RUPEE USDOLLAR NOMINAL EXCHANGE RATE OF INDIA: BEHAVIOUR, COINTEGRATION AND VECTOR AUTOREGRESSION

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Abstract: The paper studied the nominal exchange rate behavior of Rupee U.S. Dollar during 1970-2015 with the help of semilog or exponential model, variance ratio test, Bai-Perron (2003) test , H.P. Filter model(1997) ,AR,ARIMA and GARCH models respectively. Johansen co integration (1988) test and VECM (1991,1996) were used to relate exchange rate with its determinants showing the process of error corrections.
The paper concludes that nominal rupee exchange rate has been depreciating with respect to U.S.Dollar at the rate of 5.57% per year or exponentially at the rate of 0.365% per year during 1970-2015.The nominal exchange rate does not follow random walk and random walk with drift. It has three structural breaks at 1984,1991 and 1998 respectively. It showed clear non linear trend after minimizing cyclical behavior. Its AR(2) process is stable and convergent and ARIMA(1,1,1) showed stationary and stable but its ARIMA(2,1,2) is nonstationary. The exchange rate series contains high volatility as shown by GARCH(1,1,1) model. Nominal exchange rate is positively significantly related with current account deficit, fiscaldeficit, external debt as percent of GDP and whole sale price index and negatively significantly related with interest rate and trade openness respectively during 1970-2015. Johansen cointegration Rank test assured that Trace Statistic has 6 co integrating equations and Max Eigen Statistic has 3 cointegrating equations. Thus VECM is a stable model but divergent with speedy significant error corrections of change in current account deficit and fiscal deficit as percent of GDP and change in interest rate respectively.

Key words-Rupee U.S. Dollar exchange rate, structural break, random walk, stationary, autoregression, co integration, vector autoregressive error correction

I. Introduction: The exchange rate is a key financial variable that affects decisions made by foreign exchange investors, exporters, importers, bankers, businesses, financial institutions, policymakers and tourists in the developed as well as developing world. Exchange rate fluctuations affect the value of international investment portfolios, competitiveness of exports and imports, value of international reserves, currency value of debt payments, and the cost to tourists in terms of the value of their currency. Movements in exchange rates thus have important implications for the economy's business cycle, trade and capital flows and are therefore crucial to understanding financial developments and changes in economic policy. Timely forecasts of exchange rates can therefore provide valuable information to decision makers and participants in the spheres of international finance, trade and policy making. Nevertheless, the empirical literature is skeptical about the possibility of accurately predicting exchange rates.
REER gap corresponds to underlying current account gap; adjustment of an excess imbalance would involve a change in expenditure (domestic demand) as well as a change in REER. A positive (negative) REER gap implies an overvalued (undervalued) exchange rate. REER gaps are not necessarily related to expected future exchange rates, and may occur in any economy, including those with floating exchange rates.

For the most part, exchange rates responded as expected to the terms-of-trade shock and helped support external adjustment in both commodity exporters and importers, as countries with depreciating currencies observed a stronger response of net export volumes. With a few exceptions, exchange rate flexibility played a key role in cushioning the negative terms-of-trade shock, including by reducing the need for large fiscal adjustment (where currency depreciations contained the loss of commodity revenues measured in local currency). The treatment of commodity terms of trade (TOT) differs for the current account (CA) and real effective exchange rate (REER) regressions depending on the duration of the shock. A permanent TOT gain that boosts real income and wealth is expected to appreciate the REER, but to have limited impact on the CA level, as permanent real income and spending would move in tandem. On the other hand, a temporary change in the TOT would affect the CA via the consumption-smoothing channel and the inter-temporal substitution channel, although the overall impact is ambiguous as these work in opposite directions . The coefficient suggests that a temporary 1-ppt fall in the TOT is associated with a 0.25 percent of GDP fall in the CA in a country with an average level of trade openness. Recent TOT changes are estimated to explain about 1.2 and 0.6 percent of GDP of the CA deterioration for oil and nonoil exporters, respectively. Given that the actual CA balance deteriorated by much less the underlying

CA improved. The estimated coefficient indicates that a 1- ppt of GDP increase in "temporariness" increase the CA norm by 0.6 ppts. The recent declines in oil prices led to a 0.4 percent of GDP decline in temporariness, raising the CA norm by 0.2-0.3 percent. TOT shocks can also enter indirectly through its impact on medium-term growth estimates. A one percent decline in the 5-year ahead growth forecast is associated with (i) a 0.5 ppt of GDP increase in the CA balance; and (ii) a 2.5 percent weakening of the REER. Recent downward revisions in the medium-term growth forecast for commodity exporters (0.1 and 0.4 percent for oil and nonoil, respectively) are responsible for a slightly higher CA norm.

This paper tries to explain the patterns of exchange rate behavior of India and also tries to show the relation with its determinants during 1970-2015.

II. Literature review: Ahmed Saeed, Rehmat Ullah Awan, Maqbool H. Sial and Falak Sher(2012) studied an econometric analysis of determinants of exchange rate for US Dollar in terms of Pakistani Rupee within the framework of monetary approach from January 1982 to April 2010 for Pakistan .Stock of money, foreign exchange reserves and total debt of Pakistan relative to United States along with Political instability in Pakistan as a dummy variable are taken as determinants of PKR/USD exchange rate during the managed floating regime in Pakistan. ARDL approach to co-integration and error correction model are applied. Empirical results confirm that stock of money, debt and foreign exchange reserve balance all in relative terms are significant determinants of exchange rate between Pakistani Rupee and US Dollar. Moreover, Political instability has a significant negative effect on the value of domestic currency. T.R. Oziegbe , C.O.K. Ibidapo and A. Sharimakin (2011)investigate the Nigerian naira and United States dollar exchange rates under Flex Price Monetary Model (FPMM) spanning time series of 1986-2008 and found that the Trace and Maximum Eigenvalue tests indicate at least one cointegrating vector at 5 percent (%) significant level therefore suggesting a long-run equilibrium relationship between the bilateral naira-dollar exchange rates vis-à-vis FPMM ethics therefore the results are in strong support of the Flex Price Monetary Model. Latife Ghalayini(2014) constructed ARIMA model and study the volatility of this exchange rate time series to construct econometric models capable to generate consistent and rational forecasts for the dollar/euro exchange rate. In one hand, the basic theories, the Power purchasing parity and the Interest rate parity explain partially the dollar/euro exchange rate. In other hand, we have seen above that a simple ARIMA model can provide an evolution equation with a simple interpretation. Although the exchange rate series presents a high volatility, the presence of serial correlation suggests that the model do not seem toadequately capture the correlation information in the time series and the model cannot be used for hypothesis test or forecasting. Furthermore, ARIMA model can be criticized because it fails to provide an explanation of the causal structure behind the evolution of the time series. Therefore, the model developed in this study consider in addition to the two variables proposed by basic theories, two other variables, one variable representing the Money Aggregates, and one variable representing the Business Cycles. Ian Wilson(2009) presented an expanded model of the monetary approach, which includes three fiscal variables that were shown to have an impact on inflation. This model was used to examine the exchange rate between the U.S. dollar and

currencies from a group of U.S. trade partners. The deficits and outstanding debt financed domestically or by foreign investors do impact the effective exchange rate in the long run,

but not in the short run. Specifically, over the short run, the effective exchange rate is independent of debt and deficits. Despite initial discouraging support for the monetary model

of exchange rate determination, recent support for the model continues to mount. Aristidis Bitzenis and John Marangos(2007) examined for the Greek drachma-US dollar exchange rate in the flexible-price monetary model. The Johansen multivariate technique of cointegration is applied to an unrestricted form of the monetary model. Using quarterly data covering the period 1974–1994, strong evidence is found in favour of the existence of co-integration between the nominal exchange rate, relative money supply, relative income and relative interest rates. The monetary model is validated as a long-run equilibrium condition. Yu-chin Chen Kwok Ping Tsang(2010) used monthly data between 1985 and 2005 for Canada, Japan, the UK and the US, and employ a state-space system to model the relative yield curves between country-pairs using the Nelson and Siegel (1987) latent factors, and combine them with monetary policy targets (output gap and inflation) into a vector autoregression (VAR) for bilateral exchange rate changes. We find strong evidence that both the financial and macro variables are important for explaining exchange rate dynamics and excess currency returns, especially for the yen and the pound rates relative to the dollar. Moreover, by decomposing the yield curves into expected future yields and bond market term premiums, we show that both expectations about future macroeconomic conditions and perceived risks are priced into the currencies. These findings provide support for the view that the nominal exchange rate is determined by both macroeconomic as well as financial forces.I. Botha and M. Pretorius(2009) found determinants of the SA exchange rate which were classified according to 3 broad categories, namely real, monetary and financial variables, as well as past and expected values. Cointegration was found between these variables .Univariate and multivariate models were compared to the simple random walk model using the MAD/mean ratio. Multivariate models performed well in comparison to the univariate models, specifically the one step ahead, out-of-sample forecast. The VARMA model had a low MAD/mean ratio of 1.5% followed by the VAR and random walk at 4.6% and 4.8% respectively. This was, however, not the case in the dynamic, out-of-sample forecast. With a longer forecast horizon, the univariate models (ARCH and ARIMA) outperformed mostly multivariate models, except for the VECM that outperformed all the models. From the results of this research the random walk model did well, below 5%, therefore it is up to the practitioner if a more complex model, such as the VARMA, or the simple random walk model should be used to forecast the exchange rate in the short-run. The study of Hafsa Hina and Abdul Qayyum(2015) employs the Frankel (1979) monetary model of exchange rate to examine the long run behavior of Pakistan rupee per unit of US dollar over the period 1982:Q1 to 2012:Q2. Johansen and Juselious (1988,1992) likelihood ratio test indicates one long-run co integrating vector among the fundamentals. Co integrating vector is uniquely identified as Dornbusch (1976) monetary model by imposing plausible economic restrictions. Finally, the short-run dynamic error correction model is estimated on the bases of identified co integrated vector. Out of sample forecasting analysis of parsimonious short run dynamic error correction model is able to beat the naïve random walk model on the basis of root mean square error, Theil's U coefficient and Diebold and Mariano (1995) test statistics. Alessandro Nicita(2013) investigates the importance of exchange rates on international trade by analysing the impact that exchange rate volatility and misalignment have on trade and then by exploring whether exchange rate misalignments affect governments' decisions regarding trade policies. The methodology consists of estimating fixed effects models on a detailed panel dataset comprising about 100 countries and covering 10 years (2000-2009). The findings of this study are generally in line with those of the recent literature in supporting the importance of exchange rate misalignment while disregarding that of exchange rate volatility. In magnitude ,exchange rate misalignments result in trade diversion quantifiable in about one per cent of world trade. This paper also shows evidence supporting the argument that trade policy is used to compensate for some of the consequences of an overvalued currency, especially with regard to anti-dumping interventions. The findings of this research carry three broad policy implications.

First, policymakers need to pay attention to the exchange rates of their countries and those of other countries as the effect of currency misalignments on international trade is considerable. Second, the relative valuation of currencies can explain only a small part of global trade imbalances. Adjustments in exchange rates can be only part of the solution for global rebalancing and need to be accompanied by other policy actions. Finally, strategies to avoid the resurgence of protectionist measures should include multilateral cooperation related to the stabilization of exchange rates towards their equilibrium level. Furrukh Bashir and Adeel Luqman(2014) aimed to analyze the determinants of real exchange rate in Pakistan. Time series data is collected from 1972 – 73 to 2012 – 13. Johansen co-integration test and error correction model isutilized for examining long run and short run elasticity's. The study concludes that real exchange rate is depreciated by terms of trade and Price level. While trade restrictions and workers' remittances are exerting negative effect or appreciating real exchange rate of Pakistan in the long run. Riané de Bruyn, Rangan Gupta &Lardo Stander(2013) decided to test the long-run monetary model of exchange rate determination for the South African Rand relative to the US Dollar using annual data from 1910 – 2010. The results provide some support for the monetary model in that long-run co-integration is found between the nominal exchange rate and the output and money supply deviations. However, the theoretical restrictions required by the monetary model are rejected. A vector error-correction model identifies both the nominal exchange rate and the monetary fundamentals as the channel for the adjustment process of deviations from the long-run equilibrium exchange rate. A subsequent comparison of nominal exchange rate forecasts based on the monetary model with those of the random walk model suggests that the forecasting performance of the monetary model is superior.

III. Methodology and data: To study the behavioural patterns of Rupee Dollar exchange rate during 1970-2015,we use semilog trend model, exponential trend model to get trend lines, We use variance ratio test ,random walk with drift model to verify randomwalk.To find stationary of the exchange rate we used ARIMA(1,1,1) and AR models. We find structural breaks using Bai-Perronmodel(2003) and use H.P. Filter model (1997) for smoothness of cycles. To study the determinants of exchange rate we fitted multiple regression model ,Johansen co integration model (1988) and VECM(1996,)including its residuals test of autocorrelation, normality ,and heteroscedasticity.

We collected data for Rupee U.S.Dollar exchange rate, current account balance per cent of GDP, fiscal deficit per cent of GDP. external debt per cent of GDP ,terms of trade, interest rate(discount rate),trade openness, and whole sale price index with 2010=100 of India during 1970-2015 from World Bank and International Financial Statistics.

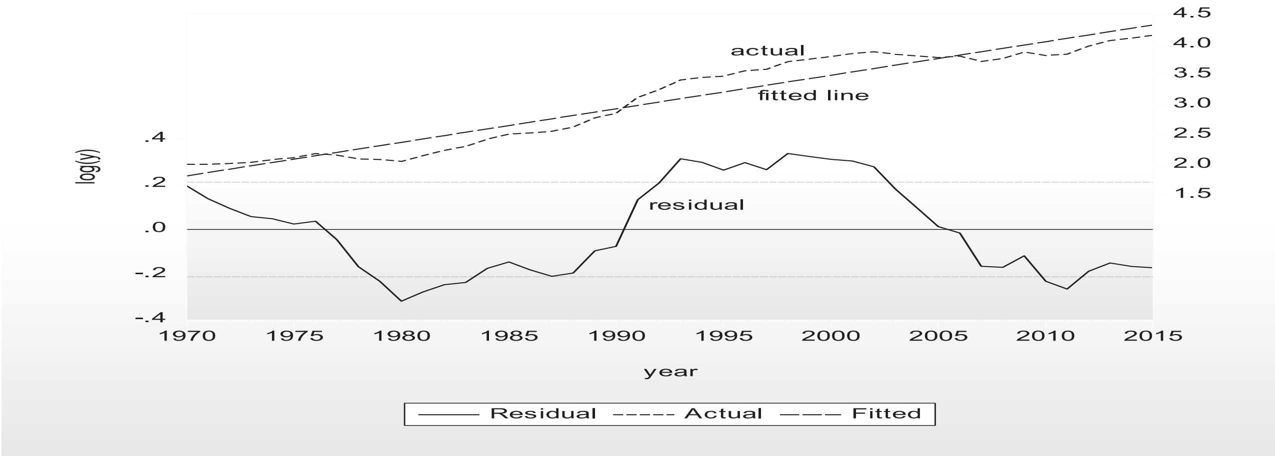
IV. Econometric Findings: [A] Behaviourial patterns: India's Rupee US Dollar nominal exchange rate has been increasing at the rate of 5.57% per year during 1970-2015 which is statistically significant.

Log(y)=1.765861+0.05576t
(28.152)* (23.99)*

R^2=0.929,F=575.72* ,DW=0.1035 , where *=significant at 5% level,y= Rupee US Dollar , t=year

In Fig-1,the trend line is plotted which is steadily upward rising.

Fig-1: Trend line of Rupee U.S.Dollar



Source: Computed by author

This nominal rate of Rupee US Dollar during 1970-2015 has been fitted exponentially which is more reliable than the linear trend.

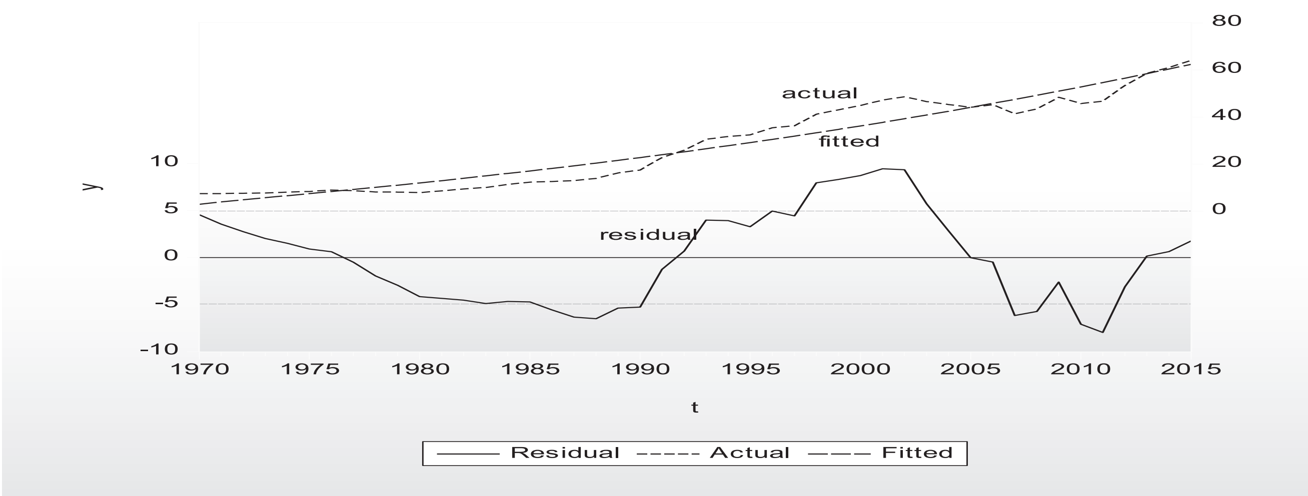
$Y=e^{0.08601+t^{0.36515}}$

Where t values of 0.086 is 0.673 which is not significant but t values of 0.36515 is 38.115 which is significant at 5% level. R^2=0.929,AIC=6.07 ,SC=6.15 ,DW=0.174,

It states that India's Rupee U.S.Dollar rate has been increasing exponentially at the rate of 0.365% per year during 1970-2015.

In Fig-2,the exponential growth of the nominal rate is upward rising very steeply and is seen clearly .

Fig-2:Exponential trend



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In variance ratio test, joint test assures that maximum absolute z value is 6.371811 which is significant at 1%

level which means Martingale is accepted and even in individual tests in all periods z statistic are significant at 5% level, thus the nominal rate does not follow exponential random walk hypothesis during 1970-2015.

Table-1:Variance ratio test

Joint Tests	Value	df	Probability	
Max |z| (at period 13)*	6.371811	45	0.0000	
Individual Tests				
Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	1.464284	0.147377	3.150321	0.0016
3	1.898300	0.237824	3.777158	0.0002
4	2.266346	0.306120	4.136758	0.0000
5	2.549254	0.357593	4.332450	0.0000
6	2.799978	0.398722	4.514369	0.0000
7	3.048080	0.433086	4.729033	0.0000
8	3.377660	0.463623	5.128435	0.0000
9	3.722419	0.491434	5.539739	0.0000
10	4.045781	0.516857	5.892892	0.0000
11	4.316913	0.540408	6.137789	0.0000
12	4.553090	0.562625	6.315206	0.0000
13	4.720758	0.583940	6.371811	0.0000
14	4.784577	0.604750	6.258085	0.0000
15	4.791968	0.625295	6.064289	0.0000
16	4.790017	0.645455	5.871853	0.0000

*Probability approximation using studentized maximum modulus with parameter value 15 and infinite degrees of freedom

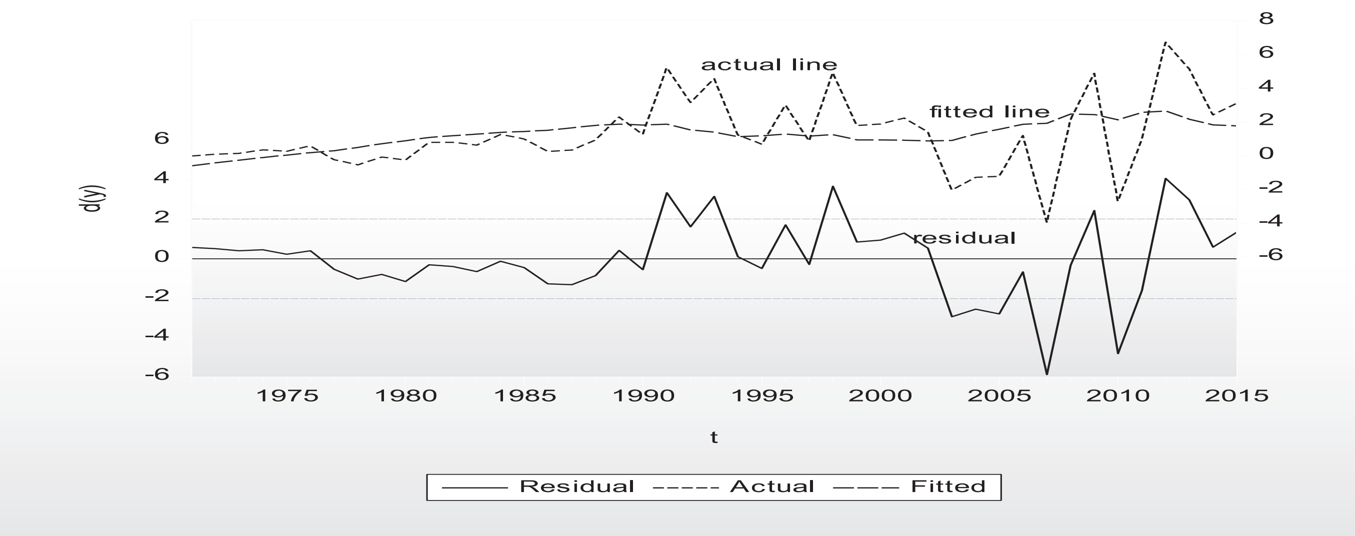
Source-Computed by author

Even the nominal exchange rate in India during 1970-2015 does not follow random walk with a drift model which is estimated below.

Δy_t=-0.204266-0.097318y_{t-1}+0.172141t
(-0.304) (-1.63) (2.13)*
R^2=0.135,F=3.29* ,DW=1.48 , AIC=4.31 , SC=4.43,*=significant at 5% level,

In Fig-3,the fitted line and the drift are shown clearly.

Fig-3:Random walk with a drift



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India's nominal exchange rate of Rupee U.S.Dollar during 1970-2015 showed three structural breaks in 1984,1991 and 1998 which are computed by Bai-Perron(2003) test which was found significant at 5% level and sequential F statistic of break test are significant for those three breaks.HAC standard errors and covariance (Bartlett Kernel, Newey-West fixed bandwidth=3.0, Trimming 0.15) technique was applied.

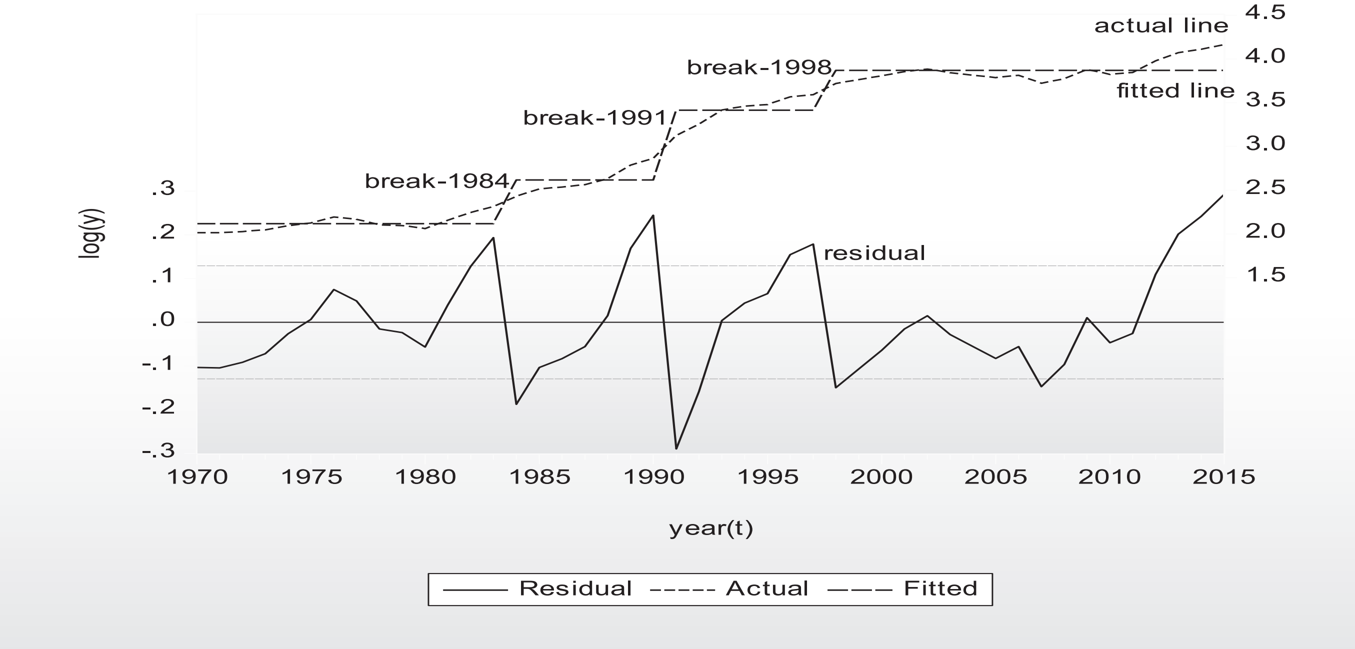
Table-2:Structural breaks

Variable	Coefficient	Std. Error	t-Statistic	Prob.
		1970 - 1983 -- 14 obs		
C	2.117993	0.033596	63.04306	0.0000
		1984 - 1990 -- 7 obs		
C	2.617425	0.076595	34.17239	0.0000
		1991 - 1997 -- 7 obs		
C	3.413120	0.082309	41.46692	0.0000
		1998 - 2015 -- 18 obs		
C	3.868939	0.048921	79.08602	0.0000
		R^2=0.974,F=528.23*		
	Sequential F-statistic determined breaks:	3		
Break Test	F-statistic	Scaled F-statistic	Critical Value**	
0 vs. 1 *	102.8054	102.8054	8.58	
1 vs. 2 *	30.77218	30.77218	10.13	
2 vs. 3 *	20.68134	20.68134	11.14	
3 vs. 4	7.643463	7.643463	11.83	

* Significant at the 0.05 level, ** Bai-Perron (Econometric Journal, 2003) critical values.
Source-Computed by author

In Fig-4,three structural breaks in 1984,1991,1998 have been plotted clearly which are upward during 1970-2015.

Fig-4:Structural breaks



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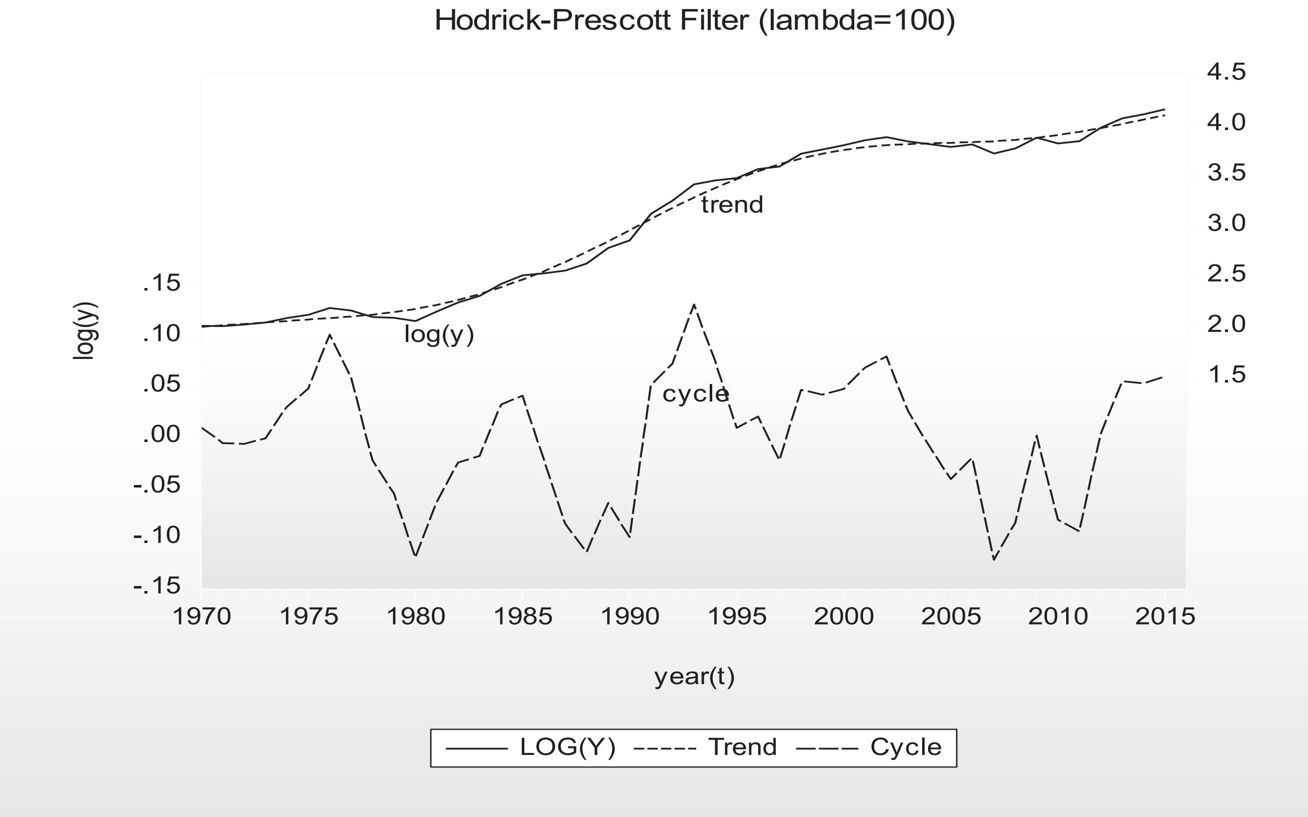
Hodrick-Prescott Filter model(1997) transformed the cyclical path of log nominal exchange rate of Rupee-U.S.Dollar during 1970-2015 into smooth non-linear trend line which is plotted in Fig-5 and was found significant.

Fig-5:H.P.Filter model



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The auto regressive process with lag two is stationary , non-convergent and stable because t values of the coefficients of autoregression are significant and its values of roots are less than one but one coefficient is greater than one thus why it is not convergent. The regression is highly significant.

$logY_t=7.6639+1.361413logy_{t-1}-0.368228logy_{t-2}+u_t$

(0.864) (9.45)* (-2.55)*

$R^2=0.99$, F=3021.128* , AIC=-2.599 ,SC=-2.47 ,DW=2.148 , *=significant at 5% level, Inverted AR roots are 0.99 and 0.37.

The estimated ARIMA(1,1,1) process of the nominal exchange rate during 1970-2015 is stationary because AR(1) is convergent and stationary and MA(1) process is convergent and stationary which are significant at least 6% level.

$Logy_t=14.48734+0.99584logy_{t-1}+\varepsilon_t+0.282799\varepsilon_{t-1}$

(0.323) (61.247)* (1.906)*

$R^2=0.993$,F=3062.142* ,DW=1.88,Inverted AR root=1,inverted MA root=-0.28,AIC=-2.56,SC=-2.44,*=significant at 6% level

In ARIMA(2,1,2) model, AR(2) process is stationary and divergent but MA(2) process is convergent and nonstationary, therefore ARIMA(2,1,2) model is nonstationary and divergent but the model is stable since all the roots are less than one.

$logy_t=5.7447+1.6312y_{t-1}-0.638117y_{t-2}+\varepsilon_t-0.368722\varepsilon_{t-1}+0.104609\varepsilon_{t-2}$

(1.38) (5.10)* (-2.00)* (-1.06) (0.52)

$R^2=0.993$,F=1504.94 , DW=1.98 ,AIC=-2.55,SC=-2.35,*=significant at 5% level. Inverted AR roots are 0.98 and 0.65 but inverted MA roots are 0.18±27i ,therefore the model is stable and is a good fit.

The volatility of the nominal exchange rate of Rupee US Dollar during 1970-2015 showed by GARCH(1,1) model where z statistic of the coefficients are insignificant at 5% level and R^2 is negative.

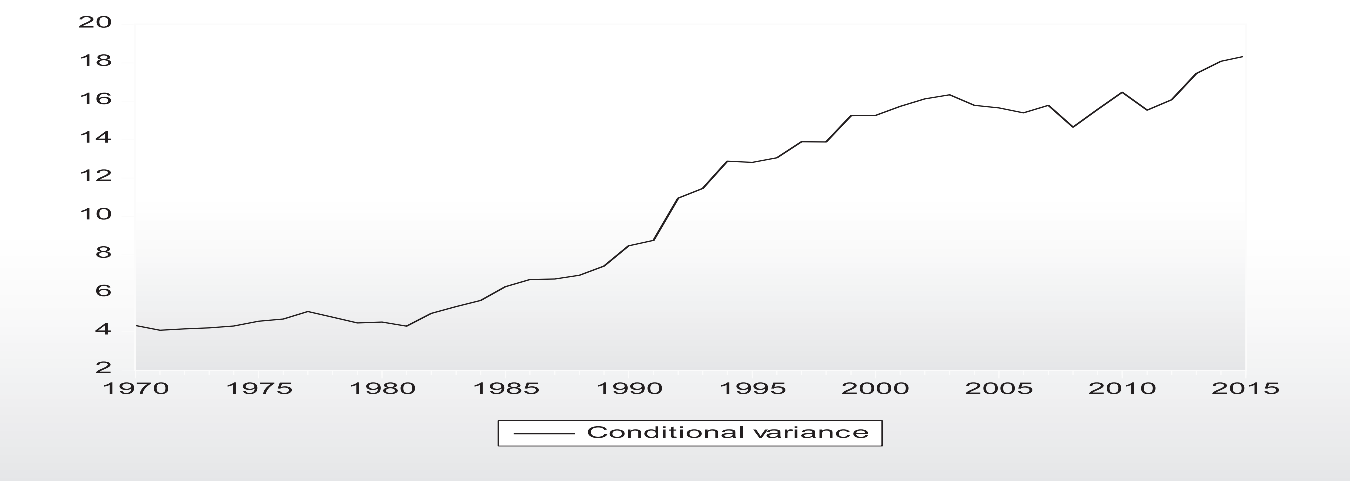
$h_t=-0.461864+1.462369\varepsilon_{t-1}^2-0.325767h_{t-1}$

(-0.0039) (0.0094) (-0.0022)

$R^2=-16.04$,AIC=5.15,SC=5.26,DW=0.000647,logy is taken as variable.

The volatility is shown by the conditional variance which is depicted in Fig-6.

Fig-6:Conditional variance



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[B] Determinants of exchange rate

The multiple regression analysis suggests that nominal exchange rate of Rupee U.S.Dollar is positively related with current account deficit as percent of GDP ,fiscal deficit as per cent of GDP, external debt as percent of GDP and whole sale price index with base 2010=100 which are significant at least 5% level during 1970-2015 and negatively related with interest rate(discount rate) and openness significantly during the same but terms of trade is negatively related with rupee dollar rate which is insignificant. The estimated multiple regression equation is given below.

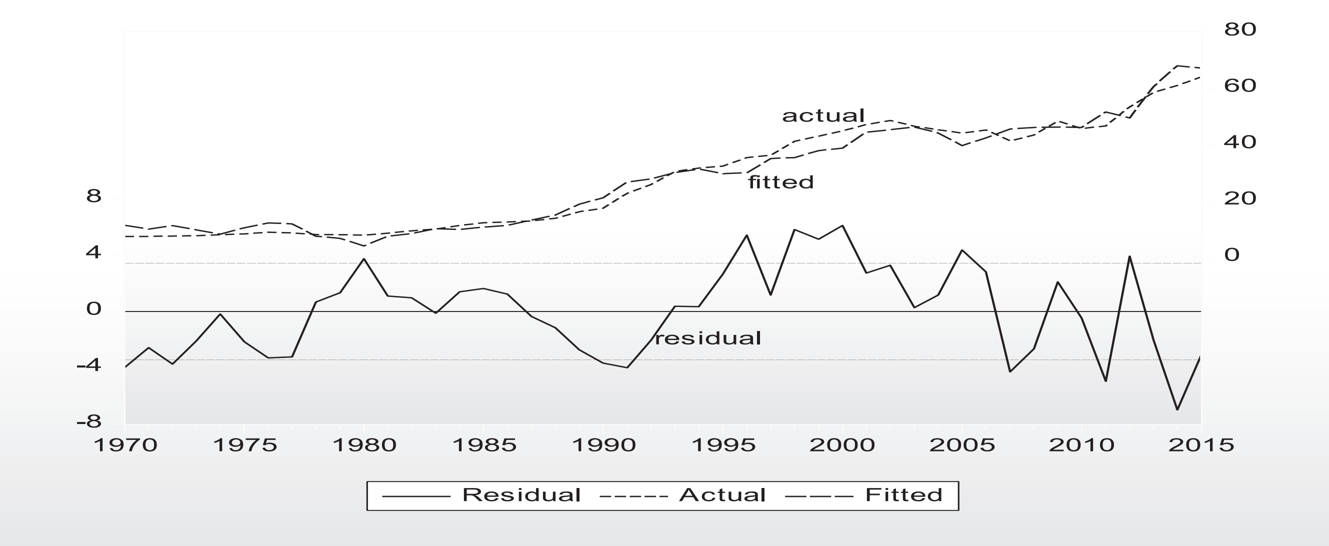
$Y=16.5043+1.60798x_1-0.023017x_2+0.9481x_3-1.3902x_4+0.7378x_5-0.38604x_6+0.5787x_7+u_i$

(3.37)*(2.819)* (-0.60) (2.502)* (-2.98)* (5.41)* (-2.32)* (8.095)*

$R^2=0.970$,F=179.08* ,DW=0.91,AIC=5.46 , SC=5.77,*=significant at 5% level where x_1= current account deficit per cent of GDP, x_2=terms of trade,x_3=fiscal deficit per cent of GDP,x_4=discount rate,x_5=external debt per cent of GDP,x_6=trade openness,x_7= whole sale price index with 2010=100.

In Fig-7,thenon-linear estimated regression line and actual line were plotted neatly both of which are non linear and moving upward.

Fig-7:The non-linear actual and Fitted line of multiple regression

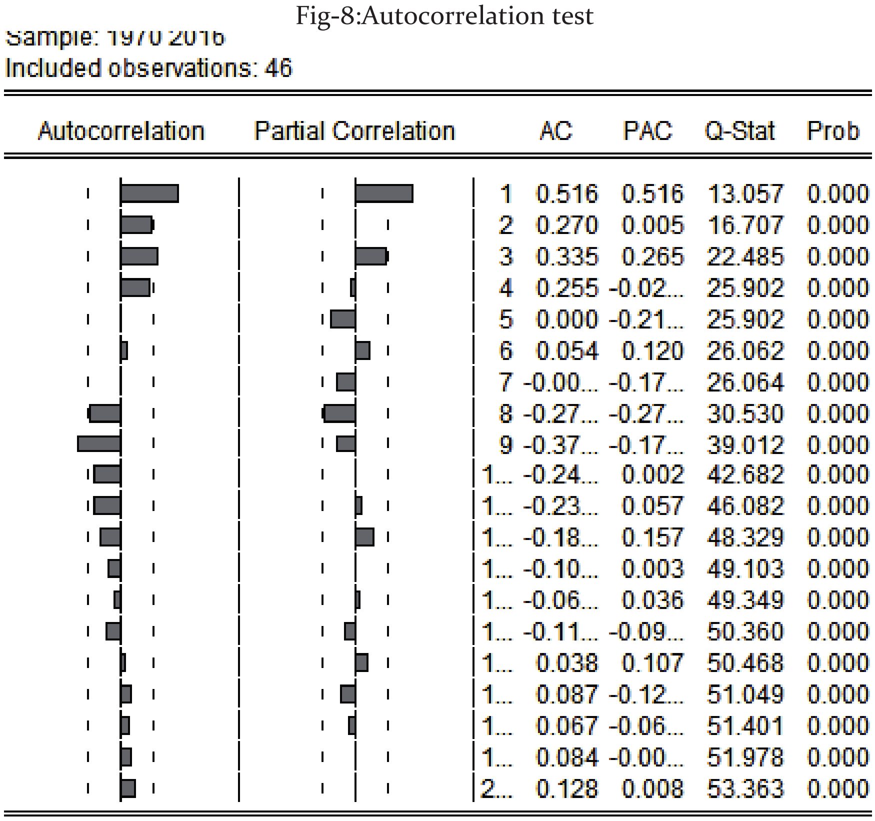


Source: Computed by author.

The residuals of the estimated regression equation has serial correlation because Breusch-Godfrey Serial Correlation LM test showed that $nR^2=14.48877$ whose Chi –square distribution is significant at 5% level and F=17.01249 which is also significant at 5% level.

In Fig-8,it is also confirmed that residual auto correlation test confirmed that it has auto-correlation and partial auto-correlation problems too.

Fig-8:Autocorrelation test



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Johansen cointegration Rank test assured that Trace Statistic has 6 cointegrating equations and Max Eigen Statistic has 3 cointegrating equations which are significant at 5% level so that there is cointegration in the order of CI(1).In Table-3,their values have been arranged.

Table-3:Cointegration

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.824086	256.7657	159.5297	0.0000
At most 1 *	0.687883	180.3043	125.6154	0.0000
At most 2 *	0.601258	129.0717	95.75366	0.0000
At most 3 *	0.477579	88.61632	69.81889	0.0008
At most 4 *	0.441180	60.04795	47.85613	0.0024
At most 5 *	0.371085	34.44309	29.79707	0.0136
At most 6	0.210674	14.03770	15.49471	0.0819
At most 7	0.079154	3.628370	3.841466	0.0568
Hypothesized No. of CE(s)	Eigenvalue	Max Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.824086	76.46142	52.36261	0.0000
At most 1 *	0.687883	51.23256	46.23142	0.0135
At most 2 *	0.601258	40.45539	40.07757	0.0453
At most 3	0.477579	28.56837	33.87687	0.1885
At most 4	0.441180	25.60486	27.58434	0.0877
At most 5	0.371085	20.40540	21.13162	0.0629
At most 6	0.210674	10.40933	14.26460	0.1864
At most 7	0.079154	3.628370	3.841466	0.0568

* denotes rejection of the hypothesis at the 0.05 level,
**MacKinnon-Haug-Michelis (1999) p-values
Source-Computed by author

Since we have found cointegration among the determinants of exchange rates then the Vector Error Correction Model is estimated below where error correction processes are added.

[1]Δy_t=-0.05947+0.0331y_{t-1}-0.478Δx_{1t-1}+0.000867Δx_{2t-1}+0.444Δx_{3t-1}-0.6149Δx_{4t-1}
(-0.127) (0.125) (-0.96) (0.058) (1.5) (-1.39)
+0.3418Δx_{5t-1}-0.1333Δx_{6t-1}+0.4944Δx_{7t-1}+0.07251EC
(1.41) (-0.87) (3.02)* (1.07)
R^2=0.438 ,F=2.95 ,

[2]Δx_{1t}=-0.2695-0.0076Δy_{t-1}-0.0124Δx_{1t-1}+0.00351Δx_{2t-1}-0.186Δx_{3t-1}+0.1529Δx_{4t-1}
(-1.3) (-0.06) (-0.071) (0.53) (-1.42) (0.78)
+0.1772Δx_{5t-1}+0.0383Δx_{6t-1}+0.0529Δx_{7t-1}+0.08096EC
(1.65) (0.569) (0.731) (2.71)*
R^2=0.428 ,F=2.82,

[3]Δx_{2t}=-1.1145+2.333Δy_{t-1}+6.0595Δx_{1t-1}-0.4194Δx_{2t-1}-0.3249Δx_{3t-1}+1.519Δx_{4t-1}
(-0.224) (0.827) (1.44) (-2.63)* (-0.103) (0.324)
-0.0736Δx_{5t-1}+2.3234Δx_{6t-1}-1.3347Δx_{7t-1}-0.2464EC
(-0.028) (1.43) (-0.76) (-0.34)
R^2=0.272 ,F=1.41

[4]Δx_{3t}=0.0219-0.5921Δy_{t-1}+0.5577Δx_{1t-1}+0.0078Δx_{2t-1}-0.3714Δx_{3t-1}+0.5503Δx_{4t-1}
(0.086) (-4.11)* (2.61)* (0.961) (-2.30)* (2.29)*
+0.20108Δx_{5t-1}-0.1300Δx_{6t-1}+0.2253Δx_{7t-1}+0.1374EC
(1.529) (-1.57) (2.53)* (3.75)*
R^2=0.453,F=3.139

[5]Δx_{4t}=-0.0463+0.119Δy_{t-1}+0.05526Δx_{1t-1}-0.01336Δx_{2t-1}+0.13868Δx_{3t-1}-0.02961Δx_{4t-1}
(-0.264) (1.19) (0.37) (-2.37)* (1.24) (-0.178)
-0.03942Δx_{5t-1}+0.07988Δx_{6t-1}-0.0625Δx_{7t-1}-0.08647EC
(-0.432) (1.39) (-1.01) (-3.40)*
R^2=0.442,F=2.99

[6]Δx_{5t}=0.2764-0.2711Δy_{t-1}-0.7606Δx_{1t-1}-0.01387Δx_{2t-1}-0.6163Δx_{3t-1}-0.6163Δx_{4t-1}
(0.613) (-1.05) (-2.0) (-0.958) (0.776) (-1.44)
+0.5445Δx_{5t-1}-0.2986Δx_{6t-1}+0.1624Δx_{7t-1}-0.02711EC
(2.32)* (-2.03)* (1.02) (-0.416)
R^2=0.315,F=1.73

[7]Δx_{6t}=1.4506-1.1865Δy_{t-1}+0.4643Δx_{1t-1}+0.0197Δx_{2t-1}-0.5161Δx_{3t-1}+0.4301Δx_{4t-1}
(2.57)* (-3.69)* (0.976) (1.08) (-1.43) (0.806)
+0.0514Δx_{5t-1}-0.1487Δx_{6t-1}+0.3423Δx_{7t-1}+0.1638EC
(0.178) (-0.808) (1.72) (2.01)
R^2=0.429 ,F=2.84

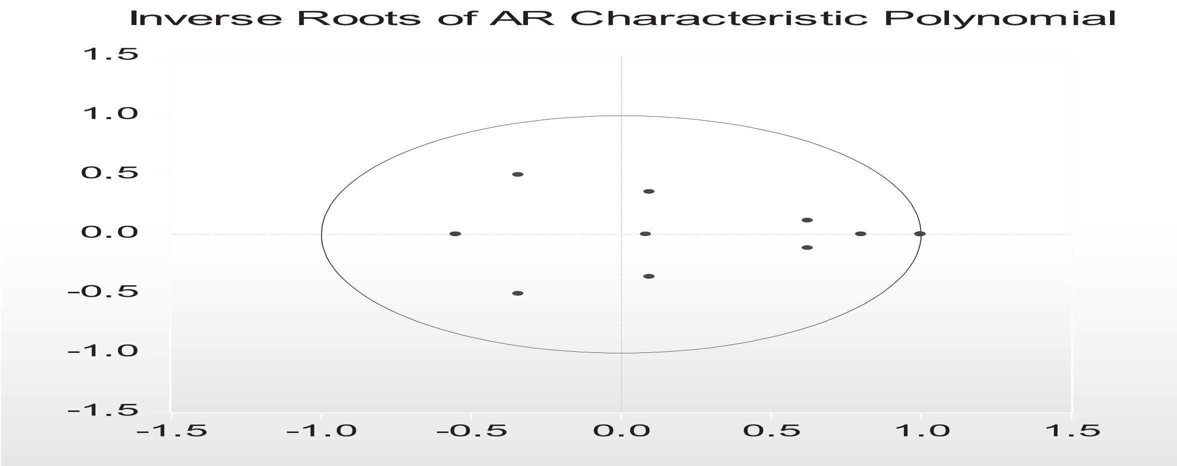
[8]Δx_{7t}=0.6818-0.2929Δy_{t-1}+0.3801Δx_{1t-1}+0.0136Δx_{2t-1}-0.8253Δx_{3t-1}+0.2465Δx_{4t-1}
(1.34) (-1.01) (0.89) (0.84) (-2.56)* (0.515)
+0.0747Δx_{5t-1}+0.1173Δx_{6t-1}+0.7767Δx_{7t-1}+0.0263EC
(0.284) (0.71) (4.36)* (0.359)
R^2=0.507 ,F=3.88

In the VECM, some error corrections showed good results like in the equations of Δx_{1t},Δx_{3t},Δx_{4t}, which are significant at 5% level but others are insignificant. This VECM is a stable model because it has 7 unit roots, and other 9 roots are less than one ,all of which lie in the unit root circle. In Fig-9, the roots are shown in the unit root circle and in the Table-4,the values of roots are shown.

V. Limitations and future scope: Exchange rate determinants are important instrumental variables which control international trade and finance in external market and inflation in home and foreign markets where NEER and REER are crucial which are excluded in our analysis. Inflation and interest rate differentials if included in the model,could ensure better results.An another measure of inflation i.e.percentage change in CPI can be taken for analysis which was excluded in our model. In India, this analysis can be extended and compared in the different monetary systems so that role of exchange rate was found out for future research.

VI. Policy recommendations: To keep exchange rate stable, policy makers should turn terms of trade favorable making low current account deficit ,fiscal deficit and external debt. Target inflation rate can show favourable exchange rate. India's policy of rupee depreciation had not been favour in all times rather she should be careful about falling REER and NEER under flexible exchange rate policy. India needs more precautions in applying capital account convertibility.

Fig-9:Unit root circle



Source-Computed by author

Table-4:Values of roots

Root	Modulus
1.000000	1.000000
1.000000	1.000000
1.000000	1.000000
1.000000	1.000000
1.000000	1.000000
1.000000	1.000000
1.000000	1.000000
0.803729	0.803729
0.625278 - 0.115858i	0.635921
0.625278 + 0.115858i	0.635921
-0.339878 - 0.500140i	0.604695
-0.339878 + 0.500140i	0.604695
-0.549221	0.549221
0.097799 - 0.357749i	0.370875
0.097799 + 0.357749i	0.370875
0.084920	0.084920

Source-Computed by author

The Impulse Response Functions are not converging to zero as t tends to infinity that's why the vector error correction model is nonstationary and if there is any external shock it will not tend towards equilibrium. In Fig-10 ,it is shown vividly.

VII. Conclusions: The paper concludes that rupee exchange rate has been depreciating with respect to USDollar at the rate of 5.57% per year or exponentially at the rate of 0.365% per year during 1970-2015.The nominal exchange rate does not follow random walk and random walk with drift. It has three structural breaks at 1984,1991 and 1998 respectively. It showed clear non linear trend after minimizing cyclical behavior. Its AR(2) process is stable and convergent and ARIMA(1,1,1) showed stationary and stable but its ARIMA(2,1,2) is no stationary. The exchange rate series contains high volatility as shown by GARCH(1,1,1) model. Nominal exchange rate is positively significantly related with current account deficit, fiscal deficit, external debt and whole sale price index and negatively significantly related with interest rate and trade openness respectively during 1970-2015. Johansen cointegration rank test assured that Trace Statistic has 6 cointegrating equations and Max Eigen Statistic has 3 cointegrating equations. Thus VECM is a stable model but divergent with speedy significant error corrections of Δx_{1t},Δx_{3t} and Δx_{4t} respectively.

Fig-10:Impulse Response Functions

Source-Computed by author.

The residual test for autocorrelation of the VECM confirms that it has problem of autocorrelation which have been visible in the Fig-11 below.

Fig-11:Autocorrelation

Source-Computed by author , Even, VECM contains serial correlation as observed by the residual serial correlation LM test where all LM statistic became insignificant which is given in the Table-5 below.

Table-5: Residual serial correlation LM test

Lags	LM-Stat	Prob
1	71.03572	0.2550
2	63.36042	0.4991
3	61.61174	0.5614
4	69.40582	0.3003
5	77.94147	0.1130
6	70.12394	0.2798
7	59.66513	0.6304
8	73.57044	0.1934
9	66.04888	0.4059
10	53.37733	0.8256
11	59.11875	0.6494
12	107.1459	0.0006

Source-Computed by author

Doornik-Hansen residual normality test showed that skewness in components 1 ,8 and joint are significant in $\chi 2$ distribution, kurtosis in component 8 and joint are significant in $\chi 2$ distribution and Jerque-Bera is significant in component 1,8 and joint and all others are insignificant, therefore residuals are multivariate normal in null hypothesis is rejected. In Table-6,they are shown.

Table-6: Normality test

Component	Skewness	Chi-sq	df	Prob.
1	-1.040316	7.776142	1	0.0053
2	0.545795	2.545844	1	0.1106
3	-0.233377	0.498979	1	0.4799
4	-0.047609	0.021108	1	0.8845
5	0.135864	0.171022	1	0.6792
6	0.612974	3.146797	1	0.0761
7	0.295657	0.792835	1	0.3732
8	-1.560492	14.23232	1	0.0002
Joint		29.18505	8	0.0003
Component	Kurtosis	Chi-sq	df	Prob.
1	5.456099	1.269610	1	0.2598
2	2.446324	2.605903	1	0.1065
3	3.565630	2.386100	1	0.1224
4	2.918726	0.412750	1	0.5206
5	2.874998	0.249819	1	0.6172
6	2.590637	2.532493	1	0.1115
7	2.609210	0.095251	1	0.7576
8	9.751418	7.304175	1	0.0069
Joint		16.85610	8	0.0316
Component	Jarque-Bera	df	Prob.	
1	9.045751	2	0.0109	
2	5.151747	2	0.0761	
3	2.885079	2	0.2363	
4	0.433859	2	0.8050	
5	0.420842	2	0.8102	
6	5.679290	2	0.0584	
7	0.888086	2	0.6414	
8	21.53650	2	0.0000	
Joint	46.04115	16	0.0001	

Source-Computed by author

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