drift. Some evidence reveals that the forecast of the Markov model outperform in predicting the direction of change in exchange rate.

Obstfeld & Taylor (1997), for the first time, applied the TAR models to real exchange rates. International and Inter US monthly sub groups of data of relative CPIs were collected to test the TAR adjustments. They predicted the constraints by means of maximum likelihood and obtained reasonable approximation. Monte Carlo simulated likelihood ratio (LR) was also used to prove the superiority of TAR model over the standard AR model.

STAR models were also implied by the Ocal and Osborn (1997) to investigate the non linear relationship between consumption and production in UK industry. Ley bourne and Mizen (1997) used these STAR models for analyzing trends in consumer prices. Skalin and Terasvirta (1998) examined business cycle in Sweden by means of applying STAR models.

Sarantis (1999), test the non-linearity in real effective exchange rate using Smooth Transition Autoregressive (STAR) family of models. The monthly data over the period 1980:1-1996:4 is collected for ten major industrial countries, the (G-10).Linearity of exchange rate of 8 industrial countries is rejected during the period of 1980s and 1990s. The model fulfills all diagnostics and gives satisfactory results of non-linearity present in REER. He compares the out-of-sample forecasting performance of STAR model with linear AR model and Hamilton Markov Regime Switching model. Result shows that STAR model shows better performance than Markov Switching model. But with regard to linear models there is not much to choose between the linear models and STAR.

Taylor and Peel (2000) investigated the nonlinearity in dollar–sterling and dollar–Mark exchange rate. The study focuses on the possibility of deviation of exchange rate from the level implied by monetary fundamentals. Adjustment process is found to be nonlinear because nonlinear factors governed the cost of arbitrage. The study also reports that exponential STAR can well approximate the non linearity found in them.

Forecasting performances of the two models that is linear AR (1) model and non linear TAR model was simultaneously checked by the Kuo and Mikkola (2000).Root mean square criteria (RMSE) criteria were applied on out-of-sample forecast to the univariate time series data of USD / DEM real exchange rates. Quarterly values for both the variables were collected for the first quarter of 1957 to fourth quarter of 1998. The linear AR process was fitted to real exchange rate series for the reason that it is considered sufficient enough to capture all the effects of mean reversion and thus helps in predicting the exchange rates in long run. Research papers found in near past have widely used TAR models for exchange rate forecasting in theoretical as well as empirical studies. The ultimate edge that TAR models have over others (particularly AR model) is its capability of accurately forecasting specially in out- of- sample testing. However the results obtained by applying TAR models when compared with results of AR model it has been found that the forecast of TAR models mainly depends upon the period covered for estimation purpose and also in long run its forecasts become doubtful as compared to AR models estimation.

No unanimous decision can be found by available literature about the predictive powers of nonlinear models used for exchange rate determination, especially when the models are applied out of sample. Clarida et al. (2003) has especially focused on the power of regime switching models to predict exchange rates and has established their superiority over the random walk models as previously suggested by Engel and Hamilton (1990).

Coporale and Spagnolo (2004) examined the presence of structural breaks in foreign exchange rates of three East Asian countries, namely South Korea, Indonesia and Thailand. In 1997 East Asian countries experienced financial crises and face speculative attacks which led the massive deprecation of their currencies and represent a major regime shift. They employ the Markov Regime Switching Model that allows discrete shifts in the mean and variance. The study compares the ability of nonlinear (markov regime switching, smooth transition autoregressive) and linear (random walk) models to capture the dynamics of exchange rates in the presence of structure breaks. Monthly data of local currency against the US dollar has been employed over the period 1970:1-2001:5.The results show that nonlinearities are better captured in Markov Regime Switching model. The model is also found to perform better than the Random Walk in terms of both in-sample and out –of-sample forecasting.

Whether any associations exist among real exchange rate and trade balance in long run or not is the question that was being analyzed by Duasa (2009).Demand for exports and imports were analyzed by cointegration test assuming asymmetric adjustment. The results found after applying MTAR model (that is momentum-threshold autoregressive model) indicated that real exchange rates have asymmetric cointegration with the balance of trade. When TAR model was applied to same data, export volume was also found to have asymmetric cointegration with real exchange rate. The adjustment back toward equilibrium point is comparatively fast which follows relative increase in trade balance when estimated by M-TAR error correction trade balance model above long-run value in contrast to the relative decrease in trade balance below long-run value. TAR error-correction import demand model proposes that as soon as the value of demand for imports drops down below the long run value, it gets adjusted rapidly.

Inflation plays an important role in economic growth. The dynamics of inflation rate was analyzed by different models. These models perform better only when the series under consideration is linear. Hence the assumption of linearity in time series is crucial in developing models. However recent empirical work shows that the underlining dynamics generating mechanism of inflation rate is non-linear.

Keeping this in view Rehman et al (2011) investigate the presence of non-linearity in inflation series of Pakistan. They use STAR models to investigate non-linearity in inflation rate. Inflation rate of consumer price index on month-on-month bases was taken. Period covering values from July 1992 to Feb 2011.The study shows that ESTAR and LSTAR type non-linearity cannot be rejected hence Pakistani inflation series possesses non-linear behavior. When the model was compared to its competing AR (p) linear model it was found that non-linear model has lower residual variance. The forecasting performance of non linear models was better than that of the AR models.

Chapter 4

Methodology

In this chapter we discuss the competing models used in forecasting exchange rate. We start with linear univariate autoregressive (AR) model then we discuss nonlinear threshold autoregressive (TAR) model which serves as a benchmark for comparison.

4.1 Linear Autoregressive Model

The most frequently linear time series model used in the financial series is Autoregressive process introduced by Yule (1927). These time series models are well suited and can be easily estimated within the framework of least-squares regression. The autoregressive model is one of the groups of linear models that attempt to predict an output based on its previous values. The Autoregressive model, for variable X, with lag *p* can be written as

$$X_t = c + \sum_{i=1}^{p} \varphi_i X_{t-i} + \varepsilon_t \qquad (4.1)$$

Where $\varphi_1, \ldots, \varphi_p$ are the parameters of the model, c is a constant and ε_t is white noise error term. It is considered as a sequence of independent and identically distributed random variables with the mean value "0" and Variance σ^2_ε

Where roots of AR (p), that is,

$$\theta(\varphi) = 0$$

lies outside the unit circle for stationarity of the process. Then mean and variance of AR (p) process is independent of time.

Autocorrelation function (ACF) of AR (p) does not break off at small lag length, whereas the Partial Autocorrelation Function (PACF) of AR (p) process cut off at lag k>p. Therefore PACF is used for the identification of AR (p) process.

4.1.1 Forecast with AR Model

For the purpose of forecasting, it is assumed the present and past values of $\{\varepsilon_t\}$ and $\{x_t\}$ are known.

Let the AR (1) model be

$$X_t = c + \partial X_{t-1} + \varepsilon_t \quad (4.2)$$

For the next time period the model (4.2) takes the form

$$X_{t+1} = c + \partial X_t + \varepsilon_{t+1} \quad (4.3)$$

The value of X_{t+1} can be forecasted if the coefficient c and ∂ are known conditioned upon the available information at time period t

$$E_t X_{t+1} = c + \partial X_t \quad (4.4)$$

In the same pattern

$$X_{t+2} = c + \partial X_{t+1} + \varepsilon_{t+2} \quad (4.5)$$

Where the forecast of X_{t+2}, conditioned upon the available information at time period t, will be

$$E_t X_{t+2} = c + \partial E_t X_{t+1}$$

Using (4.4)

$E_tX_{t+2} = c + \partial (c + \partial X_t)$

Thus X_{t+2} can be forecasted using the forecast of X_{t+1}. Thus the forecasts can be constructed using forward iterations; the forecast of X_{t+i} is used to forecast X_{t+i+1}.

Since

$X_{t+i+1} = c + \partial X_{t+i} + \varepsilon_{t+i+1}$ it follows that

$$E_tX_{t+i+1} = c + \partial E_tX_{t+i} \qquad (4.6)$$

From (4.4) and (4.6) it can be observed that it is possible to estimate the whole sequence of i-step ahead forecasts by foreword iterations.

Consider

$$E_tX_{t+i} = c\,(1 + \partial + \partial^2 + \ldots\ldots\ldots + \partial^{i-1}) + \partial^{I} X_t \qquad (4.7)$$

The above equation (4.7) is known as **forecast function,** where the entire i-step ahead forecast is taken as a function of available information set in period t.

For a stationary AR model, the conditioned forecast of X_{t+I} converge to a unconditioned mean as $i \rightarrow \infty$.

As forecast cannot be perfect there would be some error. The forecast error is defined as the difference between the realized value of X_{t+I} and the forecast value in that period.

$FE(i) = X_{t+i} - E_tX_{t+i}$

4.2 Non Linear Threshold Autoregressive Model

Modeling financial time series using nonlinear models is now a subject of immense interest in literature. These nonlinear models are getting more famous than the linear models. According to Franses and Dijk (2000), one class of such nonlinear models is the regime switching models e.g. Threshold autoregressive model.

Such class of models captures the discrete changes occurring in the data generating process; in our study we focus on only one such type of model namely the TAR (Threshold Autoregressive) model.

The nonlinear pattern of a variable can be explained by TAR, where the variable under consideration is known as a threshold variable. TAR model was primilary introduced by Tong (1978), and, Tong and Lim (1980). In TAR model, when the level of series reaches a specific threshold value, autoregressive structure changes. Obstfeld & Taylor (1997), O'Connell (1998), Pippenger & Goering (1998) and Erjnaes & Persson (2000) used TAR models to captures dynamics of exchange rate. In real exchange rate, TAR model was first applied by Obstfeld & Taylor (1997).

Some interesting features of threshold autoregressive TAR model are:

- These are more flexible models as compared to linear models because they capture the usual features of economics and financial data more easily.
- Movement between regimes depend upon past observations
- They assume sharp switch between regimes
- They take regime as an observable variable.
- They assume discrete changes in regimes.

Suppose our model is Threshold autoregressive of order 1.Then it can be written as ,

$$y_t = \beta_0^{(1)} + \beta_1^{(1)} y_{t-1} + \varepsilon_t \text{ if } y_{t-1} \leq \gamma \qquad (4.8)$$

$$y_t = \beta_0^{(2)} + \beta_1^{(2)} y_{t-1} + \varepsilon_t \text{ if } y_{t-1} > \gamma \qquad (4.9)$$

Where

y_t= variable under consideration

ε_t = sequence of independent and identically distributed random variables with mean value "0" and Variance σ^2_ε

γ= threshold value of the variable y.

$\beta_1^{(1)}$ and $\beta_1^{(2)}$ are coefficients of AR(1) term in regimes (1) and (2) respectively.

On one side of threshold, the sequence of {yt} is ruled by one autoregressive process and there is a different AR (autoregressive) process on the other side of the threshold. Although the sequence {yt} is linear in every regime, possibility of switching regime reveals that the whole {yt} sequence is nonlinear. The shocks to {εt} is responsible for regime switching.

We can write the set of equations (4.8) and (4.9) in one equation as

$$y_t = \beta_{0,1} + \beta_{0,2} D_t + \beta_1 y_{t-1} + \beta_2 D_t y_{t-1} + \varepsilon_t \qquad (4.10)$$

Where $D_t$is an indicator function which assumes values 1and 0 as

$D_t = 0$ if $y_{t-1} \leq \gamma$; $D_t = 1$ if $y_{t-1} > \gamma$

The parameters of equation (4.10) can be linked with those of (4.8) and (4.9)

$\beta_{0,1} = \beta_0^{(1)}$, $\beta_{0,2} = \beta_0^{(2)} - \beta_0^{(1)}$, $\beta_1 = \beta_1^{(1)}$,

$\beta_2 = \beta_1^{(2)} - \beta_1^{(1)}$

There are two separate regimes defined by the threshold parameter γ .If we know the threshold value; the observations can be separated according to parts above or below the threshold value. The separated parts can be estimated using OLS. We may choose TAR of order other than 1; in this case the lag length is chosen using t-test on the individual coefficient, F-test on group of coefficients, or the AIC and/or SBC.

4.2.1 Estimating Threshold

Mostly this value is unknown. Chan (1993) describes the procedure using least square estimation to get this threshold value. The value of threshold must lie within the highest and lowest values of the series. Generally top and the lowest

15 % values are omitted from the search to make sure that there are adequate amount of values on both sides of the threshold.

Hence threshold value must lie within the band containing the middle 70% of the values. Plenty of searches are done to get the minimum residuals sum of squares (RSS) and the value with minimum RSS will be the consistent estimate of threshold. After finding the threshold, TAR model is estimated using least squares estimation technique.

4.3 Unit Root Test

We first examine the stochastic properties of data. Famous Augmented Dickey Fuller (ADF) test was used to check the stationarity of all series. In non-stationary or trended series standard regression method can easily lead to invalid results. . Dickey-Fuller discussed three possible types of unit root.

$$\Delta y_t = \gamma y_{t-1} + \sum_{i=1}^{p} \beta_i y_{t-1} + \varepsilon_t \qquad (1)$$

$$\Delta y_t = \alpha_o + \gamma y_{t-1} + \sum_{i=1}^{p} \beta_i y_{t-1} + \varepsilon_t \qquad (2)$$

$$\Delta y_t = \alpha_0 + \gamma y_{t-1} + \alpha_2 t + \sum_{i=1}^{p} \beta_i y_{t-1} + \varepsilon_t \qquad (3)$$

We use general to specific approach to select lag length and in the final specification we test the hypothesis which is given below.

H_o : $\gamma = 0$ Unit root in the series

H_A : $\gamma < 0$ No unit root in the series

Our series would be stationary if Augmented Dickey-Fuller test statistic value is greater than the critical value.

4.4 Data and Data Source

In order to model the exchange rate of Pakistan and to choose among the linear or nonlinear models for forecasting exchange rates, the time series data of nominal exchange rate (ER), real exchange rate (RER), and real effective exchange rate (REER) over the period 1981-Q4 to 2011-Q1 has been collected, which makes the total number of observations as 118.We have taken quarterly data instead of monthly data of the three exchange rate series, as monthly data of real effective exchange rate is not available. The exchange rates are taken as local currency i-e Pak rupee value of one US dollar. We have considered three exchange rate series in order to better evaluate the performance of linear and nonlinear models, and to make good judgments on forecasting. All the time series data pertaining to exchange rates have been collected from the International Monetary Fund’s *International Financial Statistics* (IFS) and State Bank of Pakistan (SBP) annual reports. All series are expressed in natural logarithm. As our study focuses on three types of exchange rates we first define them.

4.4.1 Nominal Exchange Rate (ER)

The nominal exchange rate of Pakistan against US dollar is the rate at which Pak rupee is exchanged with one unit of US dollar.

Nominal exchange rate = PAK rupees/US dollar

4.4.2 Real Exchange Rate (RER)

The real exchange rate can be defined as the nominal exchange rate of Pakistan that takes the inflation differentials of the two countries into account. Its importance stems from the fact that it can be used as an indicator of competitiveness in the foreign trade of a country[2]. We have used following formula to calculate real exchange rate

Real exchange rate = [(Nominal exchange rate) $_{Pak}$***] *(CPI*** $_{USA}$***/CPI*** $_{Pak}$***)***

Where 2000 =100 is taken as a base year CPI of both countries. Here CPI stands for consumer price index

4.4.3 Real Effective Exchange Rate (REER)

It is an index based on the price of a basket of goods in one country relative to the price of the same basket of that country's major trading partners. The prices are expressed in the same currency, nominal exchange rate (ER) is used with each trading partner. The basket price of all trading partners is valued by their relative share in exports, imports, or total foreign trade[2].

CPI based real effective exchange rate of Pakistan is computed by deflating the nominal effective exchange rate

REER = NEER *RPI2000 = 100 is taken as a base

- NEER =ERI/ERI*
- RPI =CPI/CPI*

Where

NEER = Nominal effective exchange rate

RPI = Relative Price Index.

ERI= Domestic exchange rate index

ERI*= Foreign exchange rate index.

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[2] State Bank of Pakistan (SBP)

CPI=Domestic consumer price index

CPI* =Foreign consumer price index

The trading partners whose share is no less than one percent of Pakistan's total trade are taken in effective exchange rate. There are 21 countries whose share in Pakistan's total trade is 1 % and above. But data on some nominal exchange rate and price indices are not available. We mention 16 trading partners which comprise on Kuwait, Saudi Arabia, Iran, USA, Canada, Belgium, France, Germany, Italy, UK, Japan, Switzerland, Australia, Malaysia, Singapore and Hong Kong. These are the major trading partners of Pakistan.

4.5 Forecasting Exchange Rate

Exchange rate plays an important role in an economic health of a country; so it is desired to forecast its movements. Therefore exchange rate forecasting is necessary to better evaluate the risks and benefits attached with international business.

At the first place we make forecast using AR linear model. Then a comparison is done to judge the forecasting performance of the TAR and linear model. Forecasting is based on out of sample forecast i.e today's information is used to forecast future movements of exchange rate. As each forecast has some prediction error (**e_t**), we first calculate this prediction error which is the difference between actual value and the predicted value. This error is used to judge the accuracy of the forecast.

e_t=(Actual exchange rate)-(predicted exchange rate)

The Mean Squared Prediction Error criterion is used to evaluate the forecasting performance of the competing models.

MSPE = 1/n $\sum e^2_t$

Where 'n' is the number of forecasts. In these criteria lower the value of MSPE the more accurate the forecasting model will be.

Chapter 5

Estimation Results and Discussion

5.1 Unit Root Test

As stationary of the data set is the first step towards modeling, we start with the simple stationarity test, which is based upon autocorrelation function (ACF).

ACF = $\hat{\delta}_k / \hat{\delta}_o$

Where $\hat{\delta}_k$ is sample covariance at lag k and $\hat{\delta}_o$ is sample variance. When we plot the $\hat{\delta}_k$ against k we have sample correlogrom. We start by drawing "Correlogram" of the respective series.

Figures 5.1 (a,b,c) show correlograms of three exchange rate series. The solid horizontal line is showing the zero axis; values which are above this line are the positive values and the values which are below are negative values. It is clearly observed that ACF at different lags are quite high for example in nominal exchange rate up to lag 28, the ACF is very high. Even in the case of real and real effective exchange rate the autocorrelation function is very high initially and then gradually approach toward zero as the number of lags increases. This leads to a conclusion that all exchange rate series are nonstationary.

Figure 5.1: Correlograms of Exchange Rates in Level

Figure 5.1.a: Correlograms of Nominal Exchange Rate in Level

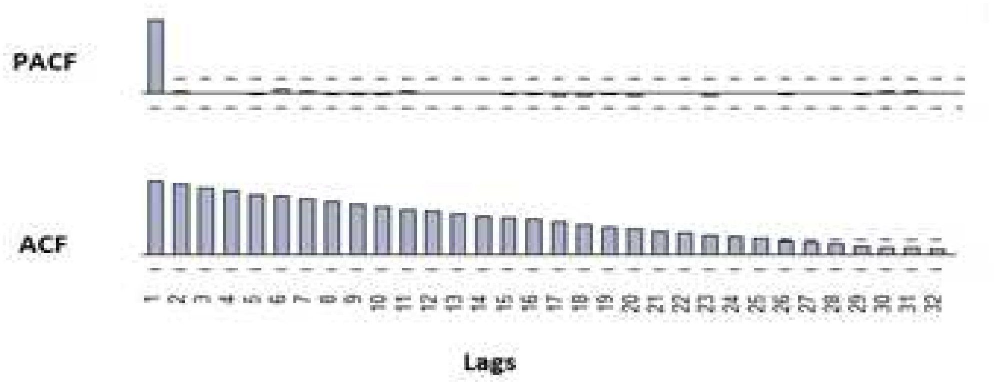


Figure 5.1.b: Correlograms of Real Exchange Rate in Level

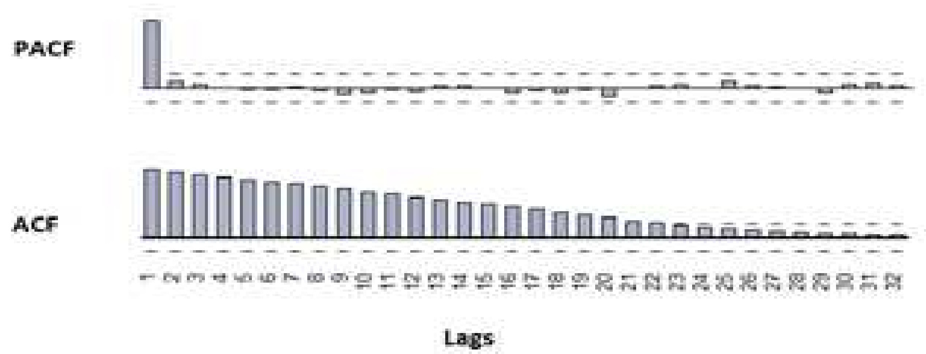
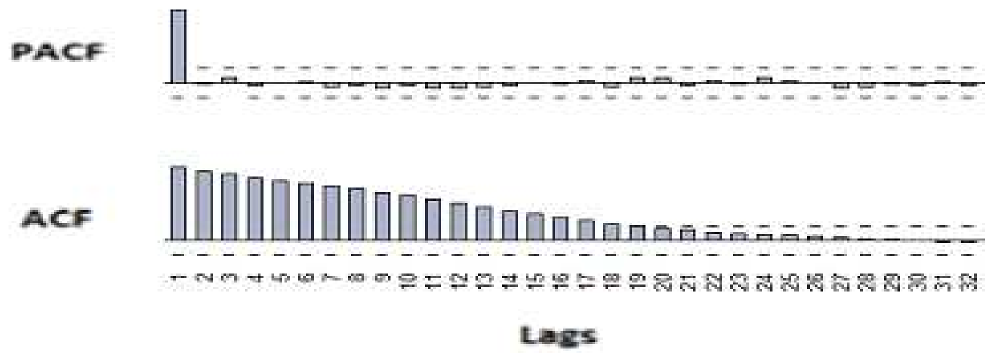


Figure 5.1.c: Correlograms of Real Effective Exchange Rate in Level



5.1.1 Augmented Dickey-Fuller Test

As correlogram cannot distinguish between difference stationary process and trend stationary process we now apply mostly used ADF (Augmented Dickey Fuller) test to check the presence of unit root. Test results of all three types of exchange rate are reported in Table 5.1.Results reveal that nominal exchange rate, real exchange rate and real effective exchange rate are unit root process.

Moreover all series have only one unit root as all series are stationary in first difference form.

Table 5.1: Unit Root Test Results

Variables	Constant/ Trend	Level	First Difference
LER	C,T	-2.18889	-9.5506***
LRER	C,T	-0.91154	-10.2251***
LREER	C,T	-2.01078	-8.91445***

Note; c,t denotes constant and trend, *** indicate significance at 1%

The next step is to identify the univariate models for nominal exchange rate, real exchange rate and real effective exchange rate with the help of ACF and PACF.

Figure 5.2: Correlogram of Exchange Rates in First Difference

Figure 5.2.a: Correlogram of Nominal Exchange Rates in First Difference

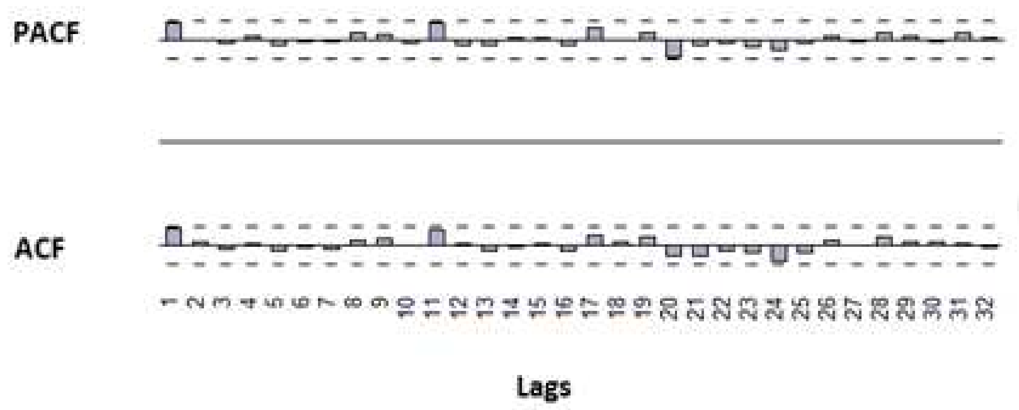


Figure 5.2.b: Correlogram of Real Exchange Rates in First Difference

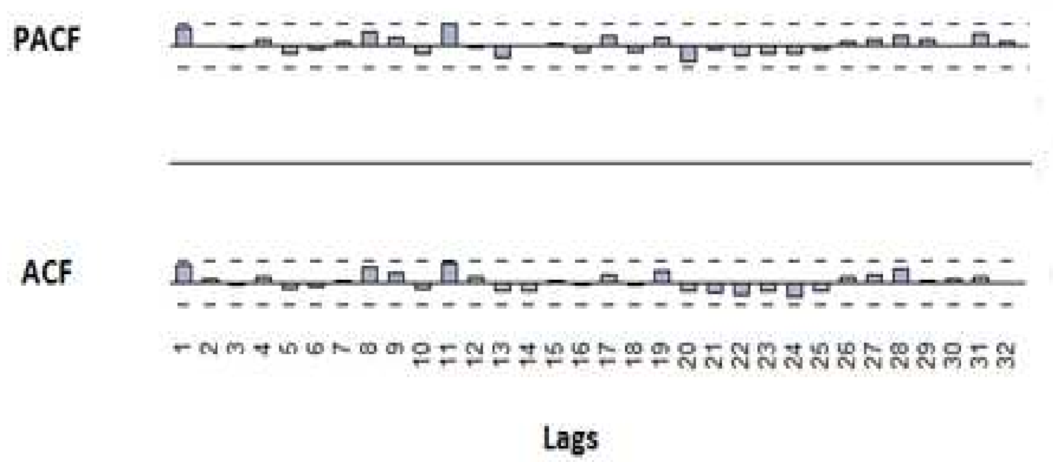
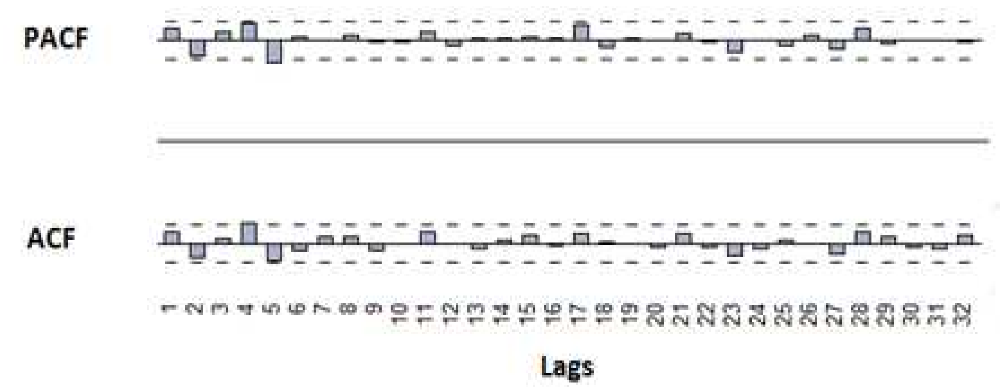


Figure 5.2.c: Correlograms of Real Effective Exchange Rate in first difference



The plot of series reveals that we are unable to find any significant spikes in ACFs and PACFs. This reveals that all three exchange rates are random walk, as we are unable to identify appropriate model for them and it is not possible to forecast change in any of the exchange rates. This can be because of the presence of structural breaks.

The random walk phenomenon was also found by Rashid (2006) for foreign exchange market of Pakistan.

5.2 Capturing Structural Breaks and detrending Exchange Rate Series

So far we have observed that all of exchange rate series exhibit random walk phenomena so that we are unable to model our exchange rate series. As we argue that even trend stationary series can be detrended as unit root process if structural breaks are not properly modeled. Therefore, we first tried to capture the possible breaks occurring in the data set. We introduce dummies for the relevant breaks. As mentioned in chapter 2, following are the structural breaks, observed in the history.

Nominal Exchange Rate

Dummy 2001:DUM1 (Dummy variable capturing first structural break in Nominal Exchange Rate)

Dummy 2008:DUM2 (Dummy variable capturing second structural break in Nominal Exchange Rate)

Real Exchange Rate

Dummy 2001: DUM (Dummy variable capturing structural break in Real Exchange Rate)

Real Effective Exchange Rate

Dummy 1985: DUM (Dummy variable capturing structural break in Real Effective Exchange rate)

If we notice in Figure (2.1) of nominal exchange rate there is significant downward jump in year 2001.Dummy 2001 is introduced to capture the change in exchange rate. This change in behavior of exchange rate is due to the 9/11 event, which, like other economies of the world, also affect the Pakistan economy. We can see a break in year 2008 which might be due to oil price shock, the currency deprecated during that time period. To address this abnormality present in data set we have introduces dummy for the year 2008.The dummy for 1985 is introduced to handle the break in real effective exchange rate series.

Results of fitting the trend with structural breaks are given below

Table 5.2: Fitting Trend with Structural Breaks in Nominal Exchange Rate

$$\hat{LER} = 2.40 + 0.02*T + 1.62*DUM1 - 2.22*DUM2 - 0.02*DUM1*T + 0.02DUM2*T \quad (5.1)$$

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.40	0.01	222.83	0.00
T	0.02	0.00	87.22	0.00
DUM1	1.62	0.12	13.91	0.00
DUM2	-2.22	0.46	-4.80	0.00
DUM1*T	-0.02	0.00	-15.67	0.00
DUM2*T	0.02	0.00	5.33	0.00
R^2 0.997				

Table 5.3: Fitting Trend with Structural Breaks in Real Exchange Rate

$$\widehat{LRER} = 3.34 + 0.01*T - 0.02*DUM*T + 1.28*DUM \qquad (5.2)$$

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.34	0.01	252.62	0.00
T	0.01	0.00	28.76	0.00
DUM*T	-0.02	0.00	-17.05	0.00
DUM	1.28	0.08	15.25	0.00
R^2 0.930				

Table 5.4: Fitting Trend with Structural Breaks in Real Effective Exchange Rate

$$\widehat{LREER} = 5.34 - 0.27*DUM + 0.00*DUM*T \qquad (5.3)$$

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.34	0.02	249.28	0.00
DUM	-0.27	0.03	-9.64	0.00
DUM*T	0.00	0.00	-18.70	0.00
R^2 0.901				

In the above tables, it can be clearly seen, that dummy variables in the equations of nominal exchange rate, real exchange rate and real effective exchange rate are significant. Intercept dummy (DUM1, DUM2, DUM) are significant, showing that the level of series was effected by structural break. Slope dummies (DUM1*T, DUM2*T, DUM*T) are also affecting the nominal exchange rate, real exchange rate, and real effective exchange rate significantly. The impact of trend (T) is positive and statistically significant, which implies that our exchange rate is depreciating during the analysis period. The coefficient of DUM1*T in nominal exchange rate equation and of DUM*T in real exchange rate equation are negatively significant. This reflect that 9/11 event affect the exchange rate of Pakistan; our exchange rate appreciated due to heavy capital inflow from abroad. DUM2*T is also significant and positive as the nominal exchange rate deprecated in year 2008 due to increase in oil prices. The coefficient of DUM*T of real effective exchange rate is significant and negative, which shows that real effective exchange rates appreciated.

From equation (5.1),(5.2),(5.3) the structural adjusted detrended series of nominal exchange rate (μ_{LER}), real exchange rate (μ_{LRER}),real effective exchange rate (μ_{LREER}) , after capturing structural breaks, are given below.

$$\mu_{LER} = LER - LER^{\wedge}$$

$$\mu_{LER} = LER - (2.40 + 0.02*T + 1.62*DUM – 2.22*DUM2 – 0.02*DUM1*T) \qquad (5.4)$$

$$\mu_{LRER} = LRER - LRER^{\wedge}$$

$$\mu_{LRER} = LRER - (3.34 + 0.01*T - 0.02*DUM*T + 1.28*DUM) \qquad (5.5)$$

$$\mu_{LREER} = LREER - LREER^{\wedge}$$

$$\mu_{LREER} = LREER - (5.34 – 0.27*DUM + 0.00*DUM*T) \qquad (5.6)$$

We now apply the ADF (Augmented Dickey Fuller) test to our structural adjusted detrended three exchange rate series.ADF test results indicate that our series are stationary at level.

Table 5.5: Unit Root Test after capturing structural break

Variables	Constant/ Trend	Level
μ_{LER}	None	-2.85***
μ_{LRER}	None	-5.09***
μ_{LREER}	None	-4.27***

Note******* indicate significance at 1 percent,

5.3 Identification of Model for Structural adjusted detrended Series

The next step is to identify the univariate model of structural adjusted detrended exchange rate series using ACF and PACF.

Figure 5.3: Correlograms of Exchange Rate in Level after capturing Structural Breaks

Figure 5.3.a: Correlograms of Nominal Exchange Rate (μ_{LER}) in Level after capturing Structural Breaks

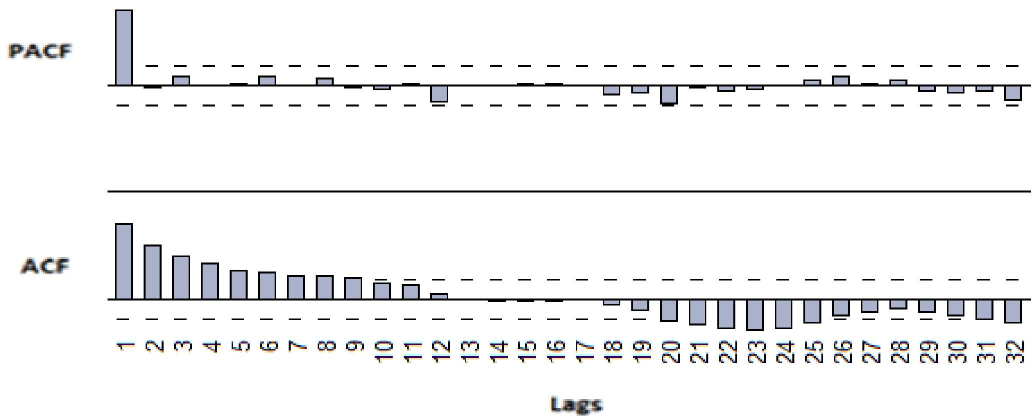


Figure 5.3.b: Correlograms of Real Exchange Rate (μ_{LRER}) in Level after capturing Structural Breaks

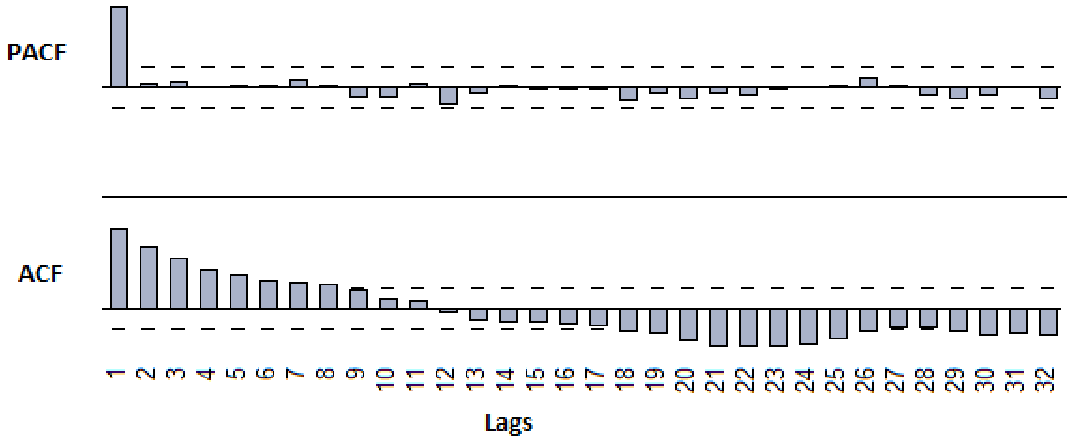
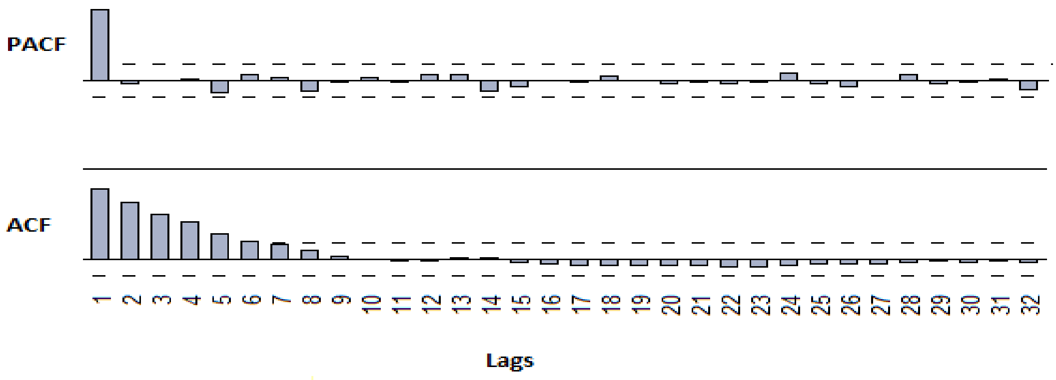


Figure 5.3.c: Correlograms of Real Effective Exchange Rate (μ_{LREER}) in Level after capturing Structural Breaks



As results in all the three correlograms show that, the three structural adjusted detrended exchange rate series can be modeled as AR (1) process. So in next stage we estimate AR (1) model for each of the three series.

5.4 Selection and Estimation of Appropriate Model

Using general-to-specific methodology and Akaike information criterion (AIC), it is found that AR (1) is appropriate model for nominal, real and real effective exchange rate. Tables reported below show the results of our estimation.

Table 5.6: Results of Linear Model for Nominal Exchange Rate

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.42	0.03	74.19	0.00
T	0.02	0.00	31.65	0.00
DUM1	1.41	0.21	6.75	0.00
DUM2	-5.32	1.23	-4.32	0.00
DUM1*T	-0.02	0.00	-7.18	0.00
DUM2*T	0.05	0.01	4.36	0.00
AR(1)	0.78	0.06	12.86	0.00
R^2 0.997				

dependent variable is nominal exchange rate (LER)

Table (5.6.a): Diagnostic Test for Linear Model of Nominal Exchange Rate

	obs-R sq	Probability
LM (1)	4.07	0.05
LM (2)	4.98	0.08
LM (3)	5.21	0.16
LM(4)	7.45	0.11
ARCH (1)	0.00	0.95
ARCH (2)	0.31	0.85
ARCH (3)	0.30	0.96
ARCH (4)	0.54	0.97

Table given above gives the estimates of nominal exchange rate as AR (1) model. The estimates show the significance of the coefficients. The impact of trend (T) and the dummy introduced for year 2001 is positive.DUM2*T is also positive, showing a deprecation of exchange rate. The coefficient of AR (1) is positively significant which is indicating that 1 % deprecation in last period exchange rate brings 0.78 % deprecation in current period exchange rate, after capturing the effect of time.

R^2 also indicates that model is good fitted. LM test is Breusch-Godfrey test for no residual autocorrelation. ARCH is to test for hetrosedasticity. Result of both the test shows that there is neither problem of autocorrelation in residuals nor is the problem of hetroskedasticity.

Table5.7: Results of Linear Model for Real Exchange Rate

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.39	0.04	96.29	0.00
T	0.01	0.00	11.49	0.00
DUM*T	-0.01	0.00	-5.63	0.00
DUM	0.95	0.18	5.35	0.00
AR(1)	0.78	0.05	15.86	0.00
R^2 0.981				

dependent variable is real exchange rate (LRER)

Table (5.7.a): Diagnostic Test for Linear Model of Real Exchange Rate

	obs-R sq	Prob
LM (1)	4.25	0.05
LM (2)	4.91	0.09
LM (3)	5.16	0.16
LM(4)	6.76	0.15
ARCH (1)	0.23	0.63
ARCH (2)	0.80	0.67
ARCH (3)	3.28	0.35
ARCH (4)	6.36	0.17

Results in Table 5.7 show the findings of the estimation of univariate model for real exchange rate. The coefficients are all significant. Model depicts that 1 percent deprecation in previous real exchange rate causes 0.78 % deprecation in present period exchange rate. Estimates also show that 98 % variation in real exchange rate is captured in the model. The model also passes all diagnostic tests.

Table 5.8: Results of Linear Model for Real Effective Exchange Rate

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.94	0.27	14.55	0.00
T	0.07	0.02	3.71	0.00
DUM	0.94	0.24	3.92	0.00
DUM*T	-0.07	0.02	-3.89	0.00
AR(1)	0.91	0.01	74.92	0.00
R^2 0.99				

dependent variable is real effective exchange rate (LREER)

Table (5.8.a): Diagnostic Test for Linear Model of Real Effective Exchange Rate

	obs-R sq	Prob
LM (1)	3.08	0.08
LM (2)	3.09	0.21
LM (3)	5.71	0.13
LM(4)	6.12	0.19
ARCH (1)	2.67	0.10
ARCH (2)	2.88	0.24
ARCH (3)	4.98	0.17
ARCH (4)	6.75	0.15

From the estimated results of linear AR model, it is clear that real effective exchange rate follow AR (1) process. Therefore the previous values of exchange rate play a significant role in the determination of current values of exchange rate. In table 5.8 the coefficient of univariate indicates that there would be deprecation in current exchange rate by 0.91% as the last period exchange rate deprecate by 1%. The model explains 99 % variation in the variable. The model shows no evidence of autocorrelation in residuals and no presence of hetroskedasticity at different lags.

5.5 Forecasting based on AR Model

We now make the forecasting using AR model, results from forecasting through AR model is given below.

Table 5.9: Forecasting Results of Linear Models

Nominal ER			Real ER			Real Effective ER		
F P	actual	Forecast with AR	F P	actual	Forecast with AR	F P	actual	Forecast with AR
2009Q3	4.42	4.46	2009Q4	3.9	3.91	2008Q4	4.61	4.57
2009Q4	4.43	4.49	2010Q1	3.88	3.9	2009Q1	4.64	4.6
2010Q1	4.43	4.51	2010Q2	3.87	3.88	2009Q2	4.63	4.62
2010Q2	4.45	4.52	2010Q3	3.83	3.87	2009Q3	4.59	4.62
2010Q3	4.46	4.54	2010Q4	3.79	3.84	2009Q4	4.59	4.6
2010Q4	4.45	4.56	2011Q1	3.78	3.81	2010Q1	4.64	4.59

Where 'F P' is Forecasting Period and 'ER' is Exchange Rate

Table given above shows the forecast results of linear model, if we graph these forecasted results we can see, the nominal exchange rate does not follow the pattern of actual exchange rate showing that forecasting is not appropriate in this case, but in case of real and real effective exchange rate the predicted values are reasonably following the actual pattern.

Figure (5.4): Forecast of Nominal Exchange Rate through Linear Model

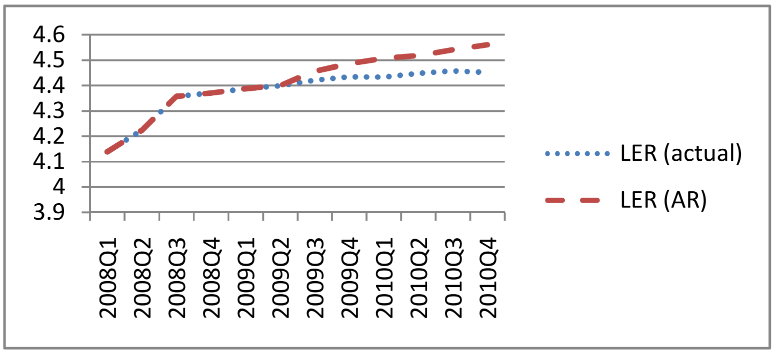


Figure (5.5): Forecast of Real Exchange Rate through Linear Model

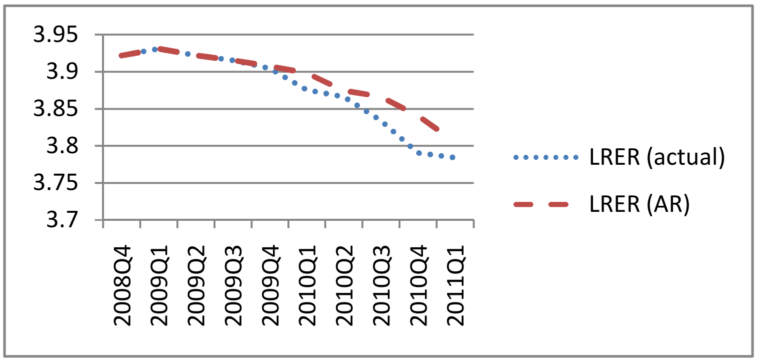
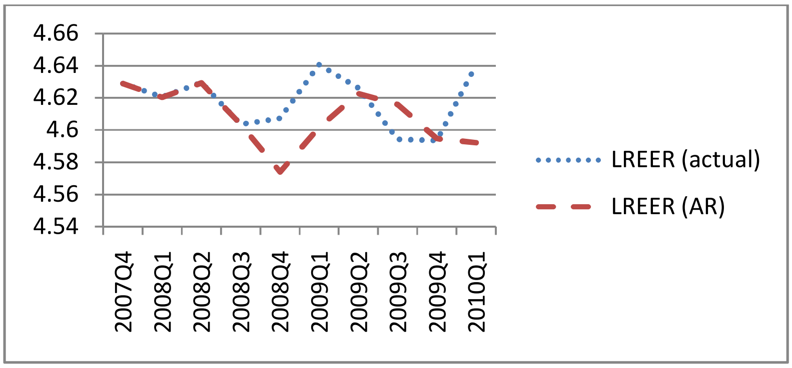


Figure (5.6): Forecast of Real Effective Exchange Rate through Linear Model



5.6 Non-Linear Threshold Autoregressive Model

So far we have disused the forecasting performance of AR model. We now move to our second question '*can forecasting be improved if we used nonlinear models'*. To answer this question we have choose one such model known as TAR model. Our series are stationary after capturing structural break. To proceed to nonlinear TAR model threshold value is required. For this purpose each exchange rate series in structural adjusted detrended form is used, In order to get the threshold value, we sort the series in an ascending order. We have considered only 70 % of residuals values after omitting the extreme 15 percent values on both side of the threshold. Hence in a sample of 118 observations there are 84 candidates for threshold. The sum of squared residual of the TAR model which is used in the estimation can be considered as a function of threshold value. We get the minimum sum of square residual as we come closer to the true threshold.

If we plot the sum of square residual of the three series, we can also check if there exists a threshold frame work.

Testing for the Existance of Threshold

Figure (5.7): Testing for the Existance of Threshold for Nominal Exchange Rate

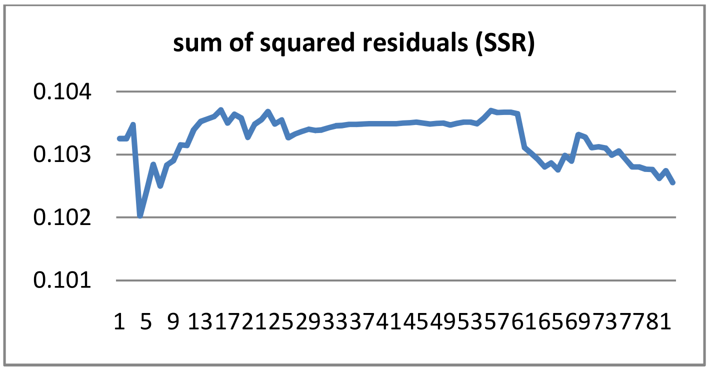


Figure (5.8): Testing for the Existance of Threshold for Real Exchange Rate

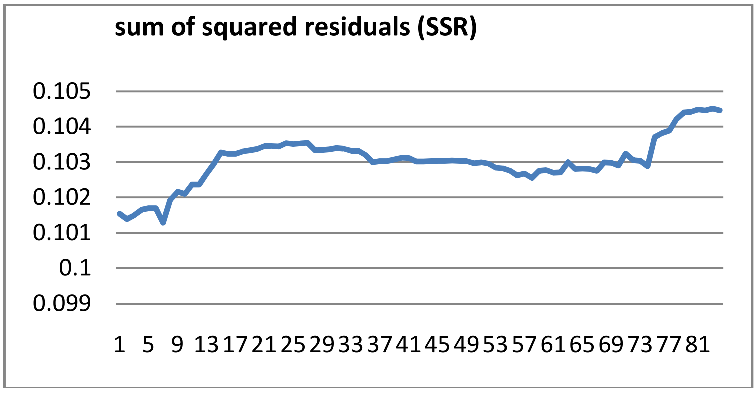
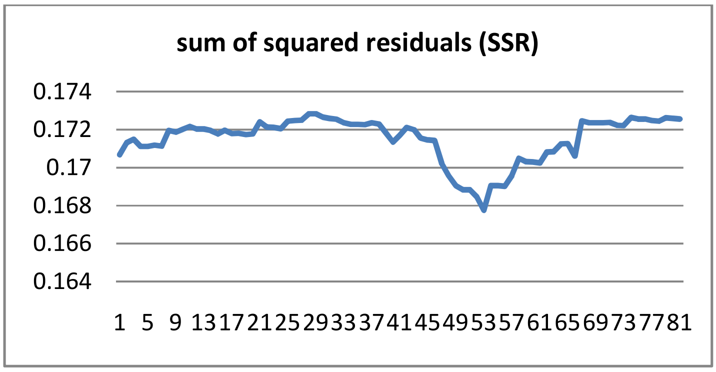


Figure (5.9): Testing for the Existance of Threshold for Real Effective Exchange Rate



The graph of nominal exchange rate depicts a sharp trough at the fourth value, showing the existence of threshold frame work. Also in real exchange rate the seventh value and in real effective exchange rate the 53 value shows a sharp trough which confirms the presence of threshold. As all exchange rates exhibit the presence of threshold we now precede and use the threshold model for estimation.

We estimate the model using equations *(5.7), (5.8), (5.9)* of all series.

$$\mu_{LER} = \alpha_{i1}\mu_{LER-1}Di + \alpha_{i2}\mu_{LER-1}(1-Di) \quad (5.7)$$

$$\mu_{LRER} = \beta_{i1}\mu_{LRER-1}Di + \beta_{i2}\mu_{LRER-1}(1-Di) \quad (5.8)$$

$$\mu_{LREER} = \omega_{i1}\mu_{LREER-1}Di + \omega_{i2}\mu_{LREER-1}(1-Di) + \omega_{i3}\mu_{LREER-2}Di + \omega_{i4}\mu_{LREER-2}(1-Di) + \omega_{i5}\mu_{LREER-3}Di + \omega_{i6}\mu_{LREER-3}(1-Di) \quad (5.9)$$

Where i = 1, 2, 3…………………, 84.

In each structural adjusted detrended exchange rate series the successive sum of square residuals are saved, for example we have 84 sums of square residual values of real exchange rate series. The minimum sum of squared residual is chosen among the 84 values. The smallest sum of square residual of nominal, real, and real effective exchange rate denoted by ‘D’ are the fourth, second and fifty third values. These values are the consistent estimates of threshold.

$\gamma^{LER} =$ D4 = 0.102028

γ^{LRER} =D7 = 0.101289

γ^{LREER} =D53 = 0.167761

Now when the threshold is known, we are able to estimate the TAR regression. Model is identified after capturing structural breaks, after specifying the lag length, and using Akaike information criterion (AIC), the best model is selected. TAR (1) is found to be best fitted for nominal, real and real effective exchange rates.

The results of TAR model are given below. The parameters are estimated by OLS.

5.6.1 Threshold Autoregressive Model for Nominal Exchange Rate

We first eliminate the variables which are insignificant from the regression equation. The final results are given below.

*LER=C(1)+C(2)*T+C(4)*DUM2*T+C(5)*DUM1*T+C(6)*D4*LER(-1)+*

C(7)(1-D4)*LER(-1)* *(5.10)*

We have estimated a model with nominal exchange rate as dependent variable and, time trend, dummy variables for structural breaks, and two AR terms for two regimes, as independent variables. The estimated results of equation (5.10) is given in Table 5.10

Table 5.10: Results of Non-Linear Model for Nominal Exchange Rate

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.2122	0.0858	2.4724	0.015
T	0.0016	0.0007	2.2218	0.0285
DUM2*T	0.0369	0.014	2.6451	0.0094
DUM1*T	-0.0004	0.0001	-2.9344	0.0041
D4*LER(-1)	0.9199	0.0354	25.9872	0
(1-D4)*LER(-1)	0.9248	0.0364	25.378	0
R^2 0.997				

dependent variable is nominal exchange rate

Table (5.10.a): Diagnostic Test for Non-Linear Model of Nominal Exchange Rate

	obs-R sq	Prob
LM (1)	4.32	0.05
LM (2)	4.49	0.11
LM (3)	4.52	0.21
LM(4)	4.98	0.29
ARCH (1)	0.01	0.92
ARCH (2)	0.37	0.83
ARCH (3)	0.48	0.92
ARCH (4)	0.53	0.97

Table (5.10.b): Wald coefficient test of Non-Linear Model for Nominal Exchange Rate

Test Statistic	Value	Df	Probability
F-statistic	4.085	(1, 104)	0.046
Chi-square	4.085	1.000	0.043

Null Hypothesis: C (5) = C (6)

Before we interpret the results we first apply the Wald coefficient test on the coefficient of nominal exchange rate of before threshold and after threshold. The test rejects the hypotheses of equal coefficients indicating that threshold plays a significant role. The coefficient of exchange rate above the threshold is significant. 1% change in exchange rate brings 0.91% change in the exchange rate above the threshold. The coefficient below the threshold is also significant indicating 1% increase in exchange rate causes 0.92 % deprecation in exchange rate i.e the previous period exchange rate deprecates the current exchange rate by 0.92%. The table shows that coefficients are significant and the level of nominal exchange rate is affected. The impact of DUM2*T is positive and significant, which indicate, the exchange rate, deprecated in 2008.According to estimate, the effect of September 2001 is significant and positive. R-square value of 0.997 shows that regression model successfully predicts the variation occurring in dependent variable. The hypothesis of no serial correlation is also accepted by LM test also there is no sign of hetrosedasticity in the model.

5.6.2 Threshold Autoregressive Model for Real Exchange Rate

*LRER = C(1)+C(2)*T+C(3)*DUM+C(4)*DUM*T+C(5)*D7*LRER(-1)+*
C(6)(1-D7)*LRER(-1)* (5.11)

The model for real exchange rate is estimated, using real exchange rate as dependent variable. The independent variables are the time trend, the dummy variable which is used for capturing structural break, and two AR terms for two regimes.

Table 5.11: Results of Non-Linear Model for Real Exchange Rate

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.7466	0.2366	3.1557	0.0021
T	0.0017	0.0006	2.706	0.0079
DUM	0.2469	0.0972	2.5386	0.0125
DUM*T	-0.0031	0.0011	-2.715	0.0077
D7*LRER(-1)	0.7813	0.0708	11.0408	0
(1-D7)*LRER(-1)	0.7809	0.0729	10.7161	0
R^2 0.981				

dependent variable is real exchange rate

Table (5.11.a): Diagnostic Test for Non-Linear Model of Real Exchange Rate

	obs-R sq	Prob
LM (1)	4.26	0.05
LM (2)	4.39	0.09
LM (3)	4.51	0.21
LM(4)	5.31	0.12
ARCH (1)	0.19	0.70
ARCH (2)	0.70	0.70
ARCH (3)	2.55	0.47
ARCH (4)	5.09	0.28

Table (5.11.b): Wald coefficient test of Non-Linear Model of Real Exchange Rate

Test Statistic	Value	Df	Probability
F-statistic	0.014481	(1, 111)	0.9044
Chi-square	0.014481	1	0.9042

Null Hypothesis: C (5) = C (6)

Table given above reports the significance of variables but the Wald coefficient test of real exchange rate accept the null hypothesis of equal coefficient. This clearly means that statistically the two coefficients are not different to each other.

Which indicates the model does not statically confirm the role of threshold. That is the coefficient above and below the threshold 0.7813 and 0.7809 shows that the effect of threshold on real exchange rate is insignificant. R-square indicates that explanatory variable of the model explain 98 % variation in real exchange rate. Up to lag 4 both LM and ARCH test are satisfied.

5.6.3 Threshold Autoregressive Model for Real Effective Exchange rate

After dropping the insignificant variables from the model, the final model is in this form given below.

$$LREER = C(1)+C(2)*T+C(4)*DUM*T+C(5)*D53*LREER(-1)+ C(6)*(1-D53)*LREER(-1) \quad (5.12)$$

We have estimated a model with real effective exchange rate as dependent variable. The time trend, dummy of structural break, and two AR terms for two regimes are used as independent variable

Results of the estimate of equation (5.12) are given below in Table 5.12.

Table 5.12: Results of Non-Linear Model for Real Effective Exchange Rate

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.4765	0.2048	2.3266	0.022
T	0.0054	0.0015	3.6763	0.0004
DUM*T	-0.0057	0.0016	-3.6599	0.0004
D53*LREER(-1)	0.9012	0.0391	23.065	0
(1-D53)*LREER(-1)	0.9029	0.0401	22.5159	0
R^2 0.987				

dependent variable is real effective exchange rate

Table (5.12.a): Diagnostic Test for Non-Linear Model of Real Effective Exchange Rate

	obs-R sq	Prob
LM (1)	2.53	0.47
LM (2)	2.98	0.56
LM (3)	3.08	0.06
LM(4)	4.96	0.16
ARCH (1)	2.57	0.11
ARCH (2)	2.80	0.25
ARCH (3)	3.79	0.29
ARCH (4)	5.18	0.27

Table (5.12.b): Wald coefficient test of Non-Linear Model of Real Effective Exchange Rate

Test Statistic	Value	df	Probability
F-statistic	1.23079	(1, 102)	0.2699
Chi-square	1.23079	1	0.2673

Null Hypothesis: C (4) = C (5)

Table 5.12 reveals the estimated results of nonlinear model. The coefficient values are significant, indicating that each coefficient has a significant impact on real effective exchange rate. The coefficients of threshold real effective exchange rate are same. This is also confirmed by testing the as null hypothesis of equal threshold coefficient by using Wald test, given in Table 5.12.b.The value of exchange rate coefficient below the threshold level is .902 showing previous period exchange rate has significant positive impact on the current period exchange rate. The 1% deprecation of previous exchange rate deprecates the future exchange rate by 0.90%.Again the threshold has no significant effect on the model. The model performs well as it explains 98% variation in real effective exchange rate. The model fulfills all diagnostics.

5.7 Forecasting of Exchange Rate using TAR Model

Here we make forecasting using the TAR model also forecasting performance of model is compared to the AR model, in order to make judgment whether the nonlinear model improved forecasting or not. The MSPE criterion is used to evaluate the performance of the two models. In this criterion lower the value of MSPE the more accurate the forecasting model will be.

Tables 5.13 given below show the forecasting performance of nominal, real and real effective exchange rate of both linear and non linear models.

Table 5.13: Forecasting Results of Non-Linear Models

Nominal Exchange Rate				Real Exchange Rate				Real Effective Exchange Rate			
F P	actual	AR	TAR	F P	actual	AR	TAR	F P	actual	AR	TAR
2009Q3	4.42	4.46	4.42	2009Q4	3.9	3.91	3.91	2008Q4	4.61	4.57	4.56
2009Q4	4.43	4.49	4.44	2010Q1	3.88	3.9	3.89	2009Q1	4.64	4.6	4.6
2010Q1	4.43	4.51	4.45	2010Q2	3.87	3.88	3.87	2009Q2	4.63	4.62	4.63
2010Q2	4.45	4.52	4.45	2010Q3	3.83	3.87	3.86	2009Q3	4.59	4.62	4.61
2010Q3	4.46	4.54	4.47	2010Q4	3.79	3.84	3.84	2009Q4	4.59	4.6	4.58
2010Q4	4.45	4.56	4.47	2011Q1	3.78	3.81	3.8	2010Q1	4.64	4.59	4.58

Where ‘F P’ is Forecasting Period

AR column is Forecast result of Linear model

TAR column is Forecast result of Non-Linear model

In order to judge the forecasting performance of both types of models MSPE criteria results are also given below.

Table 5.14: Comparison of Linear and Non-linear Models using MSPE Ratio

Variable	MSPE in Linear Model	MSPE in Non-Linear model	MSPE Ratio (Linear/Non-Linear)
Nominal Exchange Rate	0.0054	0.00018	30.209
Real Exchange Rate	0.00076	0.00061	1.24
Real Effective Exchange Rate	0.01678	0.023448	0.715

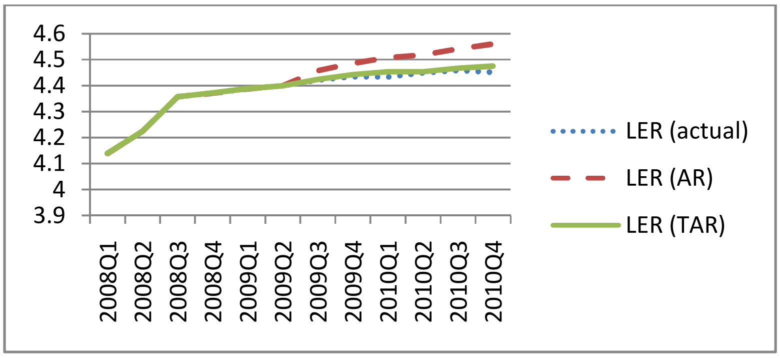
By looking at the table our estimates indicates, nonlinear model have lower MSPE in case of nominal exchange rate and real exchange rate. Nominal exchange rate (TAR) has lower mean square error of MSPE 0.00018, in real exchange rate the value of MSE is 0.00061, which as compared to its linear model is less, indicating TAR model perform well in these cases. But in case of real effective exchange rate linear model has lower MSPE which is 0.01678, indicating linear model is better here.

To better emphasize our judgment, we also take ratio of MSPE. The values are calculated as the ratio of $\mathbf{MSPE_{linear}/MSPE_{Non\text{-}Linear}}$, so that a value greater than 1 indicates a better forecast performance of the TAR model.

It can be easily seen; overall nonlinear TAR model found to be good in assessing exchange rate forecast, as the ratio of MSPE is greater than 1in two out of three cases i.e in nominal and real exchange rate. However, in case of real effective exchange rate, the performance of linear model is better.

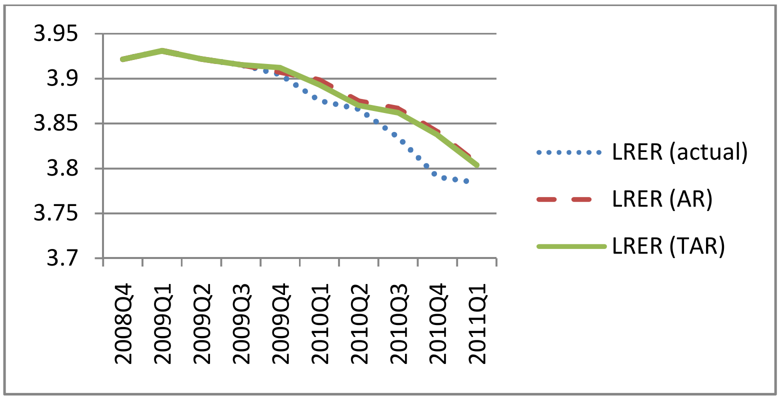
Graphically we can also observe forecasting performance of the models, we can see the line which is closer to the actual line shows better forecast of its respective model.

Figure (5.10): Comparing Forecast of Nominal Exchange Rate based on Linear and Non-Linear Model



In nominal exchange rate linear model forecast does not match with the actual value, which indicates the weak forecasting capacity of linear model, however TAR model seems to take into account the actual trail of the forecast, showing that forecasting performance of TAR is better in this case

Figure (5.11): Comparing Forecast of Real Exchange Rate based on Linear and Non-Linear Model



In real exchange rate the plain line of TAR is much closer to the actual dotted series than the dashed line of linear model. Which means TAR forecast the series better than linear model.

Figure (5.12): Comparing Forecast of Real Effective Exchange Rate based on Linear and Non-Linear Model

In case of real effective exchange rate linear model forecast is better as its values are much closer to the forecasted series.

5.8 The Diebold – Mariano Test

We now apply the DM test to statically evaluate the reliability of the forecast.

Table 5.15: Results of DM test for Nominal exchange rate

Forecasting Period	LER^2 (predicted linear)	LER^2 (predicted nonlinear)	d (LER^2pre lin-LER^2pre nonlin)
2009Q3	19.86003573	19.56539711	0.29463862
2009Q4	20.11561968	19.72739305	0.38822663
2010Q1	20.31090372	19.82742784	0.483475885
2010Q2	20.40804116	19.82772173	0.580319435
2010Q3	20.62009067	19.94345896	0.676631718
2010Q4	20.7934632	20.01958421	0.773878995
	Mean (d)	0.53286188	
	Variance (d)	0.032223978	
	Variance (g) = variance (d)/df-1	0.006444796	
	DM=mean (d)/variance (g)	82.68095937	

Table 5.16: Results of DM test for Real exchange rate

Forecasting Period	$LRER^2$ (predicted linear)	$LRER^{2(}$predicted nonlinear)	d ($RLER^2$pre lin- $LRER^2$pre nonlin)
2009Q3	15.26705581	15.30446382	-0.03740801
2009Q4	15.19537852	15.15467041	0.040708106
2010Q1	15.01224619	14.97782107	0.034425116
2010Q2	14.94829889	14.91376957	0.034529321
2010Q3	14.75066155	14.72317525	0.027486302
2010Q4	14.48278925	14.46409444	0.018694809
	Mean (d)	0.019739274	
	Variance (d)	0.000840206	
	Variance (g) = variance (d)/df-1		
	Variance (g) =(0.0008402061407/5)	0.000168041	
	DM=mean (d)/variance (g)	117.4668514	

Table 5.17: Results of DM test for Real Effective exchange rate

Forecasting Period	$LREER^2$ (predicted linear)	$LREER^{2(}$predicted nonlinear)	d ($RELER^2$pre lin- $LREER^2$pre nonlin)
2008Q4	20.92060695	20.79463057	0.125976376
2009Q1	21.17302	21.12413521	0.048884792
2009Q2	21.36920736	21.39971872	-0.030511352
2009Q3	21.30662513	21.27604186	0.030583269
2009Q4	21.11129566	21.00831641	0.102979247
2010Q1	21.08805286	20.99937957	0.088673292
	Mean (d)		0.061097604
	Variance (d)		0.003239245
	Variance (g) = variance (d)/df-1		0.000647849
	DM=mean (d)/variance (g)		94.30840797

Test rejects the null hypotheses of equal forecast among all the three series of exchange rates, as calculated values are greater than the critical value of 2.015.

Chapter 6

Summary and Conclusion

Forecasting and modeling of non-linearity in exchange rate has a great deal of interest in modern research. Many studies report the better performance of non linear models than linear models in the field of forecasting. But still there is a controversy that permitting non-linearity may not always improve the performance of forecast. The phenomenon of random walk is also associated with exchange rate. A general view about exchange rate is that it follows random walk.

Our study addresses these issues regarding exchange rate of Pakistan. The study hypothesized that exchange rate can reasonably be forecasted if structural breaks are properly captured. Moreover we have compared the forecast efficiency of linear and non-linear models. We have used linear AR model and non linear TAR model in order to see how well a forecast can be if two distinct frame of work type model are used. For this purpose data of Pakistan on three types of exchange rate series namely the nominal exchange rate, real exchange rate and real effective exchange rate have been analyzed. First we address the issue of randomness found in exchange rates. We see even though a random walk phenomenon the exchange rate can be forecasted if structural breaks are handled. To handle the issue of structural breaks dummies of the relevant breaks are introduced. After fulfilling the initial requirement, estimation is preceded. AR (1) model was identified in our case for all exchange rate series. We then made the forecasting of AR model.

In order to judge how well the forecast is, a different frame of work type model is chosen, that is nonlinear TAR model is selected. We have noticed that in case of nominal exchange rate threshold has a significant role, here two regimes are defined by the threshold. The exchange rate before and after threshold has a significant value, but in case of real and real effective exchange rate the role of threshold is insignificant. But as we proceed to forecasting of TAR model the results indicates that TAR improves the forecasting of exchange rate of Pakistan. Where forecasting performance of the competing models is judged using the criteria of MSPE, the lower the value of MSPE the better would be the performance of the model.

The results of this research show that overall nonlinear TAR model found to be good in forecasting nominal and real exchange rate of Pakistan**.** In real effective exchange rate the AR model outperforms. Hence it can be easily concluded that TAR model better estimates the exchange rate than AR model as it competes the AR model in two out of three cases of exchange rate series. Our finding support the results found in literature that nonlinear model forecast better than the linear model. Moreover it is found that exchange rate is not a random walk process. Rather it can be forecast reasonably if structural breaks are properly modeled.

The findings from the study can be helpful for further search in analyzing the behavior of exchange rate of Pakistan.

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