Non-Linear Mechanisms of Exchange Rate Pass Through into Inflation by Using Smooth Transition Regression Models

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بسم الله الرحمن الرحيم

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Submitted in the Partial Fulfillment of the
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A DISSERTATION SUBMITTED IN THE PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF THE MASTER OF SCIENCE IN STATISTICS

We accept this dissertation as conforming to the required standard.

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Syed Muhammad Shahid Ali Gilani

DECLARATION

I hereby declare that this thesis, neither as a whole nor a part of it, has been copied out from any source. It is further declared that I have prepared this dissertation entirely on the basis of my personal efforts made under the supervision of my supervisor **Dr. Irshad Ahmad Arshad**. No portion of the work, presented in this dissertation, has been submitted in the support of any application for any degree or qualification of this or any other learning institute.

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Table of Contents

List of Tables

List of Figures

List of Acronyms

ADF	Augmented Dicky Fuller
AIC	Akaike Information Criteria
ERPT	Exchange Rate Pass Through
STR	Smooth Transition Regression
CPI	Consumer Price Index
PKR	Pakistani Rupees
EA	Euro Area
IFS	International Financial Statistics
PSTR	Panel Smooth Transition Regression Model
OECD	Organisation for Economic Co-operation and Development
LSTR	Logistic Smooth Transition Regression
ECB	European Central Bank
ESTR	Exponential Smooth Transition Regression
ECB	European Central Bank
CBRT	Central Bank of Republic of Turkey
IMF	International Monetary Fund
ADI	African Development Indicators database.
GDP	Gross Domestic Product
SADC	South Asian Development Community
WDI	World Development Indicator
BIS	Bank of International Settlements
VAR	Vector Autoregressive Model
OLS	Ordinary Least Squares
CUSUM	Cumulative Sum
CUSUMQ	Cumulative Sum of Square
FPE	Final Prediction Error
HQIC	Hannan–Quinn Information Criterion
LR	Likelihood Ratio Test

Abstract

Exchange Rate Pass Through (ERPT) plays an important role in the formulation of monetary policy. The main objective of this study is to identify the transition variables causing nonlinearities in ERPT. In this thesis, we empirically studied the exchange rate pass through into inflation for Pakistan. Monthly data from 1980 to 2014 were obtained from the IMF's International Financial Statistics (IFS). Inflation Rate (Inf), Real Effective Exchange Rate (Exc), Real Interest Rate (R), Import Price (Imp), and Output Growth (G) are the variables used in this study. The technique of Smooth Transition Regression used for estimating the nonlinearities in Exchange Rate Pass Through (ERPT). All the variables in this study were stationary at first difference and Engle Granger test showed no co-integration among different time series. The suitable linear Auto Regressive (AR) model was selected by using Akaike Information Criteria (AIC), Hannan Quinn Information Criteria (HQIC) and Final Prediction Error (FPE) model selection criteria. The auxiliary equation is formed by using residuals of base line linear model and linearity is tested against STR non-linearity by using different lags of the time series variables as transition variables. Exponential smooth transition functional form is selected for real effective exchange rate and for the other three variables real interest rate, output growth and inflation the selected functional form is logistic smooth transition regression. After selecting the functional form nonlinear models are estimated for each of the transition variables. By using different criteria; R square, adjusted R square, akaike information criteria and standard error of regression, the study concludes that the smooth transition regression models can better explain the nonlinearities in the ERPT.

CHAPTER 1

INTRODUCTION

Exchange Rate Pass Through (ERPT) can be defined as percentage variation in domestic price as a result from one percent variation in exchange rate. ERPT is the measure of the extent to which the changes in the exchange rate can affect the price of imports. Variation in the price of imports affects the consumer prices and when ERPT is high then rate of transmission of the inflation is greater between importing and exporting countries.

Exchange rate is the value of one country`s currency computed with respect to another country`s currency. It is the rate at which a currency is exchanged for another currency. The reliability of exchange rate and its understanding is of much importance in making economic decisions. Interest rate, inflation rate, overall economic condition and political situation are some of the factors which can control exchange rate. When inflation rate is high for a country then exchange rate falls.

The degree to which changes in the exchange rate are imparted into prices is very important for policymakers. If a country stabilizes its monetary policy, then inflation decreases and as a result ERPT also decreases. The impact of exchange rate pass through is more significant for developing economies as it directly influences their monetary policy.

ERPT has been playing a very important role in the formulation of monetary policy. It is important to know the patterns according to which the changes in the past values of the exchange rate may affect the forecasted value of the inflation. So, the

proper knowledge of the extent of the pass through is very important for applying suitable monetary policy.

ERPT has been decreasing in the modernized countries due to low inflation regime (Camp & Goldberg, 2005). According to them during high periods of inflation, exchange rate changes are more likely to be passed through the import prices for those firms adopting volatile prices. According to Taylor (2000) it is not very easy for the firms to completely pass through the exchange rate fluctuations in the export prices, export goods because of the pressure of universal competition and stabilized inflation. Japan and U.S. are the example of this phenomena.

Import prices are, however, affected by exchange rate variations and as a result, inflation is also affected Bussiere (2006). Variations in the exchange rate may have direct and indirect effects on domestic prices. In direct medium a decrease in the exchange rate may increase the price of imports. While in indirect medium decrease in the exchange rate results in the decrease in the price of exports. As a result, demand of the exports increases and this induces an increase in the domestic price level.

Goldberg (1995) Mahdavi (2002), and others found different types of nonlinearities, mostly related to the changes in exchange rate. Pollard and Coughlin (2004) found that existing studies on exchange rate pass through mostly focused on testing for nonlinearities in the size and direction of exchange rate variations and ignoring different other potential causes of nonlinearities.

Exchange Rate Pass Through (ERPT) nonlinearities issue is getting more attention these days. New tools and techniques have been used to attain accuracy and precision. Now a days research has been carried out for observing nonlinearities in ERPT into inflation. There are several studies including (Nogueira Junior and León-

Ledesma (2010), Junttila and Korhonen (2012), Cheikh (2012)) that have proved nonlinearities for developing and developed countries by using technique of Smooth Transition Regression.

This study has discussed the impacts of nonlinearities in the exchange rate pass through on the economy of Pakistan and empirically analysed the monthly data from the period 1980 to 2014. STR model was used in the analysis to capture nonlinearities in the ERPT. The variables included in the study are; CPI inflation, real interest rate, real effective exchange rate, import prices (PKR) and output growth.

1.1 Objectives of the Study

The main objectives of this study are;

- To evaluate the influence of exchange rate on the prices of Pakistan.
- To measure Exchange Rate Pass Through (ERPT) by using smooth transition regression model.
- To identify the transition variables responsible for nonlinearities in ERPT.

ERPT plays an important role in the formulation of monetary policy. Successful monetary policy plays an important role to stabilize the economy. Hence the role of ERPT is immense and for successful monetary policy accurate knowledge about the determinant of the ERPT is required. Several studies available in literature focussing the relationship of exchange rate on inflation, ignoring some potential variables which may significantly affect the behaviour of ERPT. Hence the application of STR regression to estimate nonlinearities in the ERPT may have significant contribution to the literature.

1.2 Organization of the Study

The rest of the thesis is organized as follows. Chapter 2 consists of the literature related to the present study. The summary of the past researches is described in this chapter. Chapter 3 is related to the data description and methodology adopted in this study. Chapter 4 comprises of the findings and results of the analysis and in the final chapter summary of the findings and recommendations for the further research is given.

CHAPTER 2

REVIEW OF LITERATURE

The degree to which changes in the exchange rate are imparted into prices is very important for policymakers. The impacts of exchange rate pass through are more significant for developing economies as it directly influences their monetary policy. There are many studies that investigated the nonlinearities in exchange rate pass through for developing and developed economies. Some of them are described as follows.

Thanh (2015) conducted a study to check that the relationship between economic growth and inflation was nonlinear. Panel data was used for ASEAN-5 countries for the period 1980-2011. The group contained Malaysia, Indonesia, Vietnam, Thailand and Philippines. The data were obtained from Economy Watch and Penn World Table. Panel smooth transition regression was employed to estimate threshold value and its impacts on economic growth. The study revealed that a significant relation existed between inflation and growth over a threshold value of 7.8%. The results of study strongly proved that inflation and growth have nonlinear relationship. The study also suggested that the central bank might consider this threshold value for inflation targeting to maintain economic stability.

Cheikh (2012) used quarterly data from 1975 to 2010 to investigate possible nonlinearities in 12 EA countries using smooth transition models as an analysis tool. The study found that in some countries ERPT was greater for depreciation as compared to the appreciation. In some other countries, opposite results were observed. The study

also found that CPI inflation was higher for large changes in exchange rate as compared to small changes.

Aleem and Lahiani (2014) examined the response of consumer prices to the exchange rate for Mexico by using Threshold Vector Auto regression model. Using monthly data from the period January 1994 to November 2009 they found strong evidence of nonlinearities. The study found that domestic prices in Mexico exhibit very strong relation to positive exchange rate shock only over the threshold level of inflation rate. The study suggested that the central bank of Mexico must keep inflation under 9.48 % so that exchange rate shocks may not be transmitted to domestic prices. As long as the annual inflation rate was less than 9.84% inflation response to changes in the exchange rate would be insignificant.

Shintani *et al.* (2009) investigated the relation between inflation and ERPT by using nonlinear time series model. Monthly data was used from January 1975 to December 2007 obtained from International Financial Statistics (IFS). The study showed that STAR models were the most suitable models for nonlinear data. The study provided a very convenient foundation for investigating the relationship between inflation and ERPT. The study concluded that ERPT dynamics could be studied by STR models by using inflation as transition variable. When that procedure was applied to US domestic price and import price data, the evidence of nonlinearities was found in inflation dynamics. The results of the study revealed that when inflation was low ERPT was low.

Vinayagathasan (2013) investigated threshold inflation level and how they affected economies of Asian countries. The dynamic panel threshold regression was used for analysis. The study observed that there was a nonlinear relationship between

economic growth and inflation for 32 countries from Asia for the period from 1980-2009. Inflation threshold value was found to be 5.43 % at the 1 % level of significance. The study suggested that inflation had a harmful effect when it would be above threshold level otherwise it had no effect. The study also proved the robustness of inflation on growth by using different estimation methods. It was also found that investment ratio increased economic growth.

Ibarra and Trupkin (2011) investigated inflation threshold for a set of countries over which it had a negative effect on economic growth. Panel smooth transition regression model (PSTR) was applied to the set of 124 countries using data set from 1950 to 2007. The countries were classified into two groups, one group is of industrialized and other is of non-industrialized countries. The relationship between economic growth and inflation was estimated by using Smooth Transition Regression Model (STR). Besides threshold, they also found slope for the functions relating one regime to another. The study proved that relationship between growth and inflation was nonlinear. The threshold value of inflation was observed 4.1% in industrialized countries and 19.1 % in non-industrialized countries. For first group speed of transition was smooth while for second group it was rapid. The study also concluded that threshold inflation value decreased for those countries that attained institutional quality.

Junttila and Korhonen (2012) analyzed exchange rate pass through (ERPT) to total import prices of nine OECD countries. Quarterly data was used in the study obtained from OECD Main Economic Indicators database. The main variables were the nominal effective exchange rate, consumer prices and consumer price index. The data were in log form. All variables were price indices measured in local currencies. The study concluded that ERPT was affected by inflationary environment. The study also concluded that there was direct relationship between ERPT and inflation. When

inflation was high ERPT was also high and when inflation was low ERPT was also low. Same conclusions were same for both large and small countries.

Belke *et al.* (2014) conducted a study in 6 Euro Area countries using the quarterly data from the period 1980 to 2012. Data on real domestic demand and exports was obtained from national statistical offices and for foreign demand and exchange rate data was taken from the ECB. The smooth transition regression technique was applied for analyzing the data in the study. The study concluded that lags of domestic demand had negative effects on the export performance of the countries. The study found that the relationship between exports and domestic demand was significantly nonlinear. For Italy, Spain and Portugal ESTR proved to be a better choice while in Ireland and Greece better results were obtained by using LSTR models. The study also concluded that export performance in the long terms was linked with price developments.

Sahin (2013) used smooth transition regression models (STR) for the estimation of money demand function. Monthly data was used from the period January 1990 to May 2012 obtained from Central Bank of Republic of Turkey (CBRT). The variables included in the study were money demand, interest rate, exchange rate, industrial production, and inflation uncertainty. The study estimated the money demand function for Turkish economy by using inflation uncertainty as a transition variable in the analysis. The parameters of the model were estimated by using STR technique, by modelling non linearity suitable logistic function was determined. The study proved the nonlinear behaviour of money demand function during low and high inflation regimes.

Geng and Zhai (2015) empirically analyzed quarterly data from the period 2007 to 2012 obtained from Chinese bank. Panel smooth transition regression technique was applied for investigating the effects of interest rate on bank risk. The

nonlinear relationship was observed between instruments of monetary policy and bank risk. The transition variable used in the study was interest rate. The study observed that for a low regime interest rate had a positive relationship to bank risk and negative effect of high regime.

Cheikh and Rault (2016) investigated if exchange rate pass-through into import prices was nonlinear for Euro Area countries. The countries included in the study were Spain, Ireland, Portugal, Italy and Greece. The study investigated whether uncertainty in the macroeconomic behaviour effected pass through in nonlinear way. LSTR model was applied for the analysis purposes. Monthly data was used for the period 1993 to 2012. All variables were obtained from the OECD data base where as data on exchange rate was taken from International Financial Statistics (IFS). The analysis concluded that ERPT was higher during the periods of macroeconomic confidence crisis.

Eyden *et al.* (2013) investigated the relationship between inflation and growth in Africa. Multiple regime smooth transition regression technique was applied for the analysis. The annual data was used for a group of 10 African countries for the period 1980 to 2009.The main indicators in the study were inflation, GDP growth and output growth. Data for all variables was obtained from African Development Indicators (ADI) database. First lag of inflation was used as a transition variable in the study. The nonlinearity was observed for the transition variable inflation. The study proved that for different regimes inflation-growth relationship showed different dynamics. The two threshold values for the model were 9% and 30% respectively. The study concluded that inflation of about 9 % was less harmful for the economies of the countries in the group.

Espinoza *et al.* (2010) investigated the relationship between inflation and growth by using the smooth transition technique. Panel data for a set of 165 countries was used from 1969-2007.The smooth transition regression was applied to find the threshold for inflation above which it had a negative effect on the growth. The observed threshold value was 10 % for the developing countries. For advanced countries threshold value was found to be very low. The study found threshold of 10 % for oil exporting countries.

Mohanty *et al.* (2011) conducted an empirical study to investigate the inflation threshold for India. The relationship between inflation rate and real GDP growth of India was analysed in the study. Quarterly data was used in the study for the period 1996-97 to 2010-11. Three different methods, including smooth transition regression models were used for the analysis of data. The study observed that there existed a significant relationship between inflation and growth. The inflation threshold value was found to be 5.5 %. The study provided the evidence of regime shift at 5.5 %. Inflation had a positive effect on growth up to 5.5 % and beyond the threshold effect of inflation was negative.

Routh (2014) applied different time series models to capture different dynamics of inflation. The study was conducted on monthly data for the period 1990 to 2009. The study observed that the dynamics of the inflation were nonlinear for different regimes of inflation. Smooth transition technique was used to model transition between different regimes. The autoregressive and exogenous variable as transition variables were used in the analysis. Both the exogenous and autoregressive transition models successfully modelled inflation. Different tests proved that smooth transition models were better than the linear models.

Aslanidis and Christiansen (2012) analyzed the stock bond correlation. The data were recorded at a weekly frequency for the period from 1986 to 2009. The smooth transition regression technique was used to study the changes between different regimes. Different financial and economic transition variables were used in the analysis. The study proved that STR models with many transition variables were better than models with single transition variable. The study also concluded that yield spread, short rate and VIX were among the most important transition variables.

Cengiz and Sahin (2013) applied smooth transition regression models to the data of Turkish labour force participation rates. Quarterly data was used from the first quarter of 2000 to fourth quarter of 2011.The data were obtained from Turkish Statistics Institute. The study analyzed the dynamics of rates of participation in terms of gender difference. The smoothness parameter showed a steady change for two regimes. The study found it higher for female workers as compared to the male workers. Rates of participation decreased during recession period and smoothly increased during expansion periods.

Seleteng *et al.* (2013) studied the relationship between inflation and growth for South Asian Development Community (SADC) region countries. This organization is a group of 14 countries. The yearly data was obtained from different sources like International Financial Statistics (IFS) and World Development Indicator (WDI) for the period 1980 to 2008. In the study, they investigated the relationship between inflation and growth by using smooth transition regression models. Threshold level of inflation was found endogenously. The study also found the smoothness parameter for the linkage of high and low inflation regime. The nonlinear relationship was observed between inflation and growth. The estimated threshold level for Africa was found to be

4 %, while for other countries threshold level was higher. 18.9 % was the estimated threshold level for SADC region countries.

Villavicencio (2008) conducted a study to analyze the nonlinearities in exchange rate. The study empirically analyzed data on the real effective exchange rate for a group of 14 countries including UK, USA, Norway, Mexico, Turkey, Indonesia, Japan, Korea, Mexico, India, Eurozone, Brazil, Argentina and Australia. Monthly data for the period 1980 to 2005 was used. The robust tests were applied for checking linearity and found the evidence in 9 out of 14 countries. The results of the study suggested that even if the real exchange rate was analyzed by using nonlinear models, outliers in the data could lead to misleading results. The situation could be worse if outliers were in transition variable. The LSTR model was found better for analyzing the data. The study concluded that for advanced countries speed of transition was slower as compared to the developing countries.

Duarte *et al.* (2013) investigated the relationship between water use and income for a group of 65 countries. The dataset was used for the period 1960 to 2008. Different techniques like fixed effect models, panel smooth transition models, late panel smooth transition regression were used for analysis. The results of different techniques suggested the robustness of the results. The nonlinear relationship was observed between water use and per capita income. The study observed that there was an increase in water usage for lower income groups and for higher income groups the level decreased. The value of smoothness parameter was observed slow between different regimes.

Nogueira Junior (2010) examined the impact of inflation on ERPT for Brazil. The data was obtained from IFS data base. Quarterly data were used from 1995 to 2007.

All the data used in the analysis is in the log form. The data was empirically analyzed by using he smooth transition regression technique. LSTR model was used for analyzing the data. All the variables used in the analysis were in the log form. Different lags of the inflation are used as the transition variables. The study concluded that ERPT can be controlled by using a reliable monetary policy. It was also demonstrated that stabilized inflation results in low ERPT

Mohammad *et al.* (2015) studied the nonlinearities in the exchange rate. Monthly data was used in the study for the time period of 1994 to 2015.The data was obtained from the Bank of International settlements (BIS). LSTR and ESTR models were used to observe nonlinearities in the ERPT. The null hypothesis of linearity was rejected against the alternative of nonlinearity. The study concluded that nonlinear models are better for explaining the nonlinearities in ERPT.

Tayyab *et al.* (2012) applied smooth transition auto regression model to measure the real exchange rate changes. Monthly data was used from 1980 to 2010. The study investigated by applying different tests that series was nonlinear. Taylor approximation was applied to decide between LSTR and ESTR. The transition variables were used up to three lags. The study found that ESTR was better for modelling exchange rate.

Gnimassoun and Mingnon (2015) investigated the relationship between exchange rate and current account imbalances. Panel data for a set of 22 countries was used. Two groups were included in the study. First group consisted of 11 Euro zone members and second group of 11 non-Euro zone members. Monthly data were used from 1980 to 2011. Panel Smooth Transition regression model was used for the analysis. Linearity was rejected against STR nonlinearity. The study found that in Euro

zone member countries the threshold was 11 % for transition between different regimes and for non-Euro zone it was found to be 14 %.

Zorzi et al. (2007) observed the impact of ERPT into prices in 12 different countries. Monthly data on the variables included in the study was used up to 2007. These countries were taken from Asia, Eastern Europe and Latin America. The technique of Vector Autoregressive Model was applied. The study disproved the concept that ERPT into consumer price is higher in developing countries as compared to the developed countries. The study also found the positive relationship between ERPT and inflation.

Masha and Park (2012) examined the effect of ERPT into prices for Maldives. Quarterly data obtained from the IMF resources was used in the study. The model was examined by using the nonparametric techniques. The recursive VAR model was also used for measuring the price changes. It was concluded from the results of nonparametric test that ERPT to prices is very high as compared to the other countries. The study also empirically investigated that ERPT is significant and its impact influences the second year.

Fatai and Akinbobola (2015) investigated the impact of ERPT to prices of imports for Nigeria. The secondary data was used in the study. The annual data were obtained from the IFS and WDI for the time period of 1986 to 2012.The technique of VAR model was used for the analysis of data. Based on the analysis of the data they concluded that ERPT for the above mentioned time period was significant and moderate. The study suggested that ERPT had important implications for the policy makers for making the monetary policy.

Maka (2003) studied asymmetries in the CPI inflation to exchange rate changes in Ghana. Monthly data was used for the time period from 1990 to 2011 obtained from IFS and Ghana statistical service. The study examined both the symmetric and non-symmetric ERPT. The study observed that ERPT has no effect on the pass through. It was also concluded that during the time of raising inflation CPI inflation pass through strongly to the output growth as compared to the periods of low inflation.

Kilic (2010) studied the relationship between ERPT and inflation. Nonlinear time series analysis was conducted using STR model. Quarterly data from 1975 to 2009 was used. Data for the group of OECD countries was obtained from International Financial Statistics (IFS). The lags of different variables were used as transition variables for nonlinear modelling of the data. The study observed in all the countries the complete pass through for the inflation value above the threshold level. On the contrary, to this it was found in the study that pass through was incomplete for the countries when inflation was less than the threshold level. The study observed the nonlinearities in the modelling changes in the exchange rate and import prices.

Khemiri and Ali (2012) investigated the effect of exchange rate pass through into inflation for Tunasia. Monthly data was used for the time period from 2001 to 2009. The data were obtained from IFS. The Markov- Switching approach was applied for the analysis of the data. The study proposed two regimes for the inflation. A regime of low inflation results in low ERPT and high inflation results in low ERPT. The study showed that as interest rate increases, then level of price increases.

Nogueira and Ledesma (2010) studied the relationship between ERPT and consumer prices. Monthly data was used for Mexico for the time period of 1992 to 2005. Data was obtained from the IFS database. The study assumed that in that ERPT

into prices is nonlinear. It was also assumed that ERPT may tend to increase during the period of financial crisis. The LSTR model was applied to investigate the hypothesis of the study. The study concluded that ERPT rises during the period of macroeconomic instability. The study also concluded that stable economy is required for the reduction of ERPT.

Fahmy (2014) examined nonlinearities in pricing using the smooth transition regression models. The lags of the dependant variables and the exogenous variables were used as the transition variables for the analysis purpose. The study concluded that oil prices and the rate of inflation were the most suitable transition variables which could model the nonlinearities in the best way.

Arabaci and Ozdemir (2010) studied ERPT into inflation in three countries Israel Mexico and Turkey. Monthly data was used from 1990 to 2010. The data was empirically analyzed by using smooth transition regression model. The study concluded that ERPT diminishes as inflation decreases. As the macroeconomic environment becomes stabilized ERPT becomes weaker. The study observed LSTR type nonlinearities in modelling ERPT.

Monge and Rodriguez (2010) applied LSTR model to examine nonlinearities in inflation for Costa Rica. The monthly data was used for the period 1991 to 2009. The lag of oil prices was selected as transition variable. The study concluded that if the transition variable goes above the threshold point pass through becomes two times. The positive or negative signs did not have any significant effects.

The main focus of the study is on the nonlinearities in the exchange rate. To achieve the objective of the study beside the exchange rate, other transition variables also considered that may have significant role in the nonlinearities. Most studies

conducted in the past to measure the impact of exchange rate on the inflation have ignored some important variables which have potential impacts on the exchange rate pass through.

CHAPTER 3

MATERIALS AND METHODS

3.1 Data Source

In this study, we used the secondary data obtained from International Monetary Fund (IMF) 's database International Financial Statistics (IFS) (http://data.imf.org). Monthly data were used from January 1980 to December 2014.

3.1.1 Variables and Specification

The variables used in the study are; real effective exchange rate, inflation rate, import prices, real interest rate and output growth.

Inflation is defined as a decrease in purchasing power which is due to an increase in the price of goods and services. According to Terra (2015) Inflation rate (Inf) is the percentage change in the Consumer Price Index (CPI) over a time period.

$$Inf = \left(\frac{current\ CPI - previous\ CPI}{current\ CPI}\right) * 100$$

"Real effective exchange rate index (Exc) gives the relative strength of a currency relative to the basket of other currencies".

Import prices (Imp) are unit value of imports in Pak Rupees (PKR). According to Fisher (1930) Real Interest Rate (R) is obtained by using Fisher s equation i.e.

$$R = \quad nominal\ interest\ rate - inflation\ rate$$

"Output growth (G) is the quantity of goods and services produced in a given period of time by a firm, industry or a country." The growth rate of the large-scale

manufacturing index based (2010) is used as a proxy variable for the output growth (G).

3.1.2 Model Specification

We used the model analogous to the model that has been used by Goldberg and Campa (2005) Choudhri and Hakura (2006) and Gagnon and Ihrig (2004). The model incorporating LSTR and ESTR nonlinearities has the following form.

$$Inf = \beta_0 + \sum_{i=1}^{n} \beta_{1,i}\, Inf_{t-i} + \sum_{i=0}^{n} \beta_{2,i}\, Exc_{t-i} + \sum_{i=0}^{n} \beta_{3,i}\, G_{t-i} + \sum_{i=0}^{n} \beta_{4,i}\, Imp_{t-i} + \sum_{i=0}^{n} \beta_{5,i}\, R_{t-i} + (\beta_0^* + \sum_{i=0}^{n} \beta_{2\,i}^*\, Exc_{t-i})\, G\,(S_t, \gamma, c) + \epsilon_t$$

Inf_t =Inflation rate Exc_t = real effective exchange rate G_t= output growth

Imp_t= import price R_t= real interest rate G = transition function

S_t= transition variable γ = speed of transition c = threshold value for transition function

3.2 Methods and Techniques

The following statistical techniques have been used to achieve the objectives of the study.

3.2.1 Smooth Transition Regression Model

Smooth Transition Regression (STR) models were introduced by Tong and Lim (1986). STR models are considered as the extension of Auto Regressive (AR) models. They are applied to the time series data and allow more flexibility in the parameters through smooth transition.

STR model for a time series is suitable for understanding the behaviour of the time series changes depending on the transition variable values. The transition variable may be the lag of the dependant variable or exogenous variable.

The composition of STR models is such that two autoregressive models are linked through the transition function.

A smooth transition regression model can generally be described as a weighted average of two linear models. The weights are obtained from the values of transition function. The general form of the STR model is as follows

$$y_t = \beta_0 x_t + \beta_1 x_t \, . \, \mathrm{G}\,(s_{t-i}, \gamma, \mathrm{c}) + \mu_t$$

Here G is transition function, s_{t-i} denotes transition variable, γ measures speed of transition between two regimes and c is the threshold value for transition function.

The transition function G can be of two types Either Logistic Smooth Transition Regression (LSTR) or Exponential Smooth Transition Regression (ESTR).

3.2.2 Logistic Smooth Transition Regression (LSTR)

General form of LSTR is

$$\mathrm{G}\,(s_{t-1}, \gamma, \mathrm{c}) = (1 + \exp\{-\gamma\,(s_{t-i} - c)\})^{-1}$$

Nogueira and Leon-Ledesma (2008) explained that the value of parameter c is taken as threshold between two regimes. The nonlinear coefficient of LSTR model depends on threshold value c of the transition variable. The value of c will be either above or below that level. When $s_t - c$ approaches -∞, G $(s_t - c)$ →0 and the

coefficient will be β_0 and when $s_t - c$ approaches $+\infty$ then G $(s_t - c) \rightarrow 1$ the coefficient of the function becomes $\beta_0 + \beta_1$ and if $s_t = c$ it will be $\frac{\beta_0 + \beta_1}{2}$.

3.2.3 Exponential Smooth Transition Regression (ESTR)

The general form for ESTR is

$$G(s_{t-1}, \gamma, c) = 1 + \exp\{-\gamma (s_{t-i} - c)^2\}$$

If the specification is ESTR then changes in the value of the coefficient depend on whether the transition variable is near or far from threshold value. The inflation coefficient will be $\beta_0 + \beta_1$ when $s_t - c$ approaches $\pm\infty$ and the coefficient becomes β_0 when $s_t = c$.

3.2.4 Model Building Strategy

In constructing STR model first linear autoregressive model is estimated to determine lag order p. The model is selected with lowest AIC and highest adjusted R square. This model is also checked for autocorrelation, heteroscedasticity, and the normality of residuals. This is used as a baseline linear model in the estimation and evaluation of nonlinear model.

Apply OLS to the selected autoregressive model and obtain residuals. Then make a structural equation as

$$\epsilon_t = \alpha_0 + \alpha_1 w_{t-i} + \alpha_2 w_{t-i} s_t + \alpha_3 w_{t-i} st^2 + \alpha_4 w_{t-i} st^3$$

Where w_{t-i} is vector of explanatory variables and s_t is transition variables.

The null hypothesis for testing linearity against LSTR and ESTR are as follows:

1. $\alpha_2 = \alpha_4 = 0$ which is an LM test (LM2)

2. $\propto_1 = \propto_3 = 0$ which is an LM test (LM3)

Strength of rejection of the hypothesis is compared. If the p value is minimum corresponding to LM3 choose LSTR otherwise ESTR.

3.2.5 Non-Linear Least Square

After establishing the suitable form of the STR models the parameters of the models are estimated by Non-Linear Least Square (NLLS) applying Gauss-Newton and Marquardt algorithm.

Non-linear least square is the form of least square analysis used to fit a set of m observations with a model that is non-linear in n unknown parameters (m > n). It is used in some forms of nonlinear regression. The basis of the method is to approximate the model by a linear one and to refine the parameters by successive iterations.

3.3 Stationarity

A time series is called stationary if its statistical properties, i.e. mean, variance and covariance do not vary over time. Most of the statistical analysis tools require the assumption of the stationarity of the time series data. Prediction is easy for the series in a standardized form that the statistical properties in the past and future will remain unchanged.

We have also standardized the time series to obtain reliable statistics. These standardized values are valid only for the stationary data. If a series continue to increase the sample properties like mean, variance, etc. also continue to increase over time.

Because of the unpredictability and nonstationary time series data cannot modelled. By the analysis of nonstationary data, we obtain spurious results. To obtain reliable and consistent results non-stationary data should be transformed into stationary

process. Unlike non-stationary data stationary process bears constant mean and variance over time.

3.3.1 Augmented Dicky Fuller Test

Dickey and Fuller (1979) proposed a test to check the stationarity of the series. This is most widely used test for checking the stationarity of the time series data. Suppose we have time series Z_1, Z_2 , Z_3 ... Z_n. The equation used for this test may have the following form.

Without intercept and trend

$$\Delta Z_t = \rho\, Z_{t-i} + \sum_{i=1}^{n} \omega_i\, \Delta Z_{t-i} + \epsilon_{it} \qquad (1)$$

With intercept

$$\Delta Z_t = \delta + \rho\, Z_{t-i} + \sum_{i=1}^{n} \omega_i\, \Delta Z_{t-i} + \epsilon_{it} \qquad (2)$$

With intercept and trend

$$\Delta Z_t = \delta + \eta_t + \rho\, Z_{t-i} + \sum_{i=1}^{n} \omega_i\, \Delta Z_{t-i} + \epsilon_{it} \qquad (3)$$

The procedure for testing stationarity is same for the above the three cases, but probability values are different. The null hypothesis for testing is H_o: $\rho = 0$ (Series has unit root and is non-stationary) and the alternative hypothesis is H_a: $\rho \neq 0$ or $\rho < 0$ it means no unit root and series is stationary. The decision for the acceptance and rejection is based on t-statistics. If the p value is less than α than reject the null of non-stationarity and accept otherwise.

3.4 Co-integration

We observe co-integration for testing and estimation of stationarity of linear relationship of different time series which are stationary at same difference. In a co-

integration analysis, linear relationship of nonstationary variables is tested and evaluated. We can say that there is integration between different non-stationary time series if they all are stationary at same order and stationarity is observed in the linear relationship of time series. Co-integration means the long run relationship between different time series variables. In the case if the different time series have long term trend, then the results obtained from the regression may be spurious.

Engle Granger (1987) proposed a test for checking the co integration in the long run relationship. This is a very simple test for co integration. The Engle Granger test is a two-step procedure for the testing of co integration. Residual based test of Engle Granger requires that all variables are stationary at same order. In this test regression is applied to the time series variables and residuals are obtained. In the next step the stationary of the residuals is checked. If the test confirms stationarity of the residuals, then there is co integration among the variables.

In Engle Granger test m-lag augmented regression is estimated

$$\Delta\widehat{V_{1t}} = (\rho\text{-}1)\,\widehat{V}_{1_{t-1}} + \sum_{i=1}^{m} \phi_j\, \Delta\, \widehat{V}_{1_{t-i}} + \epsilon_t$$

Two ADF test statistics are used to test the null hypothesis of stationarity. One is based on t-statistic and the null hypothesis is (ρ=1). The other statistic is based on normalized autocorrelation coefficient ($\hat{\rho}$-1)

$$\hat{\tau} = \frac{\hat{\rho}-1}{se\,(\widehat{\rho})}$$

$$z = \frac{T(\hat{\rho}-1)}{(1-\sum_j \widehat{\rho_j})}$$

3.5 Stability Test

The stability of the coefficients of the model is checked by using the CUSUM test for the entire period. This test was developed by Brown *et al.* (1975). The stability of the regression coefficients in CUSUM and CUSUMQ is assumed under the null hypothesis. In this test values of the cumulative sum are plotted along 5 % critical limits. If the values of the cumulative sum go beyond the limits, then it is concluded that the coefficients of the parameters are unstable.

The test statistic for the CUSUM test is given by

$$A_t \quad = \quad \sum_{b=r+1}^{t} \propto_b /s$$

Where t = r+1…T, α is the recursive residual. Standard deviation of the residual as is denoted by s. If the β vector does not vary from time to time and remains constant, then E ($\propto_o$) = 0 and if the vector β changes over time then A_t will diverge from zero average line. The 5 % confidence interval measure the significance departures from the mean line which is given by $[b, \pm -0.948(T-r)^{1/2)}]$ and $[T, \pm 3 * 0.948(T-r)^{1/2)}]$.The outside movement of the A_t from the critical lines show the instability of the coefficients.

3.6 Jarque-Bera Test for Normality

Jarque and Bera (1987) proposed a test to check the normality. This is basically a test for the goodness of fit. It checks the possibility that the data follow normal distribution. The test statistic follows the chi square distribution.

$$\text{JB} = \frac{N}{6}\left[(skew)^2 + (kurt-3)^2/4\right]$$

CHAPTER 4

RESULTS AND DISCUSSIONS

In this chapter, we have provided the results of data analysis. The data was collected and then analysed to meet the objectives of the study. The main objective was to identify the transition variables responsible for nonlinearities in ERPT. Data was analysed for measuring the nonlinearities in the ERPT by using Smooth Transition Regression (STR) models. EViews 9 software was used for the analysis of data.

4.1 Descriptive Statistics

In descriptive statistics, the summary of the basic features of the data are given. This is the first step in the quantitative analysis of the data. The following table provides mean, median, standard deviation and the other useful descriptive statistics.

Table 4.1 Descriptive Statistics of Variables

	Real Effective Exchange rate	Goods, value of Import	CPI inflation Rate	Real Interest rate	Output growth
Mean	126.7	9.33e+10	45.7	8.69	58.27
Median	111.9	3.66e+10	37.2	8.90	48.64
Maximum	245.8	4.65e+11	144.9	20.03	127.5
Minimum	89.7	3.48e+09	8.46	0.74	13.92
Std. Dev.	39.7	1.19e+11	37.0	3.10	31.63
Skewness	1.4	1.429939	1.19	0.06	0.51
Kurtosis	3.5	3.747272	3.41	3.54	1.92

From the above given statistics mean and median of the any of the five variables are not same, their skewness is not close to zero and kurtosis is not close to 3. Hence the series are not distributed normally.

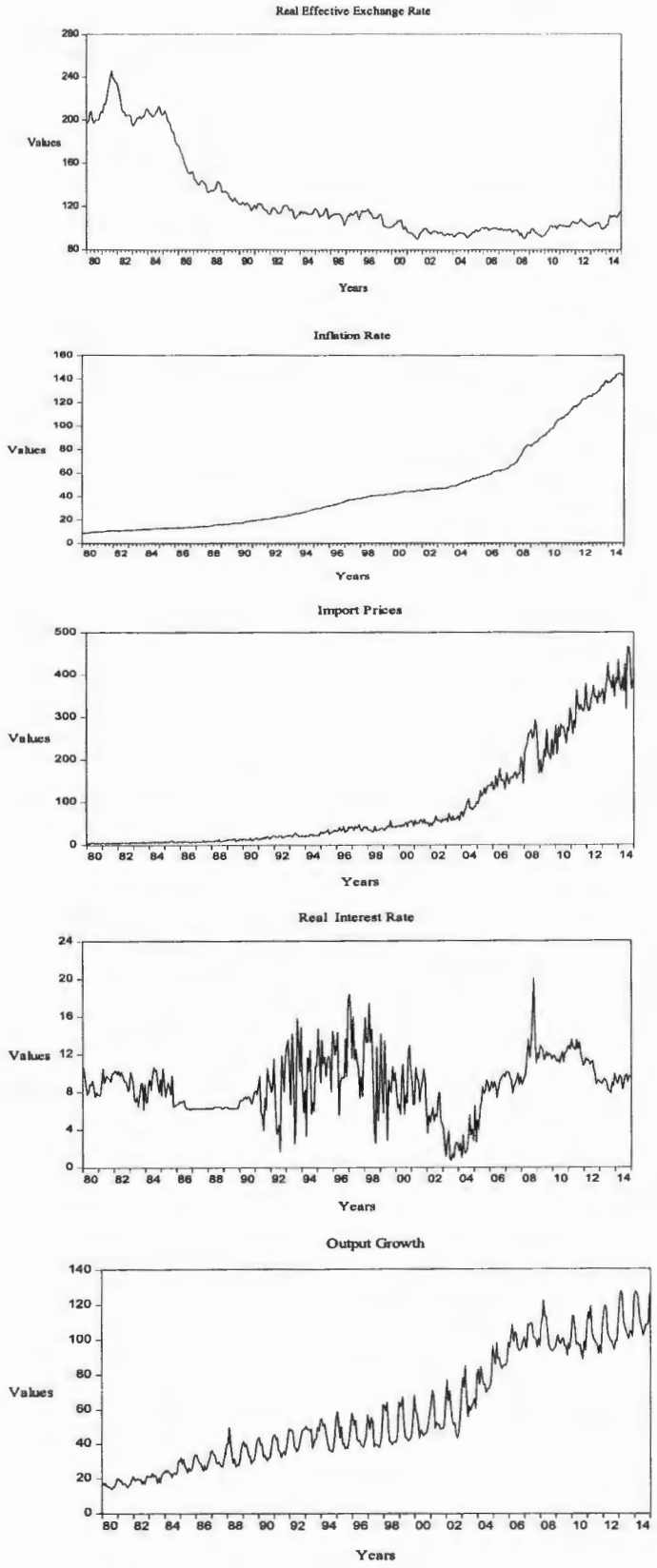

Figure 4.1: Trends of Variables at Level

From the graphs of the variables, it is observed that the variable, real effective exchange rate has decreasing trend and the variables, inflation rate, import prices, and import price show increasing trend. The variable real interest rate may be stationary.

4.2 Stationarity of Variables at level

The basic step in time series analysis is to check, whether the series is stationary or not. By stationary series, we mean a series whose basic statistical properties such as mean, variance autocorrelation is constant over time. Mostly statistical methods are built on the assumption that the time series is stationary. For checking stationarity of the series, we use Augmented Dickey-Fuller Test. The results of the ADF test are displayed in table 4.1, t-statistic and p-value are given. Based on the outputs of the test we see that time series are not stationary at level.

Table 4.2: Stationarity of Series at Level

Variable	Augmented Dickey-Fuller Test Statistics at Level			
	Intercept		Intercept and Trend	
	t-statistic	p-value	t-statistic	p-value
Exc	-2.0694	0.2574	-0.5063	0.9830
Inf	-3.0256	0.0334	-3.0509	0.1198
Imp	0.1684	0.9703	-2.5293	0.3137
R	-4.6059	0.0001	-4.6369	0.0010
G	-2.0659	0.2588	-1.6418	0.7748

4.3 Descriptive Statistics of Variables at Log First Difference

Since trends have been observed and the series are non-stationary at level we take the log of the series and first difference and observe the descriptive statistics and trends of the series.

Table 4.3: Descriptive Statistics of Series at Log Difference

Descriptive	Real Effective Exchange rate	Goods, Value of Imports	CPI Inflation Rate	Real Interest Rate	Output growth
Mean	-0.001	0.010	0.002	2.12	0.004
Median	-0.0008	0.015	0.009	2.21	0.000
Maximum	0.052	0.426	1.311	2.94	0.353
Minimum	-0.063	-0.530	-1.553	-1.11	-0.33
Std. Dev.	0.017	0.144	0.365	0.44	0.09
Skewness	-0.011	-0.003	-0.017	0.09	0.017
Kurtosis	2.845	2.644	3.45	2.5587	2.237

From the table, we observe that mean and median of the series are approximately same and skewness is close to zero and kurtosis is close to 3. Therefore, we conclude that series are normally distributed.

4.4 Stationarity of Variables at First Difference

Stationarity of the variables is checked at first difference and results of the test are given in the table below.

Table 4.4: Stationarity of Series at First Difference

Variable	Augmented Dickey-Fuller Test Statistics at First Difference			
	Intercept		Intercept and Trend	
	t-statistic	p-value	t-statistic	p-value
Exc	-13.9703	0.0000	-14.1842	0.0000
Inf	-14.9159	0.0000	-14.8870	0.0000
Imp	-7.4773	0.0000	-7.4812	0.0000
R	-12.0560	0.0000	-12.0427	0.0000
G	-10.2307	0.0000	-10.4123	0.0000

We apply the Augmented Dickey Fuller (ADF) unit root test to the series and it is observed that the p value is significant for all variables. Hence all five series are stationary at first difference.

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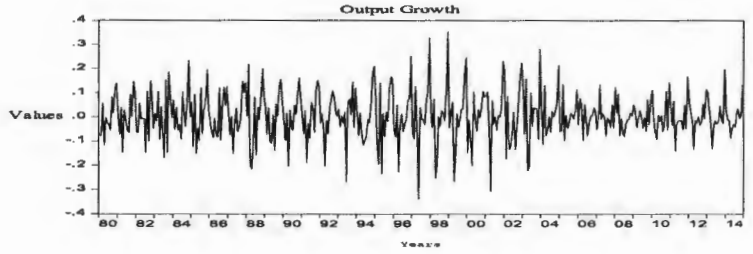

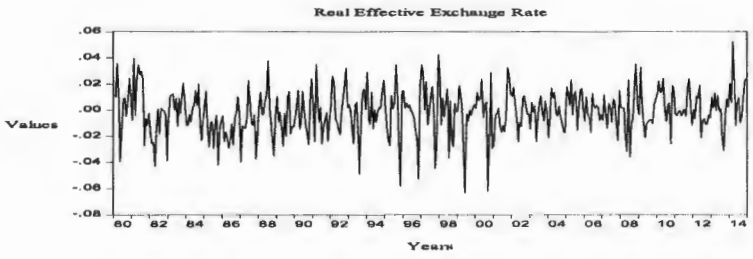

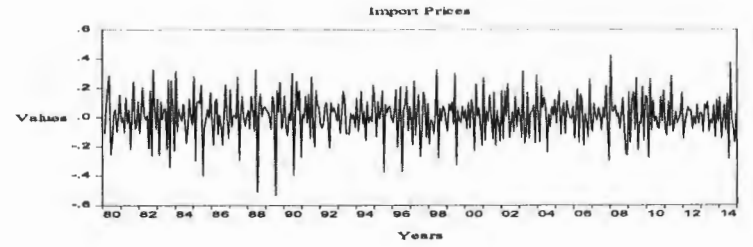

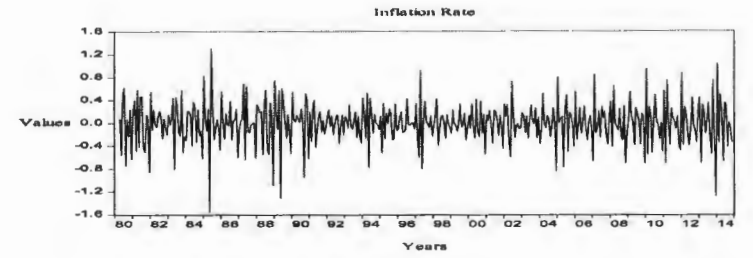

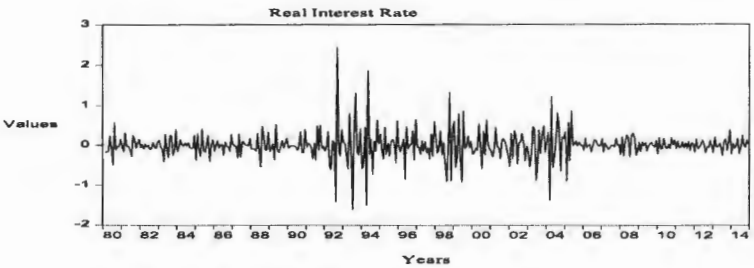

Figure 4.2: Trends of Variables after Stationarity

Graphs of all the time series show that they are stationary at first difference and have no trend.

4.5 Co-integration Test: Engle-Granger

Once we have established variables of order I (0) or I (1). A model can be setup that leads to the stationarity among variables. Co-integration is the necessary criteria for establishing stationarity among non-stationary variables. If variables do not have same trends they will not stay fixed to each other in long relation and we do not have a valid base for drawing inferences.

Co-integration test by Engle Granger (1987) provides the linkage between non-stationary and long term relationship. Null hypothesis of the test is that; Series are not co-integrated.

Table 4.5: Results of Co-integration Test

Variable	t-statistic	p-value	Z -statistic	p-value
Exc	-1.1302	0.9947	-4.0751	0.9945
Inf	-1.1304	0.9912	-4.1206	0.9943
Imp	-2.5462	0.8003	-18.1112	0.5618
R	-2.9169	0.6331	-26.1627	0.2372
G	-2.415	0.8441	-15.3111	0.6963

The values of test statistics and the corresponding p-values are given. Based on the results of the co integration test we conclude that there is no co integration among variables. This implies that we can estimate the model in log difference.

4.6 Lag Selection

After establishing the stationarity of the time series, the next step is to choose the appropriate number of lags of the dependant variable to be included in the model.

Table 4.6: Lag Selection by Different Criteria

Lag	LL	LR	d.f	p-Value	FPE	AIC	HQIC	SBIC
0	-642.168				.000016	3.11888	3.13808	3.16742
1	1614.56	4513.5	25	0.0000	3.3e-10	-7.63644	-7.52129	-7.34524
2	1746.6	264.08	25	0.0000	2.0e-10	-8.15229	-7.94118	7.61842*
3	1814.07	134.93	25	0.0000	1.6e-10	-8.35695	-8.04988	-7.58041
4	1859.82	91.52*	25	0.0000	1.5e-10*	-8.4569*	-8.0539*	-7.43778

The next step of the analysis is to choose the appropriate number of lags for the model. The table shows the results for optimal lag selection. Different criteria Likelihood Ratio Test (LR), Final Prediction Error (FPE), Akaike Information Criteria (AIC), Hannan-Quinn Information Criteria (HQIC) suggest that AR (4) model is suitable.

4.7 Linear Model

We have specified the baseline time series model for inflation and its determinants. The selected model has the lowest Akaike Information Criteria (AIC).

$$Inf_t = 0.3620^{**} - 0.7340^{**}Inf_{t-1} - 0.6165^{**}Inf_{t-2} - 0.2657^{**}Inf_{t-3} + 0.1645^{**}Inf_{t-4} - 0.6856^{**}G_t + 0.0219Imp_t + 0.6809^{**}Exc_t - 0.1629Exc_{t-1} - 0.6558^{**}Exc_{t-3} + 0.1645Exc_{t-4} - 0.1703^{**}R_t$$

R Squared = 0.46	Adj. R Squared = 0.45	F Statistic=31.34
P-value (F Statistic) = 0.00	AIC = 0.2596	SBIC=0.3763
HQIC = 0.3058	Durban Watson stat = 1.96	S.E of Regression= 0.2730

Table 4.7: Breusch-Godfrey Serial Correlation LM Test

F-statistic	p-value
1.3160	0.2694

To check the serial correlation Breusch-Godfrey is used. Since the p value of the test is greater than the level of significance, so we do not reject Ho and conclude that residuals are not correlated over different periods.

Table 4.8: Heteroscedasticity Test Breusch-Pagan-Godfrey

F-statistic	p-value
1.1284	0.3371

Heteroscedasticity of the residuals is tested by using Breusch-Pagan-Godfrey test. Since p value is again greater than the significance level, hence we conclude that there is no heteroscedasticity and residuals are homoscedastic.

Table 4.9: Normality Tests Normality Test Jarque-Bera

Test-statistic	p-value
8.4436	0.0611

Jarque-Bera test is used to check the normality of residuals. The output shows that p-value is greater than the level of significance so we conclude that the residuals are normally distributed.

Table 4.10: Ramsey Test for Specification Bias

Test-statistic	p-value
0.5722	0.5675

To check any specification error in the model we used the Ramsey Test. The output shows that p value is greater than the level of significance and there is no specification bias in the model.

Table 4.11: Q-statistic Probabilities Adjusted for 4 Dynamic Regressors

Lags	AC	PAC	Q-Stat	p-value
1	0.016	0.016	0.1037	0.747
2	-0.013	-0.013	0.1766	0.915
3	-0.016	-0.015	0.2789	0.964
4	-0.072	-0.071	2.4366	0.656
5	-0.078	-0.077	4.9897	0.417
6	-0.083	-0.085	7.9289	0.243
7	-0.024	-0.028	8.1821	0.317
8	-0.113	-0.126	13.631	0.092
9	0.084	0.071	16.640	0.055
10	-0.009	-0.036	16.672	0.082

Table 4.9 shows the Q-statistics, probability for regressors up to 10 lags. The null-hypothesis is that, "there is no autocorrelation up to order k" Since p-values are greater than 0.05 so we conclude that there is no autocorrelation up to order 10.

4.8 Linearity Tests

After estimating the baseline linear model, the next step is to obtain residuals from the selected autoregressive model and prepare the following auxiliary equation.

$$\epsilon_t = \propto_0 + \propto_1 w_{t-i} + \propto_2 w_{t-i} s_t + \propto_3 w_{t-i} st^2 + \propto_4 w_{t-i} st^3$$

Where w_{t-i} is vector of explanatory variables and s_t is transition variables.

The null hypothesis for testing linearity against LSTR and ESTR are as follows:

$\propto_2 = \propto_4 = 0$ which is LM test (LM2)

$\propto_1 = \propto_3 = 0$ which is LM test (LM3)

Strength of rejection of the hypothesis is compared. If the p-value is minimum corresponding to LM3 choose LSTR otherwise ESTR.

Table 4.12 Linearity Tests: Transition Variable, Real Effective Exchange Rate

	Exc_{t-1}	Exc_{t-2}	Exc_{t-3}	Exc_{t-4}
LM2	0.101	0.150	0.001	0.352
LM3	0.205	0.292	0.004	0.035

Table 4.12 suggests that p value is minimum corresponding to LM2 hence Exc_{t-3} is the selected transition variable and the selected form of the function is ESTR.

Table 4.13 Linearity Tests: Transition Variable, Real Interest Rate

	R_{t-1}	R_{t-2}	R_{t-3}	R_{t-4}
LM2	0.012	0.185	0.093	0.028
LM3	0.009	0.057	0.085	0.018

From this table, we see that p value is minimum corresponding to LM3 therefore R_{t-1} is the selected transition variable. The selected form is LSTR.

Table 4.14 Linearity Tests: Transition Variable, Output Growth

	G_{t-1}	G_{t-2}	G_{t-3}	G_{t-4}
LM2	0.011	0.005	0.010	0.022
LM3	0.060	0.001	0.040	0.039

From table 4.14 we conclude that G_{t-2} is the selected transition variable as p-value is minimum and selected form for the transition variable is LSTR.

Table 4.15 Linearity Tests: Transition Variable, Inflation Rate

	Inf_{t-1}	Inf_{t-2}	Inf_{t-3}	Inf_{t-4}
LM2	0.025	0.016	0.194	0.021
LM3	0.027	0.010	0.065	0.004

From table 4.15 we see that Inf_{t-4} is the suitable transition variable as p-value is minimum corresponding to fourth lag. The selected form of the transition variable is LSTR.

4.9 Smooth Transition Regression Model

Now we estimate ESTR and LSTR models using lags of variables as transition variables. The method of non-linear least square is used for the estimation of the parameters.

4.10 Transition Variable: Real Effective Exchange Rate

Subsequently, after the results of linearity tests, we applied nonlinear model in which we used real effective exchange rate as transition variable. ESTR was selected form of transition function. According to Terasvirta and Eliasson (2001) ESTR models are more suitable in that situation when the dynamic behaviour of a process for small and large values of the transition variable are same and is different for mid values. Hence the main focus is about the magnitude of exchange rate shocks and not on their direction. According to Nogueira Junior and Leon-Ledesma (2008) this property of ERPT models enables to measure nonlinearities in ERPT that may be the result of menu costs. And whether a firm is more plausible to raise prices following large than following small shocks. As we see that nonlinear model is a better fit to the given data as compared to the baseline linear model.

Linear Model

$$Inf_t = 0.3620^{**} - 0.7340^{**}Inf_{t-1} - 0.6165^{**}Inf_{t-2} - 0.2657^{**}Inf_{t-3} + 0.1645^{**}Inf_{t-4} - 0.6856^{**}G_t + 0.0219Imp_t + 0.6809^{**}Exc_t - 0.1629Exc_{t-1} - 0.6558^{**}Exc_{t-3} + 0.1645Exc_{t-4} - 0.1703^{**}R_t$$

R Squared = 0.46	Adj. R Squared = 0.45	F Statistic=31.34
P-value (F Statistic) = 0.00	AIC = 0.2596	SBIC=0.3763
HQIC = 0.3058	Durban Watson stat = 1.96	S.E of Regression= 0.2730

Nonlinear Model (Transition Variable: Real Effective Exchange Rate)

$$Inf_t = 0.3534^{**} - 0.6997^{**}Inf_{t-1} - 0.5844^{**}Inf_{t-2} - 0.2048^{**}Inf_{t-3} + 0.2047Inf_{t-4} + 0.3417^{**}\Delta Exc_t - 0.3927Exc_{t-1} + 0.8578Exc_{t-3} - 0.5101Exc_{t-4} - 0.9339^{**}G_t + 0.2149^{*}Imp_t - 0.1548^{**}R_t + [-0.0735 - 0.4201Exc_t - 0.9143\,Exc_{t-1} + 0.4925^{*}\,Exc_{t-3} + 0.8625\,Exc_{t-4}\,].\,G\,(Exc_{t-3}, \gamma, c)$$

ESTR: $G\,(Exc_{t-3}, \gamma, c) = 1 + \exp\{-57.14\,(Exc_{t-3} - 0.1109^{*})^2\}$

R Squared = 0.52	Adj. R Squared = 0.49	F Statistic=16.66
P-value (F Statistic) = 0.00	AIC = 0.2117	SBIC=0.4698
HQIC = 0.3170	Durban Watson stat = 1.98	S.E of Regression= 0.2673

As we compare both models we see that AIC is lower and adjusted R squared is higher for nonlinear model. These results suggest that for Pakistan ERPT is nonlinear to the exchange rate.

Table 4.16: Sum of the Coefficients of Real Effective Exchange Rate - Real Effective Exchange Rate

G = 0	0.295
G = 1	0.319

The above table shows the sum of exchange rate coefficients. G is the transition function and real effective exchange rate is transition variable. There is a small difference between two states. Also, we see that the speed of transition is fast and the threshold is 11%. The variation in ERPT and exchange rate has a positive relationship. When there are large changes in exchange rate the response to inflation is high and conversely. This is because of the presence of menu costs. When there is little modification in exchange rate, firms do not instantly change the prices because the cost to change prices is very high. On the other hand, if there is an increase in the exchange rate firms must have to adjust the prices, because if they do not do so there will be a very substantial effect on the firms. This phenomenon indicates a positive relationship between exchange rate variation and ERPT. Nogueira Junior and Leon-Ledesma (2008) found nonlinear and positive response between ERPT and exchange rate for two out of six countries. Cheikh (2012) also found the similar result for nine out of 12 Euro Area countries.

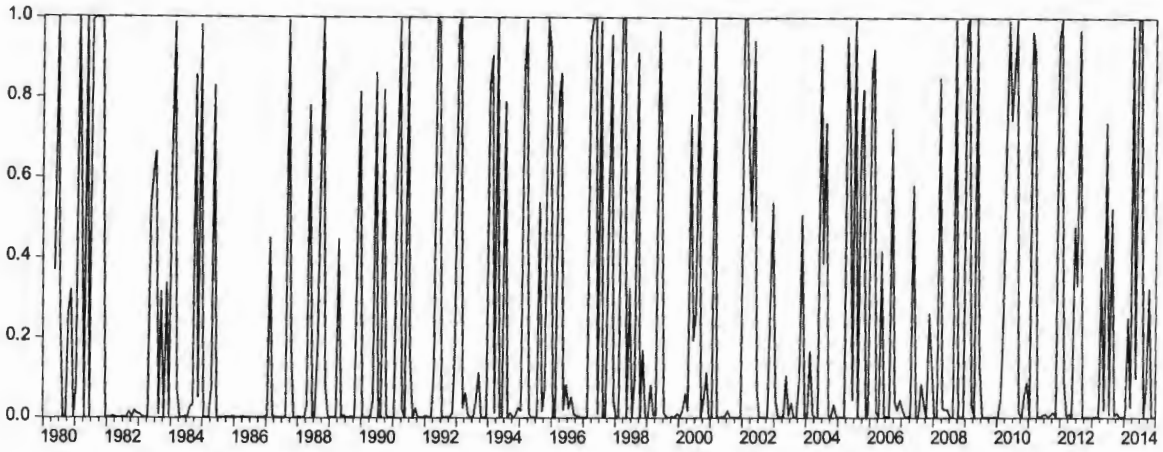

Figure 4.3: Transition Function Real Effective Exchange Rate

The above is the figure of the real effective exchange rate as transition function. The range of transition function is between 0 and 1. Since γ is high speed of transition between two regimes is fast.

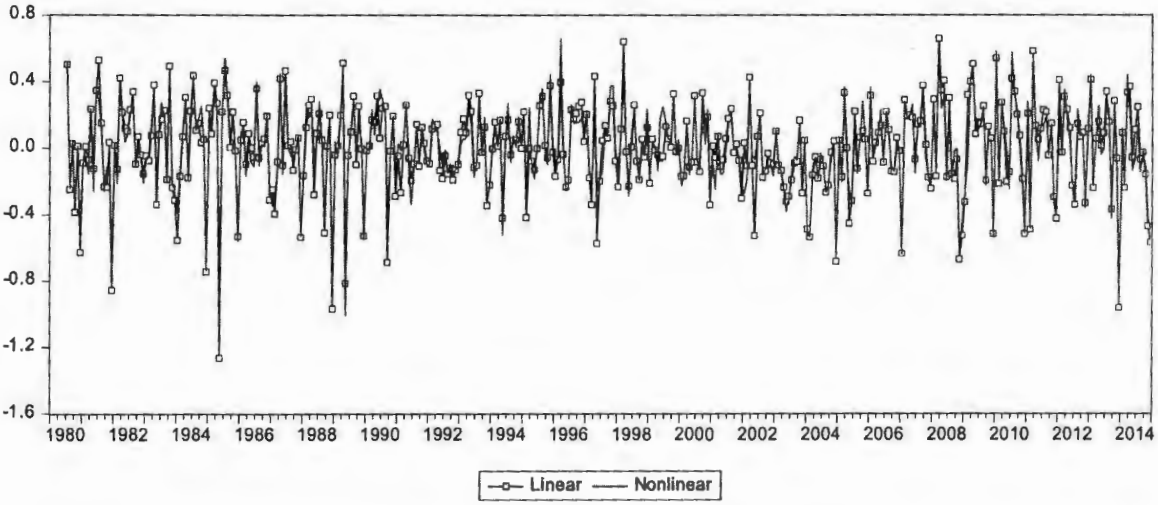

Figure 4.4: Series of Residuals for Linear and Nonlinear Models

This residuals of estimated linear and non-linear model in the above figure show stationary behaviour.

4.11 Transition Variable Real Interest Rate

Mishikin (2001) and Schimidt - Hebbel and Tapia (2002) established that levels of reliability of monetary policy have direct influence on the extent of ERPT. During the periods when economy undergoes a confidence crisis the ERPT is assumed to increase, on the contrary, when economy attains macroeconomic stability ERPT would decrease.

Real interest rate is used as a proxy variable for macroeconomic instability. R_t has a direct relationship with ERPT, when Real interest rate increases ERPT would also increase.

Linear Model

$$Inf_t = 0.3620^{**} - 0.7340^{**}Inf_{t-1} - 0.6165^{**}Inf_{t-2} - 0.2657^{**}Inf_{t-3} + 0.1645^{**}Inf_{t-4} - 0.6856^{**}G_t + 0.0219Imp_t + 0.6809^{**}Exc_t - 0.1629Exc_{t-1} - 0.6558^{**}Exc_{t-3} + 0.1645Exc_{t-4} - 0.1703^{**}R_t$$

R Squared = 0.46	Adj. R Squared = 0.45	F Statistic=31.34
P-value (F Statistic) = 0.00	AIC = 0.2596	SBIC=0.3763
HQIC = 0.3058	Durban Watson stat = 1.96	S.E of Regression= 0.2730

Nonlinear Model (Transition Variable Real Interest Rate)

$$Inf_t = 1.2833^{**} - 0.6997^{**}Inf_{t-1} - 0.3600^{**}Inf_{t-2} - 0.1028^{**}Inf_{t-3} + 0.0175Inf_{t-4} + 2.5981^{**}Exc_t - 2.6027Exc_{t-1} + 1.0484Exc_{t-3} - 0.1437Exc_{t-4} - 0.7015^{**}G_t - 0.4532^{**}Imp_{t-2} - 0.5209^{**}R_t + [-0.0203 + 0.2887Exc_t + 0.1240\,Exc_{t-1} - 0.1697^{*}\,Exc_{t-3} + 0.3527\,Exc_{t-4}\,].\,G\,(R_{t-1}, \gamma, c)$$

LSTR: $G\,(R_{t-1}, \gamma, c) = (1 + \exp\{-1.733\,(R_{t-1} - 2.1335)\})^{-1}$

R Squared = 0.53	Adj. R Squared = 0.50	F Statistic=17.61
P-value (F Statistic) = 0.00	AIC = 0.1880	SBIC=0.4408
HQIC = 0.2879	Durban Watson stat = 1.98	S.E of Regression= 0.2616

Results for linearity tests are tabulated for different lags of real interest rate as transition variable. R_{t-1} is selected as the transition variable. LSTR transition function best fits the data. Comparing nonlinear LSTR model to linear model we observe that nonlinear model better fits as compared to the linear model. Adjusted R squared is higher, AIC is lower, and standard error of regression is smaller for nonlinear model as compared to a linear model.

Table 4.17 Sum of the Coefficients Real Effective Exchange Rate – Real Interest Rate

G = 0	0.198
G = ½	0.396
G = 1	0.595

The above table shows the sum of exchange rate coefficients is positive. As expected, there is positive relationship between ERPT and real interest rate. Hence credibility plays an important role. The threshold value is 2.1%. Speed of transition is smooth between two regimes.

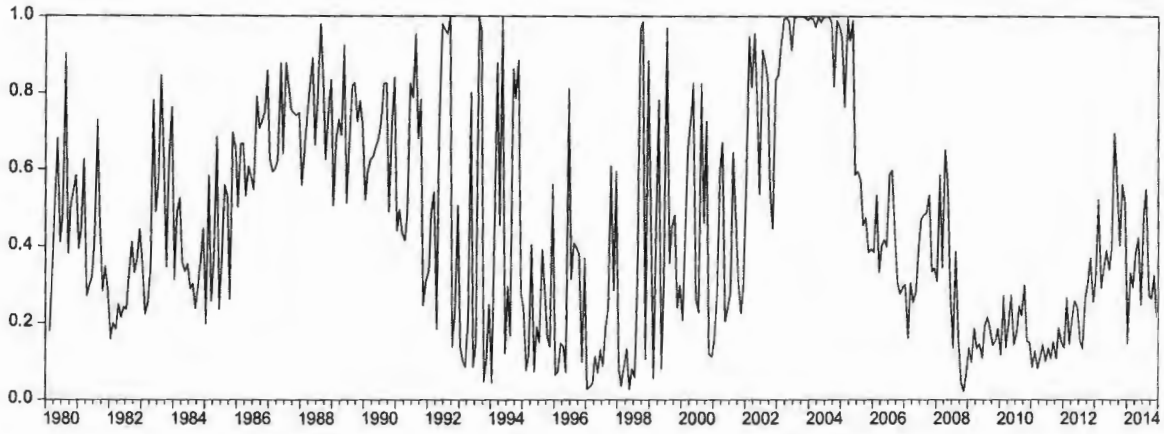

Figure 4.5: Transition Function Real Interest Rate

This is the figure of real interest rate as transition function. The years are plotted on the x axis and y axis shows the values of the transition function ranging between 0 and 1. The figure shows that the speed of transition between two regimes is slow as the value of γ is small.

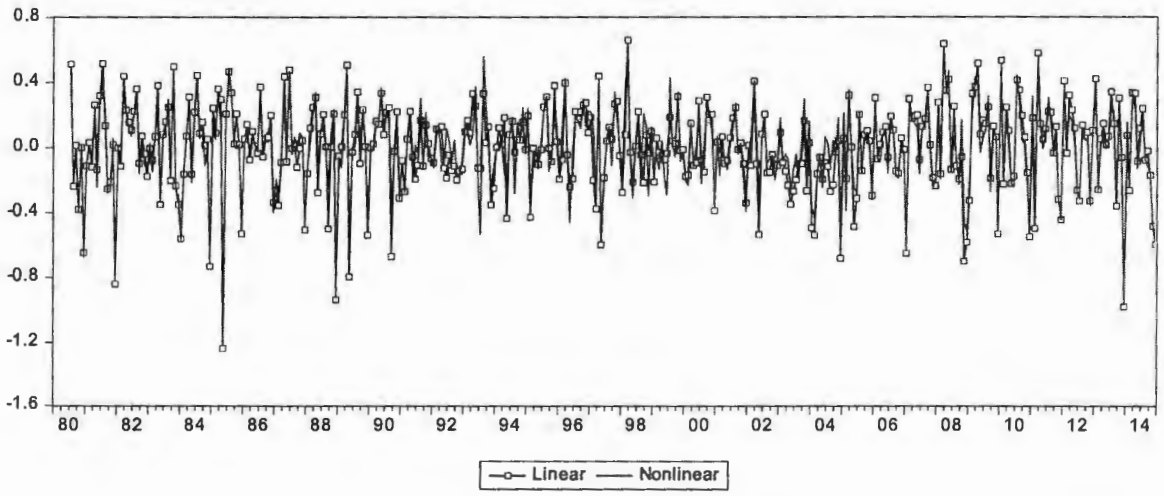

Figure 4.6: Series of Residuals for Linear and Nonlinear Models

The above figure gives the comparison of the series of the residuals from the baseline linear model and the nonlinear model using real interest rate as transition variable. The residuals series of both the models show stationary behaviour.

4.12 Transition Variable Output Growth

According to Goldfajn and Werlang (2000) output growth is an important factor affecting ERPT. Naturally, it is easy for the firms to pass over cost changes during the periods when the economy is progressing fast as compared to the recession periods when business is already declining.

The table 4.14 shows linearity tests for different lags of transition variables. Ho of linearity is rejected against nonlinearities.

Linear Model

$$Inf_t = 0.3620^{**} - 0.7340^{**}Inf_{t-1} - 0.6165^{**}Inf_{t-2} - 0.2657^{**}Inf_{t-3} + 0.1645^{**}Inf_{t-4} - 0.6856^{**}G_t + 0.0219Imp_t + 0.6809^{**}Exc_t - 0.1629Exc_{t-1} - 0.6558^{**}Exc_{t-3} + 0.1645Exc_{t-4} - 0.1703^{**}R_t$$

R Squared = 0.46	Adj. R Squared = 0.45	F Statistic=31.34
P-value (F Statistic) = 0.00	AIC = 0.2596	SBIC=0.3763
HQIC = 0.3058	Durban Watson stat = 1.96	S.E of Regression= 0.2730

Nonlinear Model (Transition Variable Output Growth)

$$Inf_t = 0.3437^{**} - 0.7192^{**}Inf_{t-1} - 0.7402^{**}Inf_{t-2} - 0.3674^{**}Inf_{t-3} + 0.1634Inf_{t-4} + 0.0292^{**}Exc_t - 0.0115Exc_{t-1} - 0.0432Exc_{t-3} + 0.1325Exc_{t-4} - 0.9963^{**}G_t + 0.0403^{*}Imp_t - 0.1412^{**}R_t + [+0.0168 + 0.0624^{**}Exc_t + 0.3175Exc_{t-1} - 0.4312Exc_{t-3} + 0.3410Exc_{t-4}\ ].\ G\ (G_{t-2}, \gamma, c)$$

LSTR: $G\ (G_{t-2}, \gamma, c) = (1 + \exp\ \{ -21.688\ (G_{t-2} - 0.056\ )\ \})^{-1}$

R Squared = 0.51	Adj. R Squared = 0.48	F Statistic=21.32
P-value (F Statistic) = 0.00	AIC = 0.2103	SBIC=0.4048
HQIC = 0.2873	Durban Watson stat = 1.95	S.E of Regression= 0.2610

Like other transition variables adjusted R squared is high, and AIC is lower for nonlinear model. Standard error of regression has larger value for nonlinear model as compared to the linear model.

Table 4.18: Sum of the Coefficients Real Effective Exchange Rate -Output Growth

G = 0	0.107
G = 1/2	0.252
G = 1	0.397

Sum of exchange rate coefficients is shown in the table which is positive. It means that when the economy is progressing over threshold ERPT is high. The response is strong and the threshold is 5.6 %.

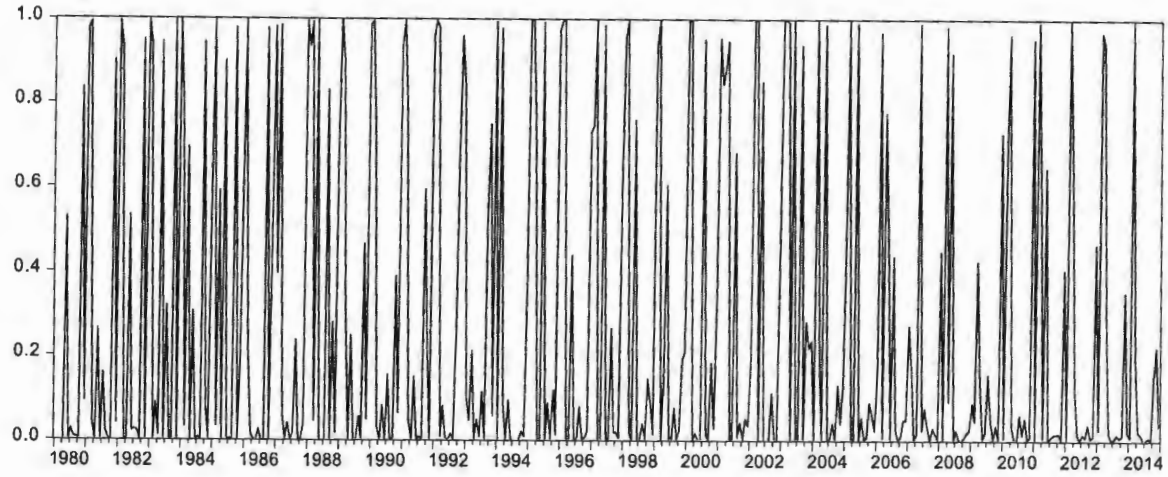

Figure 4.7: Transition Function Output Growth

The above figure is the of the variable output growth as transition function. The selected form of the function is LSTR. Time is plotted on the x axis and values for series of transition function are plotted on the y axis. The range of the transition function is between 0 and 1. As we see above that value of γ is large, so the speed of transition between two regimes is fast.

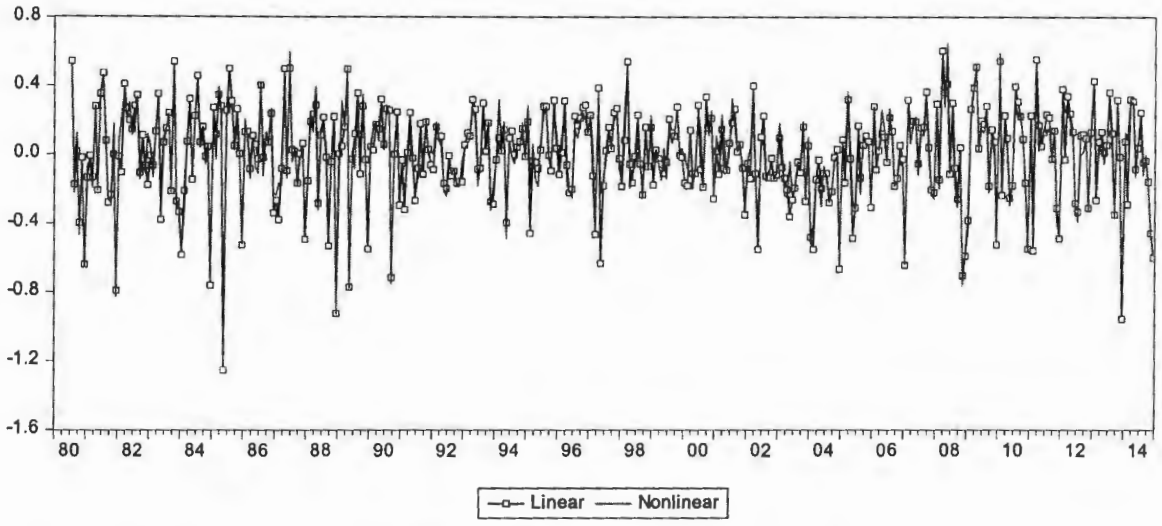

Figure 4.8: Series of Residuals for Linear and Nonlinear Models

This figure shows that the residuals of estimated models show stationary behaviour.

4.13 Transition Variable: Inflation Rate

Linearity test results for different lags of transition variable inflation are given in the table 4.15. Following the results first lag of inflation Inf_{t-1}, is selected as the suitable transition variable for capturing the nonlinearities in ERPT. This is according to the results of the previous studies that ERPT depends on inflation.

Linear Model

$$Inf_t = 0.3620^{**} - 0.7340^{**}Inf_{t-1} - 0.6165^{**}Inf_{t-2} - 0.2657^{**}Inf_{t-3} + 0.1645^{**}Inf_{t-4} - 0.6856^{**}G_t + 0.0219Imp_t + 0.6809^{**}Exc_t - 0.1629Exc_{t-1} - 0.6558^{**}Exc_{t-3} + 0.1645Exc_{t-4} - 0.1703^{**}R_t$$

R Squared = 0.46	Adj. R Squared = 0.45	F Statistic=31.34
P-value (F Statistic) = 0.00	AIC = 0.2596	SBIC=0.3763
HQIC = 0.3058	Durban Watson stat = 1.96	S.E of Regression= 0.2730

Nonlinear Model (Transition Variable: Inflation Rate)

$$Inf_t = 0.1034 + 0.9134^{**}Inf_{t-1} - 0.3900^{**}Inf_{t-2} - 0.0832Inf_{t-3} - 0.2047Inf_{t-4} + 0.0863Exc_t - 0.0012Exc_{t-1} - 0.0965Exc_{t-3} + 0.0627Exc_{t-4} - 0.0773G_{t-1} - 0.1006^{*}Imp_t - 0.1127^{*}R_t + [0.9605 + 0.0348Exc_t - 0.0157\,Exc_{t-1} + 0.0512^{*}\,Exc_{t-3} - 0.0432Exc_{t-4}\ ].\ G\,(Inf_{t-4}, \gamma, c)$$

LSTR: $G\,(Inf_{t-4}, \gamma, c) = (1 + \exp\{-1.9818\,(Inf_{t-4} - 0.2519)\})^{-1}$

R Squared = 0.48	Adj. R Squared = 0.47	F Statistic=22.13
P-value (F Statistic) = 0.00	AIC = 0.1901	SBIC=0.4130
HQIC = 0.2952	Durban Watson stat = 1.97	S.E of Regression= 0.2654

When we compare linear and nonlinear model we see that adjusted R square is higher in nonlinear model, AIC is lower, and indicating that nonlinear model better fits for the data. A threshold value for inflation is 25 %.

Table 4.19: Sum of the Coefficients Real Effective Exchange Rate -Inflation Rate

G = 0	0.0513
G = 1/2	0.0645
G = 1	0.078

Since the sum of the coefficients of exchange rate is positive, positive relationship exists between inflation and ERPT. Hence, if inflation rises over the threshold, there is an increase in ERPT.

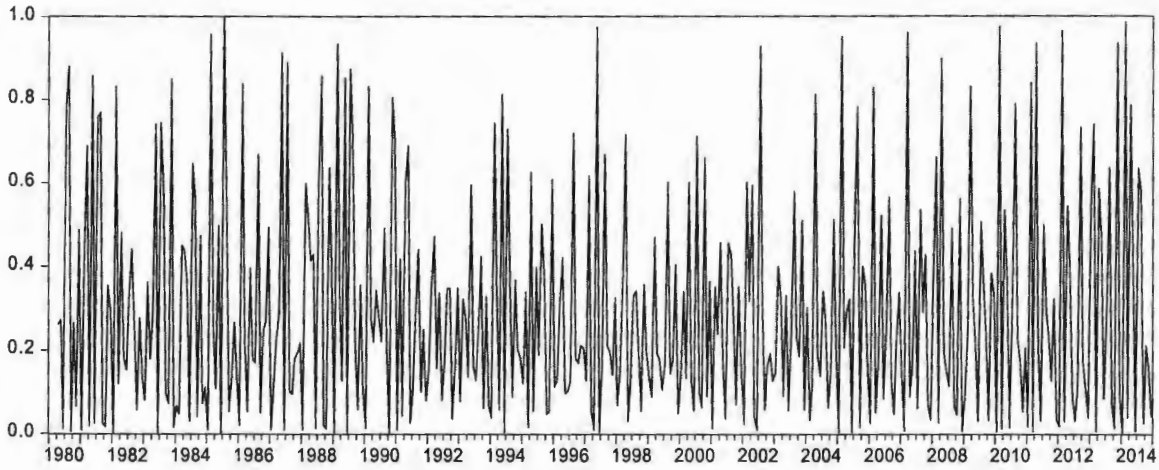

Figure 4.9: Transition Function Inflation Rate

Inflation is used as transition function in the above figure. The selected form of the function is LSTR. Time is plotted on the x axis and values for series of transition function are plotted on the y axis. The range of the transition function is between 0 and 1. The speed of transition between two regimes is smooth.

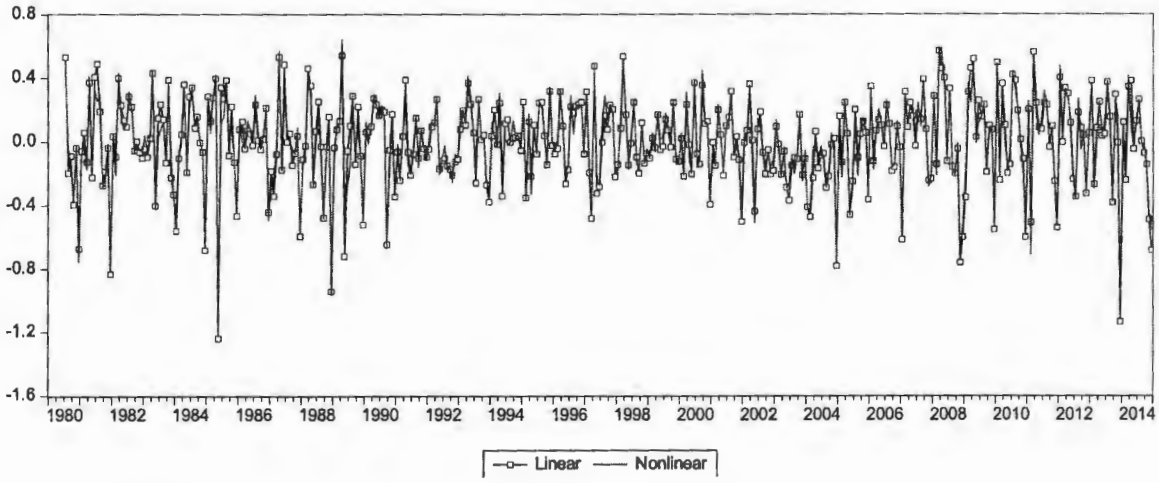

Figure 4.10: Series of Residuals for Linear and Nonlinear Models

This figure shows that the residuals of estimated models show stationary behaviour.

CHAPTER 5

CONCLUSIONS

5.1 Findings

This thesis empirically investigated the nonlinearities in the exchange rate pass through. Monthly data was used for the time period 1980 to 2014. The data were obtained from International Financial Statistics (IFS) website. The variables in the study include real effective exchange rate, real interest rate, CPI inflation rate, the value of imports and output growth manufacturing index. First, descriptive statistics of the variables is computed to see the basic features of the dataset. Data on all variables was used in the log form. Augmented Dicky Fuller (ADF) test was used for checking the stationarity of the time series data. The test results show that all series must be differenced one time to obtain stationarity. Then the data was checked for the presence of the long run relationship among the time series variables. The results of the Engle-Granger test showed that there is no co-integration among the variables. After observing stationarity and co integration, the next step is to choose the suitable lag length for the model. Different model selection criteria, Akaike Information Criteria (AIC), Hannan-Quinn Information Criteria (HQIC) suggest that AR (4) model is suitable. We have specified the baseline time series model for inflation and its determinants. The selected model has the lowest Akaike Information Criteria (AIC). This model is estimated and the residuals are obtained from this model. The residuals of the models are tested for STR type nonlinearity. Different variables and their lags were used as transition variable. The variables that is selected as transition variable is that which has lowest p-value, i.e. highest probability of the rejection of the null hypothesis. The selected transition variables are Exc_{t-3}, R_{t-1}, G_{t-2}, Inf_{t-4}. The

suitable form selected for the Real Effective Exchange Rate is ESTR and for the remaining three variables LSTR model. After establishing the suitable form of the STR models the parameters of the models are estimated by Non-Linear Least Square (NLLS) applying Gauss-Newton and Marquardt algorithm. It is observed that nonlinear models have high adjusted R squared value as compared to the linear models.

Nonlinear STR model were estimated the by using Real Effective Exchange Rate as transition variable. By comparing the linear and nonlinear models we observe that AIC has smaller value and Adjusted R Squared has higher for the nonlinear model proving the quality of the nonlinear models. The threshold value is 11 %. Sum of the exchange rate coefficients is positive showing a positive relationship between exchange rate pass through and lag of exchange rate. Speed of transition is much faster. When there are large changes in exchange rate the response to inflation is high.

Real interest rate used as a measure of macroeconomic stability. The selected form of the specification is LSTR for first lag of real interest rate. Different criteria showed the superiority of the nonlinear logistic smooth transition regression model over the base line linear model. Positive relationship observed between ERPT and real interest rate. Real interest rate is very important determinant of credibility. The threshold value is 2.1% and speed of the transition is smooth between regimes.

Output growth is also an important factor which affecting the ERPT. Null hypothesis of linearity is rejected against STR type nonlinearity and selected form of the model is LSTR. The second lag of the variable is used as the transition variable. Nonlinear model using output growth as transition variable is better than the linear model. Sum of the exchange rate coefficients is positive showing that when economy

is progressing over threshold ERPT is high. Threshold value is found to be 5.6 % and response is strong.

It is also investigated whether lags of inflation potentially affect the ERPT. linearity was checked against the STR nonlinearity. LSTR type nonlinearity is observed to exist for inflation at lag 4. Nonlinear model is estimated using fourth lags of inflation as transition variable. Threshold level for inflation is 25 %. There exists a positive relationship between inflation and ERPT.

This study concludes that performance of smooth transition regression models is better than the base line linear model. Smooth transition regression models can better explain the nonlinearities in the exchange rate pass through.

A natural implication of our findings is that monetary authorities should be cautious when assessing the transmission of exchange rate shocks to inflation. Premature or delayed policy rate movements, without sufficient evidence and understanding of non-linear dynamics could prove detrimental to price stability and impose a risk to anchor inflation expectations. ERPT increases when there is macroeconomic instability therefor to maintain the ERPT at lower levels, it is desirable to implement better economic policy.

5.2 Recommendations

For further research this work can be extended to include other macroeconomic theories. There are many other potential variables which can affect the exchange rate pass through. The study is not exhaustive in terms of the factors affecting the ERPT. Many other factors like monetary policy, balance of payments, political situations etc. are some of the factors which may be considered by the future researchers.

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