EXCHANGE RATE DETERMINATION AND FORECASTING BASED ON THE TAYLOR RULE FUNDAMENTALS

By

Hafizah Farah Inayat

PIDE2018FMPHILECO14

Supervisor

Dr. Nasir Iqbal

Department of Economics and Econometrics

PAKISTAN INSTITUTE OF DEVELOPMENT ECONOMICS, ISLAMABAD

2020

Pakistan Institute of Development Economics

CERTIFICATE

This is to certify that this thesis entitled: **"Exchange Rate Determination and Forecasting based on the Taylor Rule Fundamentals"** submitted by Hafizah Farah Inayat is accepted in its present form by the Department of Economics & Econometrics, Pakistan Institute of Development Economics (PIDE), Islamabad as satisfying the requirements for partial fulfillment of the degree of **Master of Philosophy in Economics**.

External Examiner:

Dr. Abdul Rashid
Associate Professor
International Islamic University
Islamabad

Supervisor:

Dr. Nasir Iqbal
Associate Professor
PIDE, Islamabad

Head, Department of Economics & Econometrics:

Dr. Karim Khan
Associate Professor/Head
Department of Economics &Econometrics
PIDE, Islamabad

Declaration

I ***Hafizah Farah Inayat*** hereby state that my MPhil thesis titled ***"Exchange Rate Determination and Forecasting based on the Taylor Rule Fundamentals"*** is my own work and has not been submitted previously by me for taking any degree from this University **Pakistan Institute of Development Economics, Islamabad** or anywhere else in the country/world. At any time if my statement is found to be incorrect even after my Graduation the university has the right to withdraw my MPhil degree.

Date: 1st Sep 2020

Signature of Student
Hafizah Farah Inayat
PIDE2018FMPHILECO14

Acknowledgements

I am thankful to my Creator Allah Subhana-Watala to have guided me throughout this work at every step and for every new thought which You setup in my mind to improve it. Indeed I could have done nothing without Your priceless help and guidance. Whosoever helped me throughout the course of my thesis, whether my parents or any other individual was Your will, so indeed none be worthy of praise but You.

I am profusely thankful to my beloved parents who raised me when I was not capable of walking and continued to support me throughout in every department of my life.

I would also like to express special thanks to my supervisor **Dr. Nasir Iqbal** for his help throughout my thesis. Without his help I wouldn’t have been able to complete my thesis.

Finally, I would like to express my gratitude to all the individuals who have rendered valuable assistance to my study.

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Symbols and Acronyms

ANFIS	Adaptive Neuro-Fuzzy Inference System
ANN	Artificial Neutral Network
AR	Autoregressive
ARCH	Autoregressive Conditional Heteroscedasticity
ARDL	Autoregressive Distributed Lag Model
ARIMA	Autoregressive Integrated Moving Average
ARMA	Autoregressive Moving Average
CPI	Consumer Price Index
ESTR	Exponential Smooth Transition Regression
FRED	Federal Reserve Economic Data
GARCH	Generalized Autoregressive Conditional Heteroscedasticity
GDP	Gross Domestic Product
HP	Hodrick-Prescott
IFS	International Financial Statistics
IMF	International Monetary Fund
KELM	Kernal Exreme Learning Machine
LM	Lagrange Multiplier Test
LSTR	Logistic Smooth Transition Regression
MAE	Mean Absolute Error
ML	Machine learning
MM	Monetary Model
MSPE	Mean Square Prediction Error
NLS	Non-Linear Least Squares
PKR	Pakistani Rupee
PPP	Purchasing Power Parity
RMSE	Root Mean Square Error
RW	Random Walk
STAR	Smooth Transition Auto Regression
SVAR	Structural Vector Autoregressive
SVM	Support Vector Machine

TR	Taylor Rule
TVP	Time Varying Parametric Approach
US $	United States Dollars
UIP	Uncovered Interest Rate Parity
VAR	Vector Auto Regression

Abstract

This study analyzed the link between the PKR-US dollar currency exchange rate determination and the monetary policy defined by Taylor rule. This study also incorporate the non-linearity linked to the exchange rate behavior in the Taylor rule (TR) exchange rate model by employing the Smooth Transition Auto Regression technique (STAR) over the period of 1982Q1-2019Q4. The forecasting ability of the non-linear TR model is assessed relative to the benchmark random walk model by different forecast evaluation techniques which include Root Mean Square Error (RMSE), Mean Absolute Error (MAE) and Theil's U. The linearity test results show the non-linear association between the nominal exchange rate and the Taylor rule variables. The 1^{st} order logistic STAR model is found to be the most appropriate for modeling the PKR-US dollar exchange rate behavior. The estimation results of the forecast accuracy tests i.e RMSE, MAE and Theil's U coefficient show that the non-linear TR exchange rate model have high forecasting power as compared to the benchmark random walk at all forecast horizon.

CHAPTER 1

INTRODUCTION

1.1 Background

Modelling and forecasting the currency exchange rate is one of the highly debatable topic in the international economics for the last four decades and the problem become more severe in 1973 with the failure of Bretton Woods Fixed Exchange Rate System which compelled many countries to follow the flexible exchange rate system (Kemal and Haider, 2004). Many countries experienced high exchange rate volatility due to floating exchange rate system. High fluctuations in the exchange rate results in the increased uncertainty for the investors and international traders who have to deal with the international transactions in currency exchange rate. Highly volatile currency exchange rates are linked to the high exchange rate risk (Wali & Manzur, 2013). The high exchange rate volatility in the emerging countries makes it difficult for the researchers and policy makers to accurately predict the true behavior of exchange rates.

Exchange rate determination and forecasting has been gained significant attention by the researchers and policy makers since the classical study proposed by Meese and Rogoff (1983). This study claimed that currency exchange rate shows random behavior and are not predictable. The existing literature on the exchange rate determination and forecasting is enriched with linear structural models like Purchasing Power Parity (PPP) model, Uncovered Interest Rate Parity (UIP) model, Monetary Model (MM), Autoregressive Conditional Heteroscedasticity (ARCH) model, Generalized Autoregressive Conditionally Heteroscedastic (GARCH) model, Autoregressive Integrated Moving Average (ARIMA) model based on the traditional theories and non-linear models((Artificial Neutral Network (ANN), Support Vector Machine (SVM)) that have been used to predict the changes in currency movements (see Bissoondeeal et al. (2008), Fahimifard et al. (2009), Molodtsova and Papell (2009), Kumar (2010), Wang, Morley and Stamatogiannis (2019), Colombo and Pelagatti (2019)). It is important to mention that no consensus has been developed for the last four decade regarding that which exchange rate model is the best among all in predicting the exchange rate behavior. As Rossi (2013) proposed that the forecasting ability of traditional structural exchange rate models depend upon time horizon, sample country, sample period, forecast evaluation method and the benchmark model.

1.2 Problem Statement

Pakistan has been experiencing the high exchange rate volatility since 1982 when the central bank started to follow managed-floating currency exchange rate system. The existing literature on exchange rate determination in Pakistan mainly focus on the linear structural models based on traditional exchange rate theories like PPP, MM, UIP and Trade theories (see Kemal and Haider (2004), Khan et al. (2010), Malik (2011), Hina & Qayyum (2013), Khan and Nawaz (2018)). These studies conclude that the linear structural models perform well only at the long forecast horizon but fail to explain the exchange rate behaviour over short forecast horizon. These studies do not incorporate the non-linearities in the models which are linked to the currency exchange rate dynamics and it may be the reason behind the poor forecasting performance of these models. There is also lack of studies in case of Pakistan that have explored the link between the exchange rate determination and Taylor rule fundamentals.

This study add to the existing literature by giving the factual evidence that the PKR-US$ exchange rate behavior can be modelled and forecasted more accurately by incorporating the non-linearities in the currency exchange rate modelling. This study intends to explore the link between the PKR-US dollar currency exchange rate determination and the monetary policy defined by Taylor rule. TR exchange rate model is estimated through Smooth Transition Auto Regression technique (STAR). The study also evaluates the predictive power of non-linear TR exchange rate model over different forecast horizon against the random walk benchmark.

1.3 Research Objectives

1. To analyze the behavior of PKR-US dollar exchange rate by employing the non-linear Taylor rule exchange rate model.
2. To assessed the predicting ability of Taylor rule exchange rate model against random walk benchmark over the different forecast horizon.

1.4 Significance of the Study

The exchange rate is consider as an important asset price in the small open economy like Pakistan which is also import dependent and has high public debt to GDP ratio. Exchange rates are considered important for the monetary transmission mechanism of a country and changes in exchange rate has consequential impact on the economic stability of a country. Understanding the exchange rate dynamics is, therefore, important for the policy makers of central bank because the information related to appreciation/depreciation of a currency against the foreign currency can assist the central bank in pursuing the correct monetary policy.

Correct exchange rate forecast is also important for the firms, businesses and investors who involves in the international transactions and can help them in mitigating the exchange rate risk because high fluctuations in the exchange rate results in the increased uncertainty for investors and international traders. Exchange rate is also a measure of competitiveness of an economy and exchange rate forecast can help an investor in the decision making regarding whether or not to invest in an economy.

1.5 Organization of the Thesis

Chapter two gives a brief review of the different exchange regimes in Pakistan and the exchange rate volatility over different exchange rate regimes. Chapter three provides review of the theoretical and empirical literature on the exchange rate determination and forecasting. Chapter four describes the Taylor rule based exchange rate model and an application of non-linear Smooth Transition Auto regression (STAR) technique in the exchange rate determination and forecasting. Chapter five provides an analysis based on the estimated non-linear Taylor rule exchange rate models and makes a comparison of the forecast generated from these non-linear models. Chapter six concludes the thesis with the summary of the findings and policy implications of the study.

CHAPTER 2

EXCHANGE RATE REGIMES AND TRENDS IN PAKISTAN

Pakistan has been passed through different exchange rate regimes since its independence in 1947. Pakistan has followed fixed exchange rate regime up to 1971and pegged its exchange rate with pound sterling. In June 1972, the US dollar became dominant currency across the globe with the collapse of Pound sterling and then, Pakistan pegged its currency to US dollar (Hina & Qayyum, 2015). Fixed exchange rate system was followed by the State Bank of Pakistan up to 7th January 1982. The manage float exchange rate system was followed by central bank during the period of 1982-1999 in which the value of PKR-US dollar exchange rate was devalued from 12.71 to 51.77 PKR/US dollar. Finally, the central bank followed the policy of market-based exchange rate system from 1999 onward and the value of rupee depreciated further from 58.03 to 62.55 per US dollar during the period 2000-2008 (Zamir et al. 2017).

Pakistan experienced low fluctuations in the currency exchange rate during the fixed exchange rate regime (1972-1981). Pakistan has been experiencing the high exchange rate volatility since 1982 when the central bank started to follow managed-floating currency exchange rate system. Following figures shows PKR-US dollar exchange rate volatility during different exchange rate systems. (Hussain et al., 2015). Currency exchange rate volatility is estimated through GARCH modelling technique over different time periods characterized by different exchange rate regimes.

Figure 2. 1 Exchange Rate Volatility during the Flexible Exchange Rate Regime

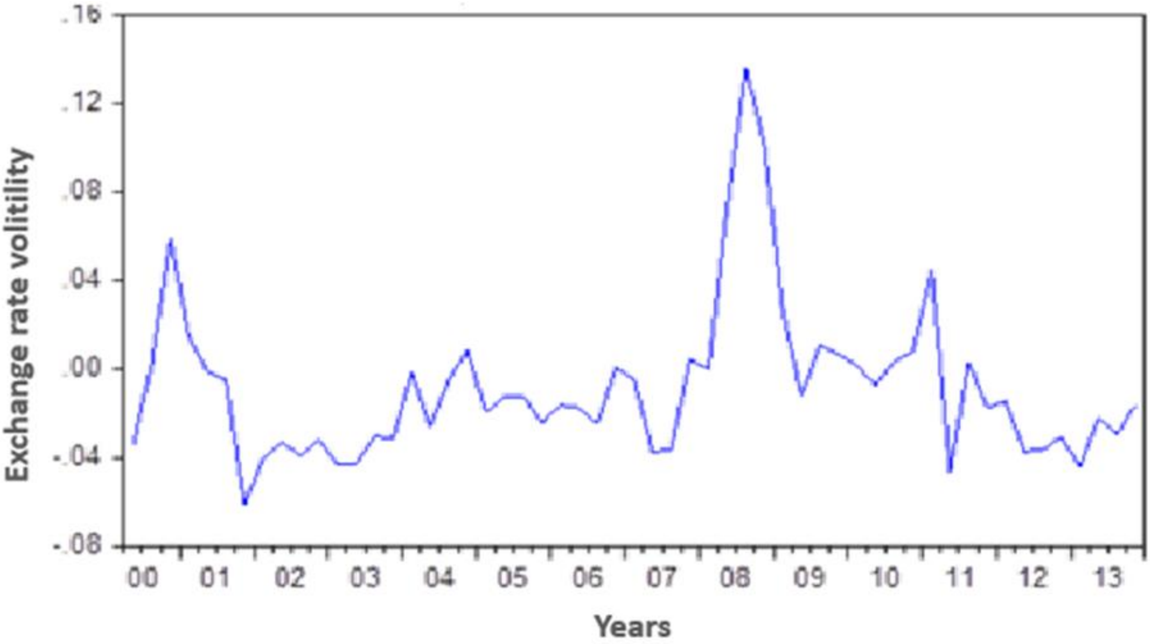


Figure 2. 2 Exchange Rate Volatility during Managed-Floating Exchange Rate Regime

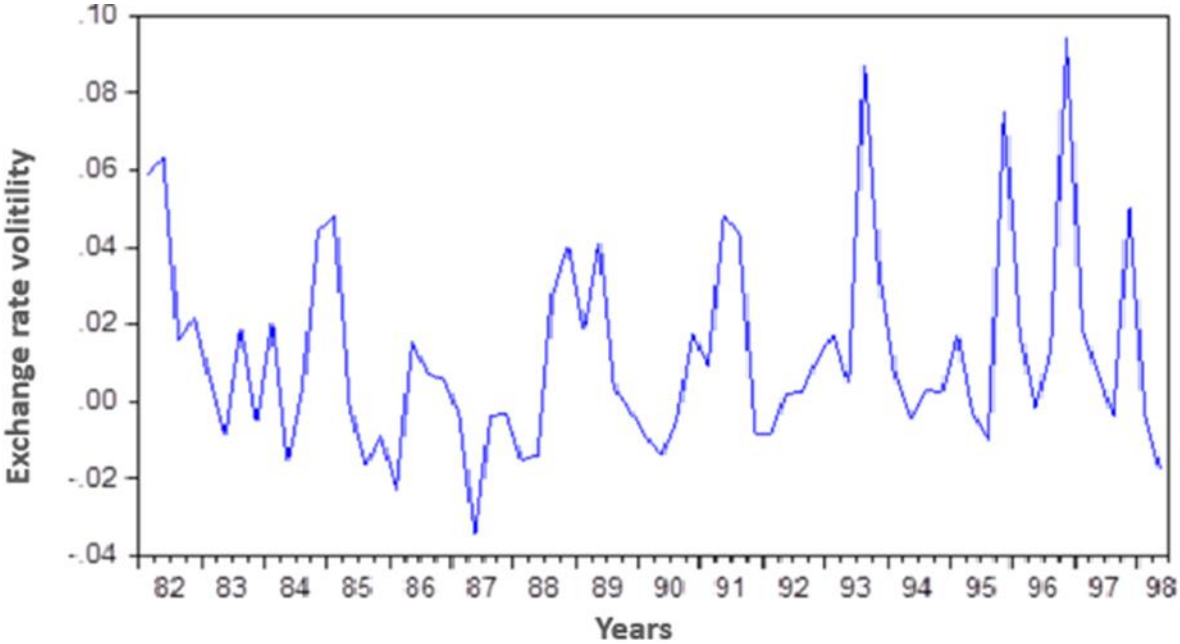
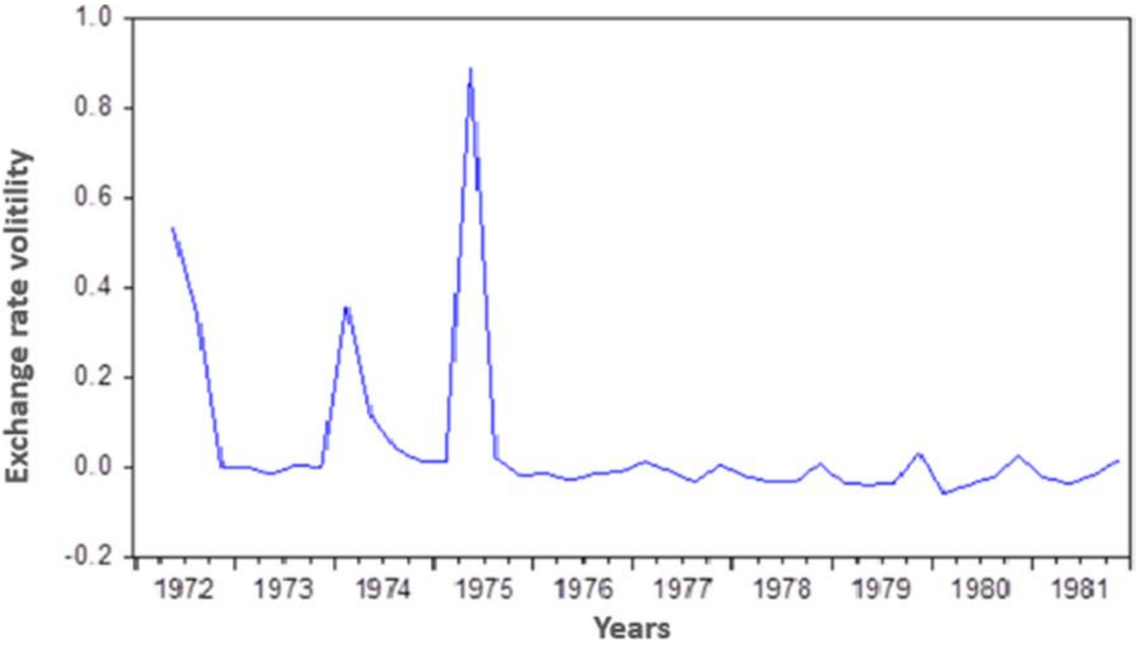


Figure 2. 3 Exchange Rate Volatility during Fixed Exchange Rate Regime



CHAPTER 3

REVIEW OF LITERATURE

3.1 Introduction

This section explain the theoretical background and empirical studies related to exchange rate determination and forecasting. Two main approaches are used by researchers to model and forecast currency exchange rate dynamics. The Fundamental approach, that explain the exchange rate dynamics on the basis of different macro-economic indicators. This approach is based on the traditional structural models derived from the standard economic theories.

Other one is the technical approach which explain and forecast the currency exchange rates on the basis of past price trends. This approach is technical in the sense that instead of using the economic fundaments of exchange rate determination, it only evaluates the past price trends to predict changes in exchange rate through computer models (Heidinger, 2018). This study only focus on the first one approach i.e. the fundamental approach for the exchange rate analysis.

3.2 Theoretical Literature

Since the pioneering study of Meese & Rogoff (1983), random walk (RW) model is regared as a standard model in the literature against which the predictive ability of the other exchange rate models is evaluated.

3.2.1 Random Walk Model (RW)

The classical study by Meese & Rogoff (1983) claimed that currency exchange rate shows random behavior and are not predictable. It further argued that no traditional structuaral model has capacity to explain exchange rate dynamics and can not beat the RW benchmark in exchange rate preditibility.

The random walk model is expressed as follows

$$\Delta s_{it+1} = \alpha + \epsilon_{it+1} \qquad (1)$$

3.2.2 Purchasing Power Parity Model (PPP)

PPP is the most fundamental theory in international finance which states that the currency exchange rate is determined by the ratio of the relative price levels of the two countries, assuming the fixed basket of goods and services. This theory is built on the "law of one price" concept. It states that a unit of currency has same purchasing power in the both home and foreign countries, assuming the fixed basket of goods and services.

The PPP model is expressed as follows.

$$\Delta s_{t+1} = \alpha + \beta(p_t - p_t^*) + \varepsilon_t \qquad (2)$$

Here p_t *and* p_t^* are the log of prices in the home and foreign country. The theory states that α=0 and β=1.

The empirical studies found a little support for PPP model to predict exchange rate changes. Cheung, Chinn and Pascual (2005) found that exchange rate are predictable only at longer forecast horizon through PPP model. Ince (2014) also evaluated the forecasting power of PPP model and found the same empirical results.

3.2.3 Monetary Model (MM)

Monetary model states that the exchange rate changes can be explained by total demand and supply of currency in a country. This theory creates a link between the curreny exchange rates and monetary fundamentals i.e money supply, prices , real income and interest rates.

Monetary model of exchange rate determination is given by:

$$s_{it} = \alpha(m_t - m_{it}^*) + \beta(y_t - y_{it}^*) + \gamma(i_t - i_{it}^*) + \varepsilon_t \qquad (3)$$

Where $(m_t - m_{it}^*)$ represent the money supply differential, $(y_t - y_{it}^*)$ represent the real income differential, and $(i_t - i_{it}^*)$ represent the interest rate differential for the home and foreign countries.

Many studies have evaluated the in-sample and out-of-sample forecasting power of the Monetary models of exchange rate and found the supportive results (see Macdonald and Taylor (1994), Mark and Sul (2001), Baharumshah et al. (2009), Hina & Qayyum (2013)).

3.2.4 Uncovered Interest Rate Parity (UIRP) Model

The UIRP theory states that the currency exchange rate is determined by the differential between home interest rate and the foreign interest rate. In other words, future exchange rate can be predicted on the basis of home interest rate and foreign interest rate.

UIRP model is expressed as:

$$\Delta s_{t+1} = \alpha + \beta(i_t - i_t^*) + \vartheta_{t+1} \qquad (4)$$

When UIRP hold, then α should be equal to 0 and β should be equal to 1. But many studies has rejected this UIRP condition and found that β is often negative and α is found to be close to zero. This is also known as forward bias puzzle in the literature of exchange rate forecasting.

The empirical literature found no supportive evidence for the UIRP model to predict exchange rate changes. Meese and Rogoff (1983) found that UIRP model does not outperform the random walk alternative with negative β coefficients that is not equal to unity. Chinn and

Meredith (2004) used the longer horizon data for G-7 countries and found a little supportive evidence for the UIRP model with positive slope parameters that are close to hypothiszed value of unity. These findings suggest that UIRP may work better at longer horizon. Alquist and Chinn (2008) also found the same results that the UIRP relation perform well only at the longer horizon.

3.2.5 Taylor Rule Exchange Rate Model

Recent literature on the exchange rate determination has developed a series of models based on the Taylor rule fundamentals which have found to be more successful in predicting the true behaviour of the exchange rate over different forecast horizons ((Molodtsova and Papell (2009), Ince (2014), Wang and Morley (2018)). These models link the Taylor rule to the exchange rate determination through Interset rate Parity theory (IRP).

Taylor (1993) introduced a rule which intend to explain the behavior of Central bank concerning the interest rate setting decision. Taylor rule is a simple equation that relates the Central bank nominal interest rate to the real GDP gap and inflation. Molodtsova and Papell (2009) assumed that the monetary policy implemented in the the home and foreign country is characterized by the Taylor rule. Subtracting the foreign country interest rate from the home country interest rate (characterized by Taylor rule) gives the following interest rate differential equation.

$$i_t - i_t^* = \alpha + \theta(\pi_t - \pi_{it}^*) + \gamma(y_t - y_{it}^*) + \rho(i_{t-1} - i_{it-1}^*) + \epsilon_{it+1} \qquad (5)$$

According to IRP theory,

$$\Delta s_{t+1} = (i_t - i_t^*) \qquad (6)$$

Replacing the interest rate differential with exchange rate return, following symmetric Taylor rule version is obtained.

$$\Delta s_{it+1} = \alpha + \theta(\pi_t - \pi_{it}^*) + \gamma(y_t - y_{it}^*) + \rho(i_{t-1} - i_{it-1}^*) + \epsilon_{it+1} \quad (7)$$

If the monetary authority of any country also target the PPP level of exchange rate, following asymmetric Taylor rule version is obtained.

$$\Delta s_{it+1} = \alpha + \theta(\pi_t - \pi_{it}^*) + \gamma(y_t - y_{it}^*) + \rho(i_{t-1} - i_{it-1}^*) + \delta q_{it}^* + \mu_{it+1} \quad (8)$$

Many studies have found the evidence of high exchange rate forcasting ability of Taylor rule model relative to other traditional structural models (see Molodtsova and Papell (2009), Galimberti and Moura (2013), Rossi (2013) and Wang and Morley (2018)).

3.3 Empirical Literature

3.3.1 International Literature

The pioneering study by Meese and Rogoff (1983) analyzed the predictive ability of traditional structural exchange rate models and found that these structural models based on the traditional economic theories perform worse as compared to the random walk model. Engel and West (2005) also proposed that fundamental macro-economic variables has no capacity to explain exchange rate dynamics.

Faust, Rogers and Wright (2001) examined the forecasting power of traditional exchange rate models using real time data.The findings concluded that the forcasting performance of the models can be improved by both the data revisions and changes in the sample size.

Mark and Sul (2001) examined the forcasting ability of the MM of exchange rate using the Panel cointegration analysis and found the strong empirical evidence of cointegrated relationship between exchange rate and monetary fundamentals.

Evans and Lyons (2005) examined the micro-based exchange rate forcasting model over the short horizon of one day to one month and compared its performance with the standard macro models and random walk model. They found that the micro-based models perform consistently much better than the standard macro models and the random walk.

Cheung, Chinn and Pascual (2005) examined the predictive ability of different exchange rate models proposed in 1990s and compared it with two reference models PPP and sticky price monetary model considering different dimensions including currencies, econometric approaches and forcasting horizons. Their overall analysis arrived at the conclusion that a model may perform better for one currency but fail to forcast changes in another currency. The forcasting performance of the models also vary with the forcasting horizon, the model may have superior predictive ability in one time period but may perform worse in another period.

Uz and Ketenci (2008) also analyzed the MM of exchange rate and found strong cointegration relationship between the exchange rate and monetary fundamentals.They also found that MM has strong exchange rate predictibilty over the long forecast horizon.

Bissoondeeal et al. (2008) evaluated the forcasting performance of non-linear Neutral Network (NN) model to predict currency exchange rate changes.This study also made a comparison between the forcasting performance of Neutral Network model (NN) and traditional linear exchange rate models. Empirical findings conclude that non-linear Neutral Network (NN) model has better exchange rate forcasting ability than the RW, ARMA and GARCH models. Among traditional models, the findings suggest that RW model perform better than the ARMA and GARCH models.

Molodtsova and Papell (2009) analyzed the exchange rate predictive ability of Taylor rule exchange rate model with different specifications by simple ordinary least square method (OLS) in rolling regression and provided the evidence that Taylor rule fundamentals have strong predictive power in exchange rate determination even at the short horizon of one month as compared to other conventional exchange rate models.

Fahimifard et al. (2009) studied different linear and non- linear models to predict daily Iran Rial and Rial/US dollar exchange rate. The findings revealed that non- linear models (Adaptive neuro-fuzzy inference system (ANFIS) and Artificial neural networks (ANN) outperform the linear models (ARIMA and GARCH) to predict 2, 4 and 8 days ahead of Rial currency against US dollar. Among linear models, GARCH model has better forcasting performance than ARIMA model and ANFIS is better than ANN among the non- linear models to predict changes in exchaneg rate.

Kumar (2010) observed the daily prices of CNX and INR/USD to predict the changes in Indian rupee against US dollar. He used a Vector autoregression (VAR) model with time varying parametric approach (TVP) to predict the currency movement. The results show that the predictive power the exchange rate model is improved by using the time varring paramteric approach.

Park and Park (2013) estimated the monetary exchange rate models with both the constant coefficients as well as the time varing coefficients and concluded that the time varing cointegration approach significantly improve the predictive ability of the monetary exchange rate models.

Galimberti and Moura (2013) analyzed the Taylor rule exchange rate models employing the Panel data regression analysis and found that forward-looking specification of the TR model shows high forecasting performance relative to other specifications.

Rossi (2013) critically analyzed the past exchange rate forecasting empirical studies and concluded that exchange rate predictive ability of a model depends upon the macro-economic variables used in the model. Taylor rule fundamentals and asset based model approach provide the strong out-of-sample exchange rate predictibilty. Linear exchange rate model perform better as compared to non-linear specification. The predictive ability of the exchange rate model vary with the forcast horizon, sample period, forcast evaluation technique and the benchmark model. The choice of a country also influence the predictive ability of a given model.

Ince (2014) evaluated the exchange rate forcasting performance of the PPP model and TR exchange rate model using the real time data.The study suggested that the forecasting ability of the models improve by employing the Panel estimation analysis.

Byrne, Korobilis and Ribeiro (2016) also examined the fundamental exchange rate models including MM, PPP, UIRP, TR model and a factor model. They used Time Varying Parametric approach TVP (accounting for the parameter instability over time) estimated by Bayesian methods and Fixed effect panel regression. The study conclude that the Time Varying Parametric models perform well as compared to the constant parametric model at short as well as long forecast horizon. Among other models, PPP model outperform the RW benchmark in all forecasting windows at short and long horizon while the UIRP model shows forecasting ability only at long horizon.

Das, Bisoi, and Dash (2017) developed Kernal Exreme Learning Machine (KELM) models to deal with non-linearity and non stationarity nature of exchange rate data and provide the evidence of strong prediction in the exchange rate movements and trends as compared to the other forcasting approaches.

Wang and Morley (2018) investigated the Taylor rule exchange rate models with different specification for UK, USA, Australia and Sweden. This study focus on the directional accuracy in the exchange rate predictibility using Pesaran-Timmermann test for that purpose. They found that the symmetric TR model specification perform best in predicting the directional change in exchange rate. For UK,USA and Australia the symmetric model with heterogenous coefficient and stock prices perform well while for the Sweden house prices are more significant in predicting the directional changes for Sweden.

Jan and Gopalaswamy (2019) investigated the trend for AUS/USD from 1988 to 2010 and identified the key factors including economic fundamentals and other currencies that are important in the currency exchange rate determination using non linear least squares (NLS) with ARMA time series model. They found that exchange rate is not only affected by the home country economic condition but foreign economic environment also influnce the AUS/USD trend. One of the important finding is that exchange rate is affected by Australian interest rate itself much more than the interest rate differential between AUD and USD.

Colombo and Pelagatti (2019) assesed standard exchange rate forcasting models through recent machine learning methods (ML) and found these tools to be more efficient in forecasting the exchange rate. Estimation results explored that no traditional exchange rate model has predictive ability over short forecast horizon (1month ahead) irrespective of the estimation method. However, the ML technique improves the forcasting performance of the standard exchnage rate models in the long horizon. The study found that the monetary model with sticky price version shows best forcasting performance.

Jamali and Yamani (2019) analyzed the forecasting performance of standard macro exchange rate models by combining the two approaches of the exchange rate determination i.e the fundamental and technical approach and improve the predictive ability of the models.

Baku (2019) identified the important financial and macroeconomic variables to predict exchange rate movements using error correction model approach and found that commodity, equity prices and domestic risk premium are important factors in exchange rate determination.

3.3.2 Pakistani Literature

The existing litarature related to Pakistan on exchange rate determination and forecasting mainly focus on the fundamental approach which is based on the conventional theories like PPP , MM and UIRP.

Kemal and Haider (2004) estimated three models monetary model, trade model and forex model of exchange rate determination for Pakistan over the period of July 2000 to August 2004 by employing the SVAR approach. The study does not support the PPP hypothesis for Pakistan over the estimation time period. Estimation results show that real exchange rate fluctuations are significantly explained by the monetary fundamentals while the nominal changes can not be explained by the monetary model. The findings of estimated trade model shows that the import and export dynamics significantly explain the changes in the exchange rate. Only nominal exchange rate is influenced by foreign exchange reserves changes.

Khan et al. (2010) analyzed the real exchange rate dynamics in Pakistan using the SVAR methodology. The study conclude that in the short run, real exchange rate changes are explained by the nominal shocks rather than the real shocks.

Malik (2011) analyzed the predictive ability of different exchange rate models including the AR, ARMA, ARCH, PPP, MM and the Combination forecast models for the Pakistan over the period of 2000-2010. The predictive ability of these models is assesed on the criteria of minimum Mean Square Prediction Error (MSPE). ARCH, AR and Combined forecast models are found to have higher forecasting ability in predicting exchange rate changes for Pakistan for selected time period.

Rashid (2012) proposed a joint model to explain the exchange rate dynamic in Pakistan which combine the three parities i.e PPP, UIP and RW into a single equation. The empirical findings shows that the UIP component of the model better explain the currency exchange rate fluctuations for Pakistan relative to the other two components of the model (i.e PPP and RW),it implies that the interest rate differential between home and foreign country better explain the exchange rate dynamics than the price differential for Pakistan. The study provide the evidence that the interaction among the PPP, UIP and RW is significant in explaining the currency exchange rate changes.

Hina & Qayyum (2013) examined the MM of exchange rate determination for Pakistan over the time period of 1982:Q1 to 2010:Q2. The results provide the evidence of strong cointegration among the variables. The error correction MM of exchange rate beat the RW benchmark in exchange rate predictibity over different forecast horizon. Khan and Nawaz (2018) also analyzed MM of exchange rate for Pakistan by employing the SVAR methdology. Results claim that interest rate differential and inflation differential explain the exchange rate dynamics in the short run while in the long run, exchange rate changes are explained by money supply and real income.

3.4 Conclusion

Empirical findings provide the evidence of strong co-integration among the variables in the exchange rate models. Some past studies claim that structural exchange rate models (based on macro-economic theories) do not perform well in the exchange rate determination and forecasting while various studies also found the evidence in favor of these structural models. Studies based on the comparative analysis of these structural exchange rate models found that TR exchange rate model has high exchange rate predictability as compared to other structural models. Non-linear models also found to have better exchange rate predictability than linear structural models. Few studies also conclude that the forecasting ability of these structural models varies with sample period, forecast horizon, sample country, forecast evaluation technique and benchmark model.

CHAPTER 4

MODEL AND METHODOLOGY

4.1 Introduction

Recent exchange rate literature has focused on a series of models based on the Taylor rule fundamentals which have found to be more successful in predicting the true behaviour of the exchange rate over different forecast horizons ((Molodtsova and Papell (2009), Ince (2014), Wang and Morley (2018)). These models link the interest rate reaction function (characterized by the Taylor rule) to the exchange rate, thus reflect the more realistic and practical behaviour of central bank policy and exchange rate dynamics. Recent development in the study of monetray policy and exchange rate also involves the use of non-linear estimation techniques and these non-linear models are found to be more succussful in predicting the exchange rate changes (Boero & Marrocu, 2002). Empirical evidence also support the presence of non-linearity in the fundamental exchange rate models. Rossi (2006) found the evidence of unstable parameters of the conventional exchange rate determination models and the time dependent association exist among the variables in the exchange rate determination model. Khan & Qayyum (2011) also confirm the existance of non-linear association among the varibles in the exchange rate determination model. Altavilla & Grauwe (2005) argued this the non-linear association is linked to the frequent exchange rate regime changes. Therefore, this study also incorporate the non-linearities in the exchange rate model by applying the non-linear STAR estimation technique to the TR exchange rate model.

4.2 Model Description

This study employ the exchange rate determination model derived from the Taylor rule type interest rate reaction function because this model reflect the practical behavior of the central banks regarding the setting of the interest rate target. Moreover, the TR exchange rate determination model is found to perform better as compared to the other conventional models like PPP, MM and UIRP models in currency exchange rate predictiblity (Molodtsova and Papell, 2009).

Taylor (1993) introduced a rule which intend to explain the behavior of Central bank concerning the interest rate setting decision. Taylor rule is a simple equation that relates the Central bank nominal interest rate to the real GDP gap and inflation by the following equation.

$$i_t = r^* + \pi_t + 0.5(\pi_t - \pi_t^*) + 0.5(y_t - y_t^*)$$

Where

i_t is used for nominal interest rate target of the central bank, r^* is used for real interest rate, $(\pi_t - \pi_t^*)$ is the difference between actual inflation and target inflation and $(y_t - y_t^*)$ is the difference between the actual real output and the potential output level.

According to TR, the central bank will increase the nominal interest rate either when inflation increases from its target level or the actual real output increases relative to its potential output level. In practice, the Taylor rule is not completely followed by many countries especially in the emerging countries which are characterized by high inflation rates and high public debt to GDP ratio.

This study employs the modified form of Taylor rule for the exchange rate determination, the approach used by Molodtsova and Papell (2009) in their study. The modified Taylor rule is given by:

$$i_t^* = \mu + \lambda\pi_t + \gamma y_t + \phi q_t \qquad (1)$$

$$i_t = (1-\rho)i_t^* + \rho i_{t-1} + \upsilon_t \qquad (2)$$

Where

i_t^* is the short term interest rate target of the central bank, y_t is the difference between the actual real output and the potential output of the economy, π_t is the rate of inflation, q_t is the real exchange rate and ρ is the coefficient for interest rate smoothing.

By putting eq. (1) in eq. (2) we will get the following equation

$$i_t = (1-\rho)(\mu + \lambda\pi_t + \gamma y_t + \phi q_t) + \rho i_{t-1} + \upsilon_t \qquad (3)$$

The monetary authority in emerging countries also target its real exchange rate to maintain the exchange rate stability, therefore, this study also incorporate real exchange rate in TR model of exchange rate determination. Assuming that the monetary policy of both the home and foreign countries is characterized by the TR, represented by equation (3) (for foreign country ϕ=0).

Subtracting the foreign country interest rate from the home country interest rate (characterized by Taylor rule) gives the following interest rate differential equation.

$$i_t - \widetilde{\iota_t} = \alpha_0 + \left(\beta_{p\pi}\pi_t - \beta_{u\pi}\widetilde{\pi_t}\right) + \left(\beta_{py}y_t - \beta_{uy}\widetilde{y_t}\right) - \beta_q qt + \left(\rho_p i_{t-1} - \rho_u \widetilde{\iota_{t-1}}\right) + \eta_t$$

(4)

Where $\alpha_0 = \mu(1-\rho), \beta_\pi = \lambda(1-\rho), \beta_y = \gamma(1-\rho)$ for both countries and $\beta_q = \phi(1-\rho)$ for Pakistan.

According to UIRP theory $\Delta s_{t+1} = (i_t - \widetilde{\iota_t})$, substituting (4) in this UIRP equation we will get

$$\Delta s_{t+1} = \alpha_0 + \left(\beta_{p\pi}\pi_t - \beta_{u\pi}\widetilde{\pi_t}\right) + \left(\beta_{py}y_t - \beta_{uy}\widetilde{y_t}\right) - \beta_q qt + \left(\rho_p i_{t-1} - \rho_u \widetilde{\iota_{t-1}}\right) + \eta_t \qquad (5)$$

Where, s_t is the natural log of exchange rate. This equation is known as the Heterogeneous TR exchange rate model. Assuming that $\beta_{u\pi} = \beta_{p\pi} \equiv \beta_{\pi},\ \beta_{uy} = \beta_{py} \equiv\ \beta_{y},\ \rho_{u} = \rho_{p} \equiv \beta_{i}$, the modified asymmetric homogenous TR exchange rate determination model is given by:

$$\Delta s_{t+1} = \alpha_0 + \beta_{\pi}(\pi_t - \widetilde{\pi_t}) + \beta_y(y_t - \widetilde{y_t}) - \beta_q qt + \beta_i(i_{t-1} - \widetilde{\iota_{t-1}}) + \eta_t \quad (6)$$

This study estimate both the above specification of Taylor rule exchange rate model.

4.3 Data

For estimating the TR exchange rate model, quarterly data over the period of 1982Q1-2019Q4 is used. Data for all the variables is available on the International Financial Statistics (IFS) IMF database and Federal Reserve Economic Data, FRED website for both the home and foreign countries i.e. Pakistan and USA respectively.

Output gap is calculated through Hodrick-Prescott (HP) filtering technique and is calculated through real GDP data. CPI data is taken to calculate the inflation rates for the home and foreign country. The end of the period nominal exchange rate data is used to calculate the exchange rate returns. Money market rates are taken for nominal interest rate variable. Real exchange rate is calculated by using the nominal exchange rate data.

4.3.1 Variables Definition and Construction

Variables are defined and constructed as follows:

Dependent Variable:

Currency Exchange rate (s_t**)**

Nominal exchange rate is defined in terms of units of Pakistani rupee (PKR) per US dollar. Exchange rate return variable is constructed using the end of period exchange rate data.

Exchange rate Return $(\Delta s_{t+1}) = lns_{t+1} - lns_t$.

Independent Variable:

- **Output Gap (y_t)** is calculated by subtracting the potential real output from the actual real output of the economy. It can be positive or negative

$$Output\ GAP\ (y_t) = Actual\ Output - Potential\ Output$$

Potential output is calculated through different methods by different economist and researchers which include statistical methods, structural methods and mixed method (combination of statistical and structural methods). Statistical methods only require real GDP data to calculate the potential output while other methods require more data to compute the potential output.

In this study, potential output is calculated through most commonly used statistical technique known as Hodrick and Prescott (HP) filter. HP filter divide the real GDP series into two components: the trend component and the cyclical component.

$$y_t = \tau_t + c_t$$

Where y is the log of GDP, τ is the trend component and c is the cyclical component. In this equation the trend component is a measure of potential output of the economy.

- **Inflation (π_t)** is calculated using the CPI as a proxy and is calculated as

$$\pi_t = (lnCPI_t - lnCPI_{t-4}) * 100.$$

- **Interest rate (i_t):** Short term nominal interest rate is defined in terms of money market rate.
- **Real Exchange rate (q_t)** is calculated through nominal exchange rate and CPI data by the following equation

$$q_t = s_t - (p_t - p_t^*).$$

- **Output Gap Differential (y_t-y_t*)** is calculated by subtracting the foreign output gap from the domestic output gap.
- **Inflation Differential (π_t-π_t*)** is calculated by subtracting the foreign inflation rate from the domestic inflation rate.
- **Interest Rate Differential (i_{t-1}-i_{t-1}*)** is calculated by subtracting the foreign interest rate from the domestic interest rate.

Log form of all the variables are used in the analysis except for the short term interest rate.

4.4 Econometric Methodology

4.4.1. ADF Test

Augmented Dickey Fuller (ADF) Test is carried out to check the stationary properties of the data. The ADF unit root test is based on testing the following regression equation.

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \sum_{j=1}^{p} \delta_j \, \Delta y_{t-j} + \varepsilon_t$$

The null hypothesis of the ADF test is that a time series y_t has a unit root or non-stationary against the alternative that y_t has no unit root or stationary.

4.4.2 Smooth Transition Auto Regression Methodology (STAR)

The non-linear Taylor rule based exchange rate model is estimated through the Smooth Transition Auto-regression methodology proposed by Granger and Terasvirta (1993). The STAR modeling has been used by many researchers for testing the the non-linearities in the economic time series because it allows for continuous and smooth transition across different regimes.

The standard STAR model is shown by the following equation

$$y_t = \emptyset' z_t + \theta' z_t G(\gamma, c, s_t) + \mu_t, \qquad \mu_t \sim iid(0, \sigma^2)$$

Where $G(\gamma, c, s_t)$ is the transition function usually bounded between 0 and 1, which depends on the transition variable s_t, transition parameter γ and the c, the vector of location parameter. z_t is the vector of the explanatory variables. $\emptyset$ and θ are the parameter vectors of the linear and non-linear part respectively.

Granger and Terasvirta (1993) proposed the following two alternative forms of the transition function namely Logistic STAR function and Exponential STAR function.

Logistic Function

$$G(\gamma, c, s_t) = (1 + exp\{-\gamma(s_t - c)^2\})^{-1}, \qquad \gamma > 0$$

Exponential Function

$$G(\gamma, c, s_t) = 1 - \exp[-\gamma(s_t - c)^2]\,, \qquad \gamma > 0$$

In case of LSTR model, the $G(\gamma, c, s_t)$ is monotonically increasing function of the transition variable s_t while ESTR model is symmetric and U-shaped around c.

The non-linear exchange rate STAR model based on the Taylor rule is represented by the following equation.

$$\Delta \boldsymbol{s_{t+1}} = \emptyset_{\mathbf{0}} + \emptyset_{\mathbf{1}}\boldsymbol{z_t} + (\boldsymbol{\theta_0} + \boldsymbol{\theta_1 z_t}).\boldsymbol{G}(\boldsymbol{\gamma}, \boldsymbol{c}, \boldsymbol{s_t}) + \boldsymbol{\mu_t}, \quad \boldsymbol{\mu_t} \sim \boldsymbol{iid}(\mathbf{0}, \boldsymbol{\sigma}^{\mathbf{2}})$$

Where $z_t = [(\pi_t - \widetilde{\pi_t}), (y_t - \widetilde{y_t}), (i_{t-1} - \widetilde{\iota_{t-1}}), \widetilde{q_t}], \emptyset_1 = (\emptyset_\pi, \emptyset_{y,} \emptyset_i, \emptyset_q)$

$\theta_1 = (\theta_{\pi,} \theta_y, \theta_{i,} \theta_q).$

This study will follow the modelling cycle proposed by Granger and Terasvirta (1993) which consist of following steps.

1. In the first step, the appropriate AR model of order *p* is selected on the basis of appropriate model selection criterion, which serves as a base for a non-linear model.
2. To test the non-linearity in the model, the null hypothsis of linearity is tested against the alternative of STR non-linearity by applying following auxiliary regression.

$$\Delta \boldsymbol{s_{t+1}} = \boldsymbol{\beta'_0 z_t} + \sum_{\boldsymbol{j=1}}^{\mathbf{3}} \boldsymbol{\beta'_j z_t s_t^j} + \boldsymbol{\mu_t^*}$$

   Where z_t is the vector of expalnatory variables and s_t is the selected transition variable from z_t. When the null hypothesis of linearity is rejected, then the appropriate STAR model (Logistic or Exponential) is selected.

3. The parameters are then estimated by employing the appropriate form of STAR model selected on the basis of linearity test.
4. The STAR model is then evaluated on the basis of different diagnostic tests. Three important misspecification tests are considered in this study proposed by Eitrheim and Terasvirta (1996) to evaluate the quality and the statistical adequacy of the model. These tests include LM test for no error autocorrelation, test for no additive non-linearity and a test for parameter constancy. Other tests include ARCH test and Jarque–Bera normality test.

5. The final model which successully pass all the diagnostic test is then used for forecasting purpose.

4.5 Forecast evaluation

The out-of-sample forecast of non-linear STAR model is evaluated (considering the transition variables which produce the evidence of non-linearity in the exchange rate model) on the basis of different forecast evaluation techniques. The forecast performance of each non-linear specification is evaluated against the random walk benchmark. The Root Mean Square Error (RMSE), Mean Absolute Error (MAE) and Theils U coefficient are used to measure the forecast accuracy of these models. All the models are re-estimated by using the data from 1982Q1 to 2010Q4 and the remaining data (2011Q1-2019Q4) is used to generate the forecast over different forecast horizon.

CHAPTER 5

ESTIMATONS AND RESULTS

5.1 Descriptive Statistics

Descriptive statistics (Table 5.1) show that average output gap in Pakistan is -1.97 during the period 1982-2019. The average inflation rate in Pakistan is 7.6 % while the average interest rate is found to be 8.4% in Pakistan. Correlation matrix shows that there is positive association between exchange rate return and domestic output gap while it has negative association with the foreign output gap. Exchange rate return is positively associated with the domestic and foreign inflation. It is also positively associated with the domestic and foreign interest rates.

Table 5. 1 Descriptive statistics

Statistics	Δs_{t+1}	y_t	y_t^*	Π_t	Π_t^*	i_{t-1}	i_{t-1}^*	q_t
Mean	0.017	-1.97E-06	0.024	7.638	2.632	8.489	4.149	4.297
Maximum	0.147	9.423	4.002	21.928	6.087	15.423	14.513	4.687
Minimum	-0.073	-9.248	-4.907	1.624	-1.620	1.050	0.073	3.763
Std. dev.	0.031	2.529	1.867	3.769	1.245	2.786	3.316	0.191
Obs.	151	152	152	148	148	151	151	152

Correlation								
	Δs_{t+1}	**y_t**	**y_t***	**Π_t**	**Π_t***	**i_{t-1}**	**i_{t-1}***	**q_t**
Δs_{t+1}	1.000							
y_t	0.001	1.000						
y_t*	-0.033	0.538	1.000					
Π_t	0.156	0.087	-0.089	1.000				
Π_t*	0.190	0.068	0.207	0.157	1.000			
i_{t-1}	0.081	0.059	-0.147	0.505	-0.164	1.000		
i_{t-1}*	0.136	0.076	0.181	-0.092	0.653	-0.042	1.000	
q_t	-0.134	-0.022	-0.008	0.006	-0.290	-0.012	-0.529	1.000

The following figures shows the trend of all the variables used in the study over the period of 1982-2019 for Pakistan and USA.

Figure 5.1 shows exchange rate trend in Pakistan over the period of 1982-2019. The value of PKR-US dollar exchange rate was devalued from 12.71 to 51.77 PKR/US dollar during the manage float exchange rate regime(1982-1999). The value of rupee depreciated further from 58.03 to 62.55 per US dollar during the period of market based exchange rate regime (2000-2008). Pakistan has been experiencing the high exchange rate volatility since 1982 when the central bank started to follow managed-floating currency exchange rate system.

Figure 5. 1 PKR/US dollar Exchange rate

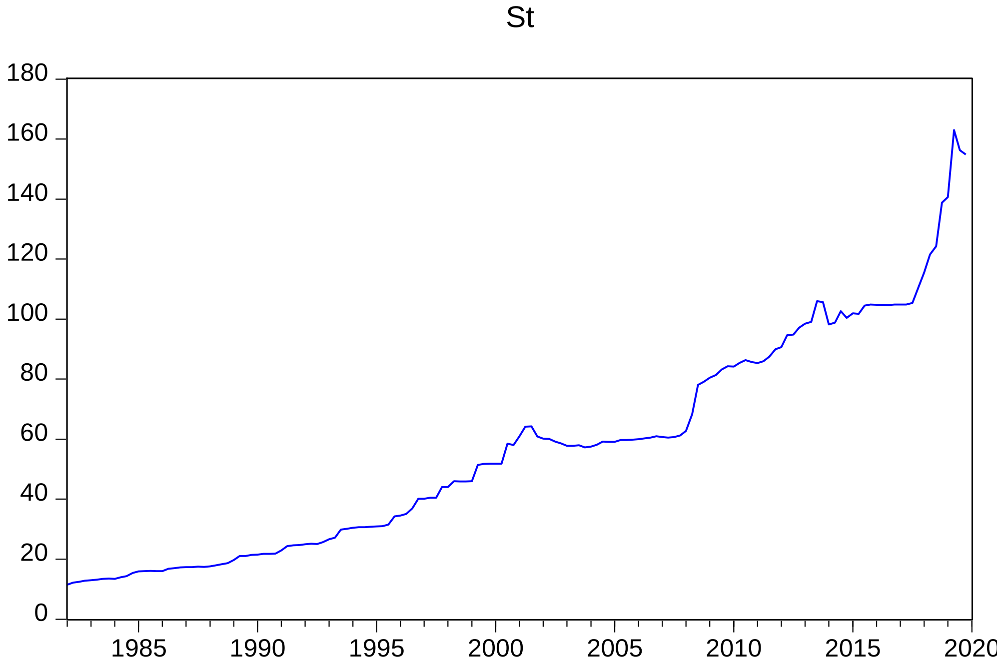


Figure 5.2 and figure 5.3 shows the inflation trend in domestic and foreign country over the period of 1982-2019. The average inflation rate in Pakistan is 7.6 % while the average inflation rate in USA is found to be 2.632%.

Figure 5. 2 Domestic Inflation

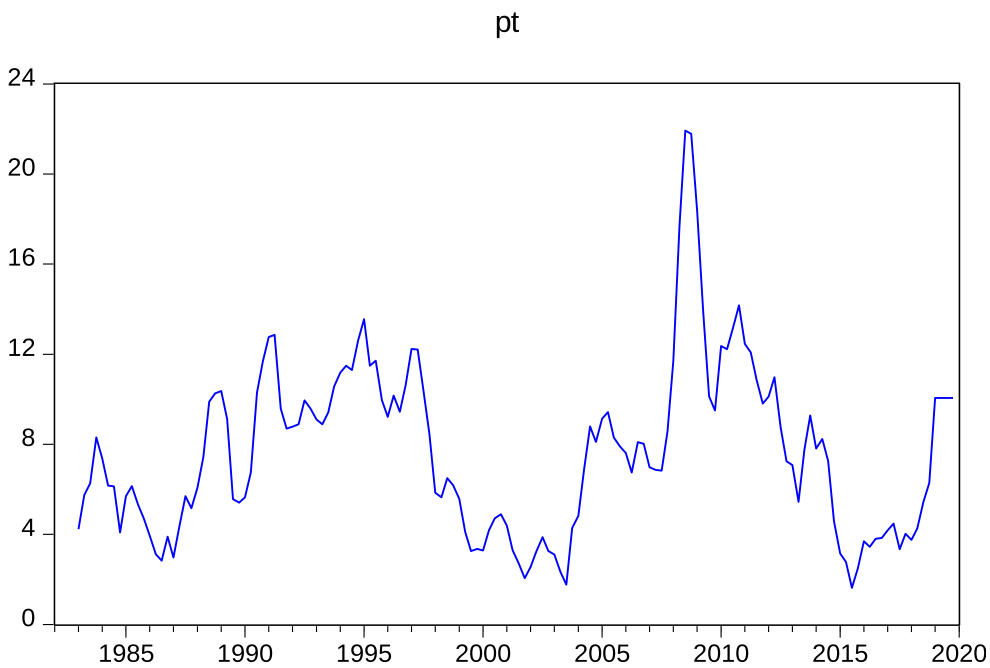


Figure 5. 3 Foreign Inflation

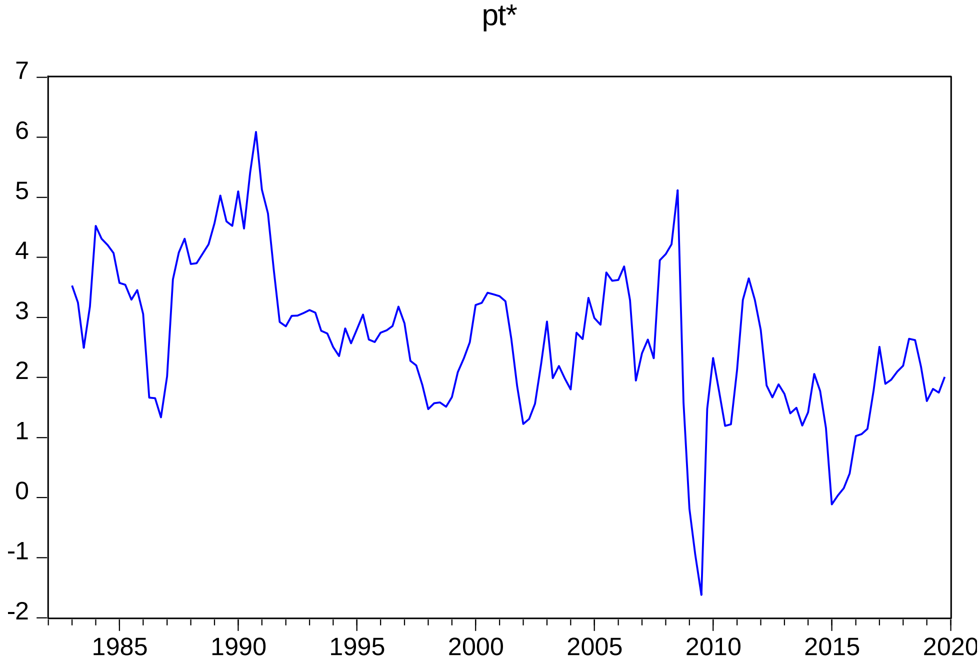


Figure 5. 4 Domestic Interest Rate

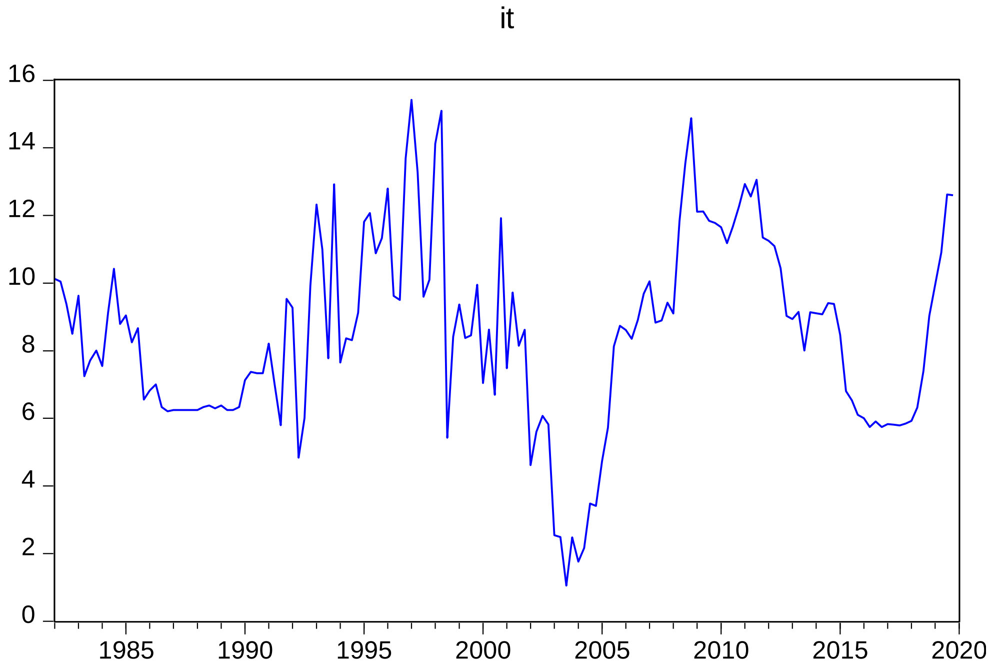


Figure 5.4 and figure 5.5 shows the interest rate trends in domestic and foreign country over the period of 1982-2019. The average interest rate in Pakistan is 8.489% while the average interest rate in USA is found to be 4.149%.

Figure 5. 5 Foreign Interest Rate

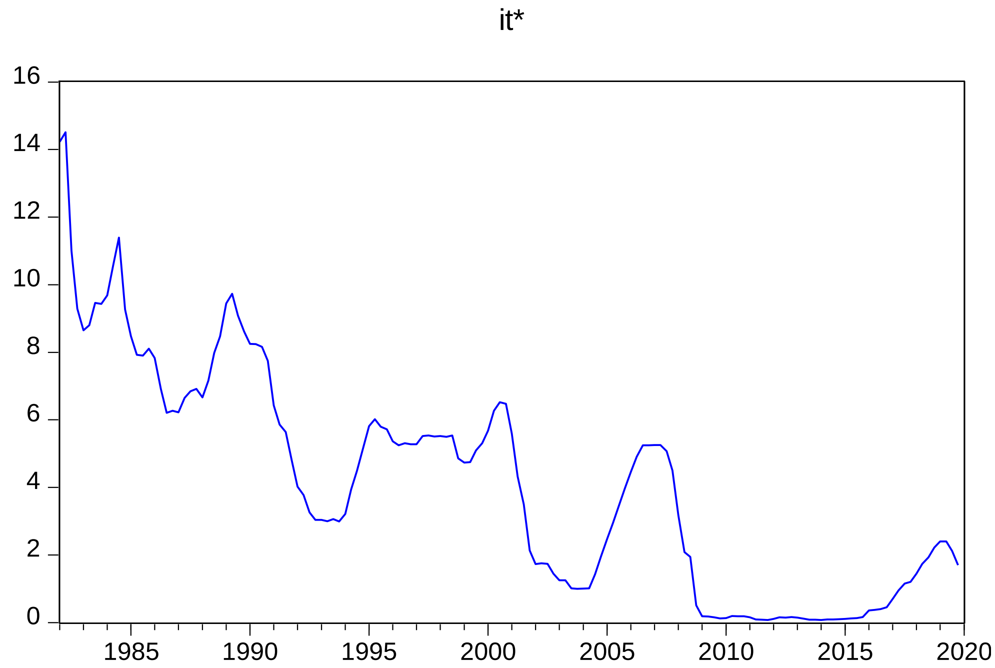
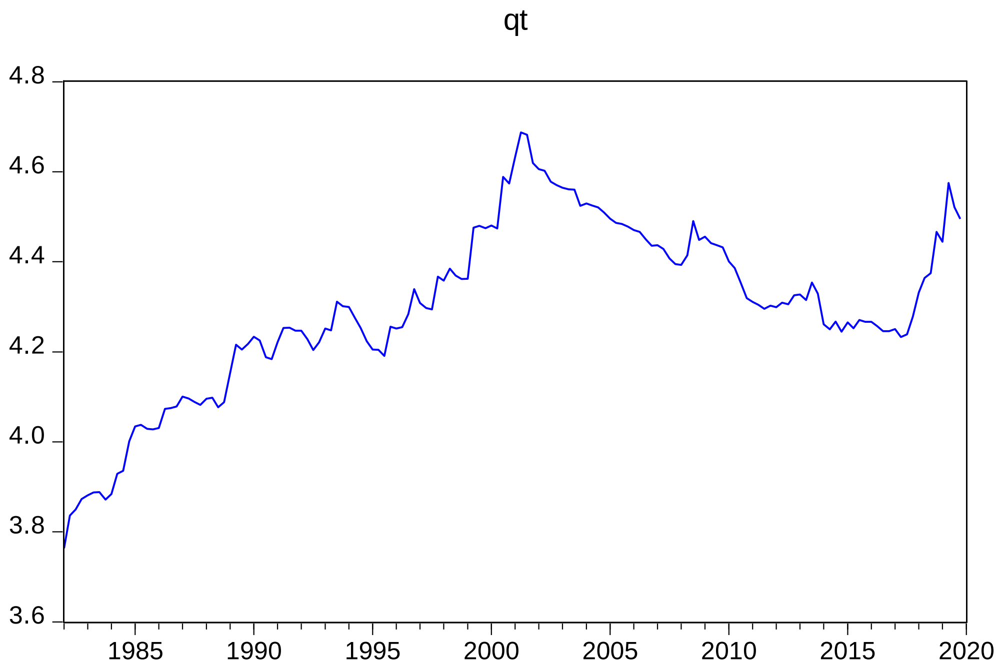


Figure 5. 6 Real Exchange rate for Pakistan



5.2 ADF Test Results

The results of ADF unit root test are presented in (Table 5.2).

Table 5. 2 ADF Unit Root Test

Variables	**ADF Test** **At Level**	**ADF Test** **At 1st difference**	**Results**
Δs_{t+1}	-5.654071***		I(0)
y_t	-5.348991***		I(0)
y_t*	-5.300493***		I(0)
Π_t	-3.240864**		I(0)
Π_t*	-3.009439**		I(0)
i_{t-1}	-2.471336	-6.370480***	I(1)
i_{t-1}*	-2.983880***		I(0)
q_t	-2.741748*		I(0)
(y_t-y_t*)	-7.005505***		I(0)
(π_t-π_t*)	-2.582021*		I(0)
(i_{t-1}-i_{t-1}*)	-1.616835	-6.370480***	I(1)

Test results show that all the variables are stationary at the level except the domestic interest rate (**i_{t-1}** **)**and the interest rate differential **(i_{t-1}-i_{t-1}*).** These variables become stationary at first difference, implies that the variables are integrated with order one.

The long run relationship between the exchange rate return and the Taylor rule fundamentals is examined by the ARDL Bound test approach proposed by the Pesaran et al. (2001). The findings shows that there exist long run relationship between the variables. For heterogeneous Taylor rule exchange rate model, the F-statistic value is 14.745 with lower bound value 2.17 and upper bound value 3.21 at 5% level of significance. For homogenous TR model, the F-stat value is 21.279 with lower bound 2.56 and upper bound 3.49 at 5% level of significance. After this linear estimations, the non-linear exchange rate model is estimated by Smooth Transition Auto regression methodology (STAR) which confirms the presence of non-linearity in the model.

5.2 Heterogenous Taylor Rule Exchange Rate STAR Model Estimations

The linearity test on the heterogenous Taylor rule exchange rate model (Table 5.3) shows that the output gap, inflation and interest rate does not cause non- linearity in the exchange rate model. The non-linearity exist in the model only in the case when exchange rate return is taken as a transition variable. The appropriate model is found to be the 1st order logistic STAR model for modelling exchange rate in Pakistan.

Table 5. 3 Linearity Test on the Heterogeneous TR model

Transition Variable	H01	H02	H03	Model
Δs_{t+1}	0.0000***	0.0000***	0.0000***	1st order logistic
y_t	0.6367	0.7826	0.1935	Linear
y_t*	0.7085	0.3837	0.2721	Linear
Π_t	NA	NA	NA	NA
Π_t*	NA	NA	NA	NA
i_{t-1}	NA	NA	NA	NA
i_{t-1}*	0.7914	0.1557	0.0260	Linear
q_t	NA	NA	NA	NA

Table 5.4 shows the estimated coefficients of the non-linear heterogenous STAR model. The value of slope parameter (γ) is 5.0672 which implies that there is gradual transition from one regime to another. The threshold value is found to be 0.0089 (antilog value equals to 1.0207).

The cofficient of exchange rate return lag by one quarter period is negative in the first regime, implies the appreciation of domestic currency in a quarter followed by depreciation of the currency in the previous quarter period. The coefficient is significant in both regimes. After reaching the threshold value the coefficient becomes positive. The value of lag exchange rate return coefficient is -0.4902 in the first regime which increases upto 0.9685 in the second regime. The impact of domestic and foreign output gap on the exchange rate return is insignificant in both the regimes.

Results also shows that the impact of domestic inflation on the exchange rate returns is significant and is lagged by one quarter period. The coefficient is negative (-0.0041) in the first regime and changes its sign in the second regime (0.0083). The foreign inflation is also negatively associated with the exchange rate return in the first regime. The value of the coefficient of foreign inflation is -0.0109 and is significant in both regimes. The coefficient becomes positive in the second regime. Results also reveal that domestic lag interest rate has insignificant impact on the exchange rate in both regimes, while the impact of foreign interest rate on the exchange rate is significant in both regimes. The foreign interest rate is negatively associated with the exchange rate returns (coefficient equals to -0.0116, which changes its sign in the second regime).

Result also shows that real exchange rate is positively associated with the exchange rate return (nominal) and its cofficient increases from 0.5272 in the first regime to -1.0382 in the second regime.

Table 5. 4 1st order Logistic Heterogeneous STAR model estimations

Transition Variable	Δs_{t+1}	
Variables	**Linear Coefficients**	**Non-linear Coefficients**
Δs_{t+1} **(lag 1)**	-0.4902** (0.0326)	0.9685** (0.0249)
y_t	0.0004 (0.4866)	-0.0009 (0.4594)
y_t **(lag 1)**	-0.0002 (0.7121)	0.0005 (0.7362)
y_t*	0.0016 (0.1906)	-0.0032 (0.1687)
y_t* **lag1**	-0.0001 (0.9107)	8.42E-05 (0.9624)
Π_t	0.0025 (0.1960)	-0.0051 (0.1805)
Π_t **lag1**	-0.0041* (0.0791)	0.0083* (0.0681)
Π_t *	-0.0109* (0.0793)	0.0220* (0.0655)
Π_t * **lag1**	0.0089* (0.0612)	-0.0179** (0.0493)
i_{t-1}	0.0012 (0.1599)	-0.0024 (0.1559)
i_{t-1} **lag1**	0.0008 (0.2458)	-0.0017 (0.2190)
i_{t-1}*	-0.0116*** (0.0068)	0.0239*** (0.0027)
i_{t-1}* **lag1**	0.0103** (0.0115)	-0.0210*** (0.0057)
q_t	0.5272** (0.0261)	-1.0382** (0.0195)

q_t lag1	-0.6153** (0.0161)	1.2185** (0.0107)
Transition Parameter γ	5.0672*** (0.0002)	
Threshold extreme C	0.0089 (0.4884)	
R-squared	0.9995	

Note: P-values are written in the Parentheses.

5.3 Homogenous Taylor Rule Exchange rate STAR Model Estimations

Linearity test on the homogenous TR model (Table 5.5) also confirms the presence of non-linearity in the model due to exchange rate returns. Table 5.6 shows the estimated coefficients of the homogenous TR exchange rate model. The coefficients of lag exchange rate return and the output gap differential are found to be insignificant. The inflation differential lag by one quarter period has negative and significant impact on the exchange rate return in the first regime while coeffecient becomes positive in the second regime. The value of inflation differential coefficient is -0.0024 in the first regime and 0.0052 in the second regime.

The coefficient of interest rate differential is also significant in both regimes. The lag interest rate differential has positive impact on exchange rate in the first regime, implies that increase in the domestic interest rate relative to the foreign interest rate will cause the depreciation of domestic currency in the first regime. The higher domestic interest rate reduces the demand for domestic currency leaving the excess money supply in the economy and depreciation of domestic currency. The coefficient turns positive in the second regime.

Table 5. 5 Linearity Test on the Homogenous TR model

Transition Variable	H01	H02	H03	Model
Δs_{t+1}	0.0000***	0.0005***	0.0003***	1st order Logistic
$(y_t-y_t^*)$	0.5255	0.6083	0.7990	Linear
$(\pi_t-\pi_t^*)$	NA	NA	NA	NA
$(i_{t-1}-i_{t-1}^*)$	0.1331	0.2876	0.5663	Linear
q_t	NA	NA	NA	NA

Table 5. 6 1st order Logistic Homogenous STAR model estimations

Transition Variable	Δs_{t+1}	
Variables	**Linear Coefficients**	**Non-linear Coefficients**
Δs_{t+1} (lag 1)	-0.1757 (0.1607)	0.3752 (0.1378)
$(y_t-y_t^*)$	0.0007 (0.1336)	-0.0015 (0.1099)
$(y_t-y_t^*)$ lag1	-0.0001 (0.8413)	0.0001 (0.8787)
$(\pi_t-\pi_t^*)$	0.0010 (0.3137)	-0.0023 (0.2619)
$(\pi_t-\pi_t^*)$ lag1	-0.0024** (0.0292)	0.0052** (0.0205)
$(i_{t-1}-i_{t-1}^*)$	0.0011** (0.0295)	-0.0025** (0.0228)
$(i_{t-1}-i_{t-1}^*)$	0.0002	-0.0005

lag1	(0.6438)	(0.5751)
q_t	0.2086* (0.0987)	-0.4417* (0.0824)
q_t lag1	-0.2730** (0.0353)	0.5820** (0.0254)
Transition Parameter γ	6.6691*** (0.0000)	
Threshold extreme C	0.0247*** (0.0000)	
R-squared	0.9993	

Note: P-values are written in the Parentheses.

Table 5.6 also shows that the slope parameter (γ) is equal to 6.669 for homogenous exchange rate model. It implies that there is gradual transition from one regime to another regime. The threshold value is equal to 0.0247 (antilog value equals to 1.058).

5.4 Forecast Evaluation:

The out-of-sample forecasting power of these non-linear Taylor rule based exchange rate models is evaluated on the basis of RMSE, MAE and Theil's U coefficient. The predictive ability of these models is compared against the random walk model (with and without drift) which is taken as the standard benchmark in the exchange rate literature. Both the non-linear exchange rate model are re-estimated using the data up to the 2010Q4 and then forecast is generated for the remaining data from 2011Q1 to 2019Q4.

The out-of-sample forecast results for all the exchange rate models are given in Table 5.7, Table 5.8 and Table 5.9 which shows the RMSE, MAE and Thiel's U statistics values over different forecast horizon. The results reveal that both the non-linear Taylor rule exchange rate models outperform the random walk model as the RMSE and MAE of both the non-linear TR exchange rate models are less than the RMSE and MAE of the random walk benchmark at all the forecast horizons. Thiel's U statistics, which compares the RMSE of the proposed model with the RMSE of the benchmark model, also confirms the superior predictive ability of the homogenous and heterogeneous TR exchange rate model as compared to the random walk benchmark.

Table 5. 7 Root Mean Square Error (RMSE)

Forecast horizon	**1**	**6**	**12**	**18**	**24**	**30**	**36**
RW model with drift	1.053034	1.447393	2.043922	2.850412	2.544482	2.644998	5.001629
RW without drift	1.221310	1.394105	1.990999	2.894982	2.606906	2.656939	4.958701
Heterogeneous TR model	0.001356	0.004070	0.005922	0.005274	0.004572	0.005100	0.005430
Homogenous TR model	0.001086	0.002479	0.004859	0.004080	0.003541	0.003353	0.003962

Table 5. 8 Mean Absolute Error (MAE)

Forecast horizon	**1**	**6**	**12**	**18**	**24**	**30**	**36**
RW model with drift	0.903705	1.143479	1.403989	1.876046	1.711128	1.880959	2.881651
RW without drift	1.094613	1.140460	1.419013	1.919263	1.794144	1.944205	2.923496
Heterogeneous TR model	0.001319	0.002942	0.004112	0.003828	0.002941	0.003406	0.003619
Homogenous TR model	0.001001	0.001793	0.002581	0.002239	0.001770	0.001799	0.002203

Table 5. 9 Theil's-U Coefficient

Forecast Horizon	**1**	**6**	**12**	**18**	**24**	**30**	**36**
Benchmark RW with drift							
Heterogeneous TR model	0.001288	0.002812	0.002897	0.00185	0.001797	0.001928	0.001086
Homogenous TR model	0.001031	0.001713	0.002377	0.001431	0.001392	0.001268	0.000792
Benchmark RW without drift							
Heterogeneous TR model	0.00111	0.002919	0.002974	0.001822	0.001754	0.00192	0.001095
Homogenous TR model	0.000889	0.001778	0.00244	0.001409	0.001358	0.001262	0.000799

CHAPTER 6

CONCLUSION AND POLICY IMPLICATION

This study examined the role of the Taylor rule fundamentals in the determination of Pakistani Rupee-Us dollar exchange rate. This study also consider the non-linearities in the exchange rate model by empolying a non-linear Smooth Transition Autoregression (STAR) technique for modeling exchange rate over the period of 1982Q1-2019Q4. The stationary properties of the data is accessed through the Augmented Dickey Fuller (ADF) test and the findings show that all the variables are stationary at the level except the domestic interest rate (**i_{t-1}** **)**and the interest rate differential **(i_{t-1}-i_{t-1}*).** These variables become stationary at first difference, implies that the variables are integrated with order one.

The ARDL Bound test approach is conducted to check the long run relationship between the variables and the results confirm the presence of long run relationship between exchange rate and the Taylor rule fundamentals. For heterogeneous Taylor rule exchange rate model, the F-statistic value is 14.745 with lower bound value 2.17 and upper bound value 3.21 at 5% level of significance. For homogenous TR model, the F-stat value is 21.279 with lower bound 2.56 and upper bound 3.49 at 5% level of significance. After this linear estimations, the non-linear exchange rate model is estimated by Smooth Transition Auto regression methodology (STAR) which confirms the presence of non-linearity in the model. The linearity test conducted provide a strong evidence of non-linearity in the exchange rate model when exchange rate return is taken as a threshold variable. The results show that the 1^{st} order logistic STAR model is the most appropriate model for modeling the rupee-dollar exchange rate behaviour.

This study also evaluated the forecasting ability of the Taylor rule exchange rate model relative to the random walk benchmark over different forecast horizon. The forecasting ablility of the model is judged on the basis of RMSE, MAE and Theil's U coefficient. The RMSE and MAE has least values for both the specifications (heterogenous and homogenous) of the non-linear TR exchange rate model which implies that the TR exchange model has superior out-of-sample predictive ability relative to the random walk model. The Theils U coefficient values (which are less than 1 for homogenous and heterogenous TR exchange rate models) also confirm the better forecasting ability of the non-linear TR exchange rate model as compared to the random walk benchmark.

The following policy implications came out from the above analysis and results:

1. The Central bank and policy makers should consider the role of Taylor rule fundamentals in the formulation of the policies regarding exchange rate stability as the Taylor rule fundamentals are the key determinants of the exchange rate.
2. This analysis gives the strong evidence of non-linearity in the exchange rate model, therefore, the Central bank, researchers and policy makers should consider these non-linearities while modeling and forecasting the exchange rate behaviour.

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Appendix

Diagnostic results for non-linear Taylor rule Model

Model Transition Variable (Δs_{t+1})	Heterogeneous TR model	Homogenous TR model
Residual Analysis		
ARCH LM test	0.2327	0.5469
Normality Test (JB test)	0.0000***	0.0000***
Test for autocorrelation	0.0014***	0.0000***
Remaining Non-Linearity Test		
$\mathbf{H_{01}}$	0.0000***	0.0001***
$\mathbf{H_{02}}$	0.0000***	0.0000***
$\mathbf{H_{03}}$	0.0000***	0.0000***
$\mathbf{H_{04}}$	0.0000***	0.0000***
Parameter Constancy		
$\mathbf{H_{01}}$	0.0000***	0.0001***
$\mathbf{H_{02}}$	0.0000***	0.0000***
$\mathbf{H_{03}}$	0.0000***	0.0000***
$\mathbf{H_{04}}$	0.0000***	0.0000***