Role of Monetary Policy in Exchange Rate Determination: A Case Study of India

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Abstract

In this study, we have analysed the effectiveness of monetary policy in affecting the exchange rate primarily under the monetary approach framework. Acknowledging the restrictive assumptions of PPP on which the monetary approach is based we have also incorporated components from the portfolio approach of exchange rate determination in our analysis. We find the monetary policy of India has a limited effect on the changes in the exchange rate. However, this effect remains more or less constant over time. We also infer from our analysis that the portfolio approach is relatively more useful in explaining the exchange rate dynamics of India if not the random walk model.

Keywords: *Monetary Approach, Monetary Policy, Exchange rate*

JEL Classification: *E58, F33, F41*

I. Introduction

In today's world in achieving macroeconomic objectives like price stability, full employment, and economic growth, the key monetary policy instrument is the interest rate. The monetary authority also has its checks and control over the total supply of money in an economy. However, in managing the economy's output and prices the monetary policy also affects the other variables, particularly the exchange rate. Due to the monetary policy's ability to affect or even control the exchange rate we say apart from the interest rate channel, another crucial channel through which monetary policy influences the economy is the exchange rate channel. Exchange rates, defined as the value of foreign currency in terms of domestic currency, are determined by a multitude of factors. The demand and supply of foreign currency in an economy are the basic determinants. Even though the demand and supply of foreign currency are generated from the imports and exports of goods and services, the overwhelming importance of global financial flows of the modern era makes the exchange rate an asset market issue, at least in the short run. So, investment flows are now considered to be the prime determinant of the exchange rate along with economic fundamentals. Every monetary policy decisions-domestic or foreign, that affects investment sentiments also affects the exchange rate. In this regard, not only the interest rate, the inflation expectation that a central bank wants to anchor, the relative supply of domestic money that makes the currency cheaper or dearer and the expected state of the economy to which the monetary policy is targeted to all are crucial in forming investors expectation and hence in exchange rate determination. Here we should note that changes in exchange rates also have significant implications for trade competitiveness,

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inflation, domestic interest rates, and overall economic stability. So, central banks in general do not allow the exchange rates to fluctuate according to the market sentiment completely. The monetary authorities directly intervene in the forex market to mitigate the excessive volatility which in turn changes the domestic money supply, unless sterilized. So the effect of monetary policy on the exchange rate is a complex relation depending upon the dynamics of the global financial markets, the degree of capital mobility in the domestic economy and also the state of the domestic as well as world economic conditions. Taylor (2001) in discussing the role of exchange rate in monetary policy rule concludes that it is still an unresolved issue how much the rule-based inflation-targeting monetary policy should react to changes in the exchange rate in a flexible exchange rate regime. There exists both, direct and indirect effects of the exchange rate on the interest rate and thus more research is needed to check which effect is desirable and how much. In this field, the most discussed theory is the impossible trinity for which we can find empirical support from Obstfeld, Shambaugh & Taylor (2005). Gaspar and Issing (2002) by examining the EURO area which can be thought of as a large, closed economy, found that the ECB still provide considerable attention to the EURO exchange rate in discussing monetary policy. In the Asian and Latin American context, Saxena (2008) concludes that most of the emerging economies' central banks of these regions intervene in the foreign exchange market as a complementary measure of their monetary policy. Also, in the Indian context, Kumawat and Bhanumurthy (2016) find that monetary policy in India has been responsive to the inflation rate, output gap and exchange rate volatility. In this study, in turn, we are interested in analysing how effective this monetary policy's responsiveness is in the exchange rate determination process. We take India as an interesting case study because of the following facts: India has become more and more global on a gradual basis since the 1990s. Not only its export supply and import demand are gaining significance in the world market, but it is also becoming a major market economy in terms of investor choice for foreign investments. So is the importance of foreign exchange management by the central bank. An orderly situation in the forex market is needed for a host of factors like maintaining export competitiveness, controlling the domestic inflation, investors' confidence etc. India even though still pursuing the partial convertibility of the capital account, occasionally faced surges in capital inflows and thus the associated problems of exchange rate appreciation. In those phases, like the period from 2003 to 2008 RBI had to heavily intervene in the forex market to arrest the downturn of the exchange rate. So, when India is trying to make the capital account fully convertible, in the background, it is important to understand the exchange rate determination process and within this system how much the monetary authority of India is involved or how much the monetary policy of India is capable of affecting the exchange rate. We have organised the rest of the study as follows: section II is devoted to the theoretical background of the empirical study which is presented in section IV. Section III presents the literature review and section V concludes.

II. Theories of Exchange Rate Determination and the Role of Monetary Policy

The traditional models of exchange rate determination, the elasticity approach and the absorption approach were useful during the fixed exchange rate regime. After that Mundell-Fleming model by incorporating the real and monetary sectors tried to deal with capital flows along with the current account transactions. In the asset market approach, explicit emphasis is given to the capital account transactions and hence on the interest rate differentials. As investors change their asset positions instantaneously to changes in their expected returns, the exchange rate also becomes volatile under this regime. The exchange rate is treated as the relative price of foreign assets instead of foreign goods. There are also two distinct branches of literature dealing with the asset market approach of exchange rates primarily based on the assumptions of whether domestic and foreign bonds are perfect substitutes or not. The models' assumptions also differ concerning the relative speed of adjustment of goods and financial market, specialisation in terms of international trade, and size of the country. In this regard, the portfolio balance approach assumes imperfect substitutability of domestic and foreign bonds primarily due to the exchange rate risks. The investor's choice over the bonds is assumed to be an explicit function of the expected returns and hence exchange rate becomes a function of relative supplies of bonds. Frankel (1983) based on the preference structure of the asset holder further classified the portfolio balance approach. The taxonomy of the asset market approach is given by Frankel (1983) also. On the contrary, the monetary approach assumes that domestic and foreign bonds are perfect substitutes. So as long as uncovered interest parity holds, bond supplies do not matter. Money market equilibrium becomes sufficient to determine the exchange rate. Again, based on the assumption of sticky prices in the short-run as opposed to the assumption of flexible prices a different sub-category of models under the monetary approach exists which focuses on the overshooting of the exchange rate in the (Dornbusch,1976; 1980). However, the monetary approach to balance of payment (BOP) models assumes price flexibility and also purchasing power parity (PPP). (see Murphy & Duyne (1980); Ogawa (1987); John (1996); Caves et. al. (1999)).

So, based on the above understanding we shall first try to estimate a reduced form model of the exchange rate under the monetary approach framework of exchange rate determination in a simultaneous framework (Vector Autoregressive model, VAR). We shall try to see whether, in that VAR framework, exchange rate overshooting is evident or not in the corresponding structural model by the impulse response function.

However, acknowledging the restrictive assumptions of PPP and perfect substitutability of domestic and foreign bonds we shall also incorporate in the reduced form model the elements of the portfolio approach of exchange rate like capital inflow, expectations over the exchange rate etc. to make to model robust and also to understand the short-run determination process of the exchange rate and the effectiveness of monetary policy therein.

III. Literature Review

The relation between monetary policy and exchange rate can be analysed from so many angles. So, there is plenty of literature in this field. In the following, we are citing some of those studies. Frenkel (1977) found evidence for the monetary approach to be operative during the period of German hyperinflation. Here he also emphasised that the monetary approach not only includes stock variables under consideration in the process of exchange rate determination but also includes flow variables like income. Murphy & Duyne (1980) presented a theoretical as well as empirical framework to compare the portfolio balance approach and the monetary approach model of exchange rate determination. They also empirically compared the purchasing power parity model's performance in this regard. However, even after getting support from the simulation exercise for the portfolio balance approach, according to them, it is difficult to judge the relative performance of these models with the limited sample they examined. Papell (1994) examined the effect of exchange rates on domestic prices in a semi-structural model where simultaneous relationships between them were assumed. However, after examining G-7 countries, find a relatively small effect on the domestic prices. Their empirical framework was based on the long-run cointegrating relation between the exchange rate and domestic price level in the open economy with sticky prices, which impose long-run Purchasing Power Parity but allow short-run fluctuations in the real exchange rate. Lastrapes (1989) examined the impact of changes in monetary policy regimes in the United States on the stochastic process that determines foreign exchange rates in the period 1976-1986 and found that monetary policy has a significant impact on reducing the exchange rate volatility. Driskill (1981) by analysing the Swiss-US bilateral exchange rate under the monetary approach framework found evidence for the short-run exchange rate overshooting due to a monetary shock. He also found nonmonotonic adjustment of the exchange rate to its equilibrium value in the long run which is of 2 to 3 years in general. Mueller, Tahbaz Salehi & Vedolin (2017) found for the US economy that excess returns on forex trading increase with the interest rate differential, monetary policy uncertainty and the Fed's monetary easing. In this context, Wei (2017) provides a comprehensive analysis of US monetary policy's effect on its different bilateral exchange rates. In examining the effect of monetary policy shift on the exchange rate volatility, interest rates are found to lose their importance on exchange rate returns after the financial crisis and consequent changes in monetary policy in the USA. However, unconventional monetary policy brings no increase in volatility in most of the foreign exchange market in the long run.

Gagnon and Ihrig (2004) found evidence from industrial countries that when monetary policy tightens its policy rates to control inflation, by affecting the inflation expectations, it also reduces the exchange rate pass-through. Bjørnland (2008) by studying Norway's monetary policy in a multivariate VAR framework found that in such a small open economy during a contractionary monetary policy shock, the real exchange rate directly appreciates, followed by a gradual decline again to the baseline. Diamandis & Kouretas (1996) for the Greek economy found evidence for the monetary approach to the exchange rate for five bilateral exchange rates for the country. On the other hand, Kim (1986)'s research empirically validated the portfolio balance approach operating through the current account balance for the Korean economy. Again, Yunus (2001) focused monetary model of the exchange rate determination from the perspective of the South Asian countries using quarterly data. Applying the Johansen multivariate co-integration technique found stable and long-run relationships among so-called fundamentals and exchange rates. Goldfajn & Gupta (2003) find support for the claim that tight monetary policy helps to recover from currency undervaluation, however, after a currency crisis. This result may not be as robust when a country instead of the currency crisis, faces a banking crisis. Hnatkovska, Lahiri & Vegh (2016) identified a difference in the effect of monetary policy on the exchange rate in developed vis-à-vis developing countries, mainly due to differential liquidity demand. Examining 72 countries they found due to a contractionary monetary policy, the domestic currency tends to appreciate in developed countries but depreciate in developing countries. Khan and Rahman (2017) established a good link between monetary policy and the exchange rate in Bangladesh in the SVAR framework.

For the Indian economy, Sen (2010) discussed the problems of capital inflow and concluded that the use of monetary policy in India has been constrained by a loose fiscal policy and capital flows. Capital inflows have the potential to cause a Dutch Disease-type situation. That is, with an increase in the capital flow exchange rate may appreciate and prevent the undesirable appreciation of the exchange rate. Kumawat and Bhanumurthy (2016) using a non-linear model of multiple-regime STAR found that during periods of low inflation, the exchange rate is normally the focus of monetary policy and also in periods of significant depreciation. How important exchange rate is in framing monetary policy we can also cite Devereux., Lane and Xu (2006) who by examining the emerging economies that experience external shocks in the interest rate and terms of trade found that exchange rate pass-through is critical in deciding the best policy rule. Pattanaik and Mitra (2001), Pattnaik, Kapur & Dhal (2003) also found the interest rate channel to be effective in the exchange rate management of the Indian economy. However, Goyel (2010) comments that even if the relative money supplies, prices, output, and interest rates are the determinants of the exchange rates, researchers found the random walk model to beat all fundamental-based short-term forecasts of a floating exchange rate (see also Meese and Rogoff, 1983). At the same time, she also emphasised that the central bank has a definite role in this regard particularly for countries like India where we still enjoy partial capital account convertibility. Here, HUTCHISON *et. al.* (2010)'s observation is that the exchange rate is not an important variable in designing the RBI's monetary policy. However, Kumawat and Bhanumurthy (2018) found exactly the opposite. Dua and Ranjan (2010) likewise, in a different setting, found the monetary model to outperform the naïve, random walk model. This also disproves the findings of Meese and Rogoff (1983). To improve the monetary model's performance even in the short-run they incorporated the elements of microstructure models like order flow, as well as capital flows, forward premium and central bank intervention. Sharma and Setia (2017) by applying the VAR methodology in the Indian context from 2001-2014 found monetary policy shock to be qualitatively robust and consistent with theory as well as empirical literature. Patnaik and Sengupta (2021) examined the RBI's periodic use of forex intervention to control the exchange rate from 2000 to 2020 and found between 2008 - 2013 the rupee was under pressure with high volatility.

From the above brief survey of the literature, we find evidence from various parts of the globe that on average monetary approach to the exchange rate or specifically the monetary policy has limited effectiveness in affecting the exchange rate. However, very few studies have analysed the Indian experience in this context and concluded anything unanimous regarding the effect of monetary policy decisions on the exchange rate. In the meantime, India's exchange rate dynamics witnessed a historically high depreciating phase, particularly since 2012. This makes us interested in India's exchange rate determination process.

By this study, we want to enrich the literature by extending the period of study to such an extent that it includes both, the pre and post-financial crisis period. We have also experimented with different sub-periods based on our observations and endogenous break analysis to understand whether the efficacy of the monetary policy over time has improved or not. More importantly, we would like to investigate whether the interest differential or the relative money supply, which one is becoming the most important in terms of exchange rate determination in India.

IV. Econometric Analysis and Discussion

We have chosen to analyse India's exchange rate for the US Dollar in a bilateral framework. Our study period is 1996 M01 to 2023 M06. We have chosen 1996 instead of 1993, the year when India officially adopted the flexible exchange rate regime because of our casual observation of the raw data of exchange rates (see Figure A.1 in Appendix I) which is further substantiated by the Bai-Perrons's (2003) endogenous breakpoint estimation analysis (see Table A.1 in Appendix I). India's exchange rate for the US Dollar starts to reveal market fluctuations only from 1996 onwards.

At the onset, we must also state that most of the variables we have used in this analysis are *I(1)*. The unit root test results are given in Appendix II. From Appendix I we can find the list of variables used in this analysis.

Now, as our first step in framing a monetary approach framework, we test whether the PPP holds for the US Dollar exchange rate of the Indian rupee.

If PPP holds, then the relation between exchange rate and domestic and foreign price levels can be expressed through the following equation (1):

$e = \frac{p}{p^*} \ldots\ldots (1)$; where e is the spot exchange rate, p is the domestic price level and p^* is the foreign price level.

Now to test whether the above equation is true or not for India, we followed the statement, "If PPP is true, inter-country commodity arbitrage ensures that deviations from a linear combination of spot exchange rates and domestic and foreign price levels should be stationary" (Corbae & Ouliaris,1988).

The above statement implies that either the series *ep/p** for India is stationary or the linear combination of *e, p* and *p** is cointegrated. Here using an appropriate price index is also important. We can find a discussion on this issue in Frenkel (1977). Following this we find the consumer price index to be the most appropriate in this regard.

However, as the following Table 1 indicates, we do not find any support for PPP to hold for the India-US exchange rate from 1996 to 2023. The series *ep/p**, indicated as *PPPCPI,* is found to be non-stationary in both the ADF and PP tests.

Again, from the regression analysis, we find the domestic and foreign price levels are affecting the exchange rate in line with the theoretical suggestions of PPP as indicated in equation (1). However, this linear combination of exchange rate and price levels is not cointegrated. In this regard, we have followed the Angle-Granger method of cointegration, where some non-stationary series, with the same order of integration *(in this case, I(1))*, are called cointegrated if the residual of the linear regression analysis of those series is found to be integrated of lower order *(I(0) for this case)*. Here firstly we have linearised equation (1) by taking the log on both sides and then regressed ln(CPI) of India and the USA on the Ln(exchange rate). The results are shown in the lower panel of Table 1. Here it is also shown that the residual of the regression equation is found to be non-stationary in ADF tests.

Table 1: PPP Stationarity Test		
A. Unit Root Test		
Null Hypothesis: PPPCPI has a unit root		
	t-Stat	Prob.*
Augmented Dickey-Fuller test statistic	-1.76	0.40
	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-1.99	0.29
B. Engle-Granger Cointegration Test		
Dependent Variable: LNUSD		
Independent Variables	Coff.	Prob.
C	3.9	0.0
LNNEW__CPI_IW_G	0.6	0.0
LNCPI__USA_All	-0.4	0.0
R-squared	0.91	
Null Hypothesis: RESIDUAL _PPPCPI has a unit root		
Exogenous: None		
Augmented Dickey-Fuller test statistic	-0.77	0.38
Note: Johansen Co-integration test also confirms the result of no cointegration.		
Source: Author's calculation.		

Now, from the PPP condition, the monetary approach is derived as follows: if the exchange rate can be expressed as a ratio of two price levels then we can express the exchange rate as a ratio of the determinants of these price levels, namely the equilibrium of money demand (a function of income and interest rate) and money supply (primarily exogenous). So, in effect, the exchange rate becomes a function of income, interest rate and money supply differential of both countries involved as the equation (4) indicates. The derivation is as follows:

The equilibrium of money demand and money supply are shown as:

$\frac{\boldsymbol{M^S}}{\boldsymbol{p}} = M^d(y, r)$ ……(2) for the domestic economy and $\frac{\boldsymbol{M^{S*}}}{\boldsymbol{p^*}} = M^{d*}(y^*, r^*)$…….(3) for the foreign economy. Now, putting equations (2) and (3) in equation (1) and after rearranging we find:

$$e = \frac{M^S}{M^{S*}} \times \frac{M^{d*}(y^*,r^*)}{M^d(y,r)} \text{……….(4)}$$

This formulation makes the relation applicable in the short-run also. It also follows that changes in exchange rates i.e., appreciation or depreciation are functions of inflation differential or in turn depend on income growth, interest and money growth differentials. So, we have tried to estimate our basic econometric model of exchange rate determination by this formulation. As stated before we have included the other variables like capital flows, RBI's net sale and purchase etc. as additional determining factors in that model.

However, before proceeding to that we would like to present the exchange rate determination of India in a simultaneous framework. This is important given 1). the considerable amount of RBI's net sale and purchase of forex on an occasional to regular basis which changes the domestic money supply, unless sterilized; 2). exchange rate passthrough in domestic inflation; 3). forex market efficiency and interest determination; 4). exchange rates effect on net exports etc. All these are accounting the effect of the exchange rate on economic variables like money supply, price level, interest rate and income respectively. So, the theoretical relation between these variables is expected to be simultaneous in nature and to capture that relation we have used the multi-variate VAR model which first estimates the reduced form equations for each variable in the system as a function of its own and each other variables' lag values. Then based on Cholesky's decomposition method we find the underlying structural equations from which we can estimate the effect of an exogenous shock of any variable, say money supply or monetary policy, on the other variables, say exchange rate, in the system. This is called the impulse response function. However, impulse response function to be stable, the underlying system must be stationary. So, even though we have estimated both, the VAR model in the level values of the variables and in their difference-form which are found to be I(0), we have only estimated the impulse response function for the differenced model.

In the following Table 2, we have presented the cointegration test results and the corresponding VAR model in levels of the variables Price level (CPI), Money supply(M3), output (IIP), monetary policy stance (MPS), exchange rate(Rs/US$). From the upper panel of Table 2, we find evidence of cointegration among the variables (even though conclusions based on trace and eigenvalue statistics differ). So, we have estimated the VAR model in levels only to find that there exists no simultaneous relation among the variables we have used. Only the exchange rate is found to affect the IIP. No variable in turn is found to be the significant determinant of the long-run value of the exchange rate, except its lag values in this model.

Table 2: Cointegration and VAR (in level) Estimates				
Sample (adjusted): 1996M04 2022M06 (315 observations)				
Variables included: LNNEW_CPI_IW_G, LNBROAD_MONEY, LNIIP_G_, LNNEW_MPS, LNUSD				
Trend assumption: Linear deterministic trend				
Hypothesized No. of CE(s)	Trace Statistic	Prob.**	Max-Eigen Statistic	Prob.**
None	142.11	0.00	74.77	0.00
At most 1	67.34	0.00	25.87	0.08
At most 2	41.47	0.00	21.17	0.05
At most 3	20.30	0.01	15.51	0.03
At most 4	4.79	0.03	4.79	0.03

**MacKinnon-Haug-Michelis (1999) p-values
Trace test indicates 5 cointegrating eqn(s) at the 0.05 level
Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
Lag is selected based on the Lag-Selection Criteria

Vector Autoregression Estimates					
t-statistics in [ ]					
	LNNEW_CPI_IW_G	LNBROAD__MONEY	LNIIP_G_	LNNEW_MPS	LNUSD
LNNEW_CPI_IW_G(-1)	0.86	-0.03	0.08	0.08	0.10
	[14.8702]	[-0.72902]	[0.30341]	[0.76860]	[1.47873]
LNNEW_CPI_IW_G(-2)	0.08	0.02	-0.40	0.03	-0.05
	[1.44783]	[0.60110]	[-1.49308]	[0.33712]	[-0.76411]
LNBROAD__MONEY(-1)	0.28	0.95	-1.09	-0.18	-0.04
	[3.33444]	[16.1336]	[-2.80988]	[-1.23384]	[-0.37488]
LNBROAD__MONEY(-2)	-0.26	0.04	1.48	0.13	0.03
	[-3.16693]	[0.65679]	[3.84412]	[0.86122]	[0.35394]
LNIIP_G_(-1)	0.07	0.01	0.36	0.03	-0.02
	[5.44359]	[1.29736]	[6.08191]	[1.44891]	[-1.14122]
LNIIP_G_(-2)	-0.05	0.01	0.11	-0.01	-0.01
	[-3.94412]	[1.42547]	[1.74200]	[-0.32017]	[-0.34904]
LNNEW_MPS(-1)	0.03	-0.01	0.54	1.08	-0.04
	[0.83532]	[-0.29933]	[3.62202]	[18.7432]	[-1.01144]
LNNEW_MPS(-2)	-0.01	0.01	-0.44	-0.14	0.04
	[-0.29039]	[0.22945]	[-2.99458]	[-2.46168]	[1.15051]
LNUSD(-1)	0.02	-0.02	**-0.52**	-0.03	1.20
	[0.50331]	[-0.60378]	**[-2.28965]**	[-0.30195]	[21.3709]
LNUSD(-2)	0.00	0.02	**0.42**	-0.06	-0.25
	[0.10107]	[0.64811]	**[1.83046]**	[-0.70473]	[-4.43124]
C	-0.26	0.07	-2.09	0.75	0.14
	[-2.08939]	[0.82354]	[-3.65501]	[3.40342]	[0.98045]

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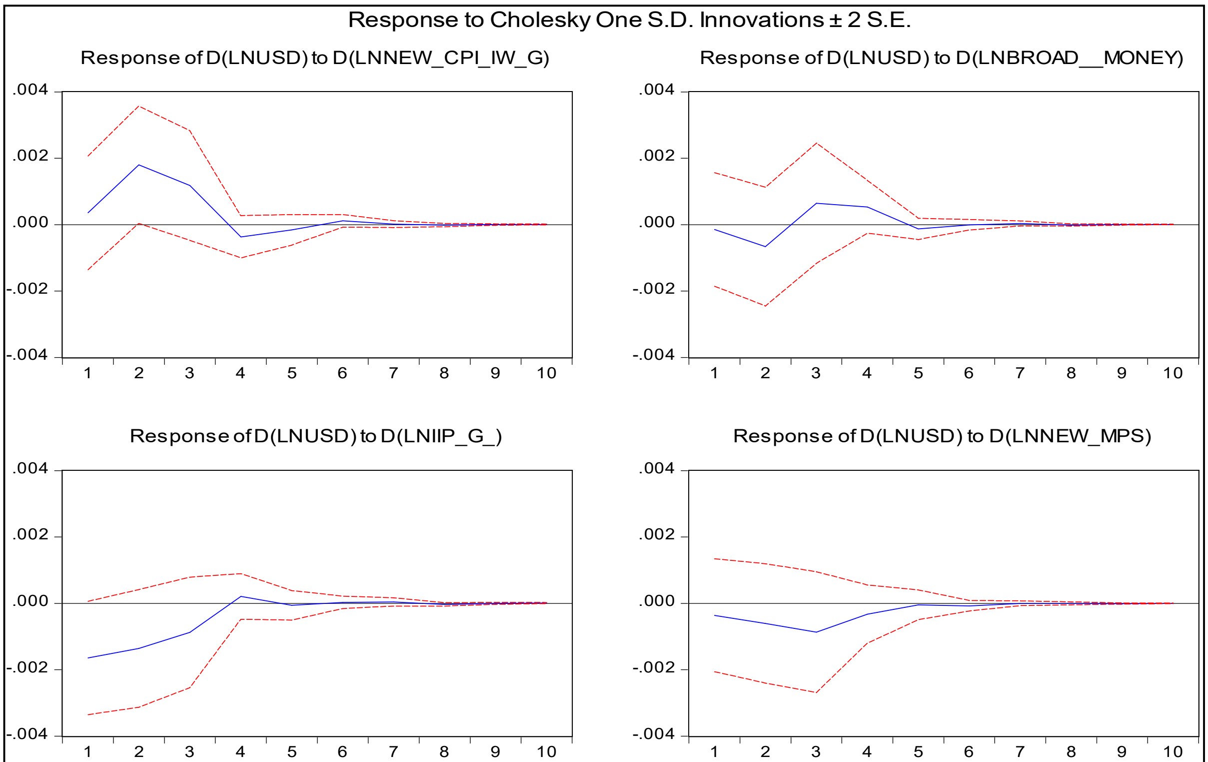
R-squared	1.00	1.00	0.98	0.99	1.00
F-statistic	41409.85	391471.50	1370.13	3905.97	6407.31

Source: Authors' calculation.

So, we estimated the short-run model with stationary variables to have the impulse response functions. We have used the variables in the same order which assumes the monetary policy or the interest rate only has a contemporaneous effect on the exchange rate. The other variables respond to the changes in monetary policy only with lags. Prices being sticky are ordered at first. In the following Figure 1, we have presented the impulse response functions of the exchange rate only.

Here we can see from the second column the responses of the exchange rate to the exogenous changes in domestic money supply and monetary policy respectively. In both cases, we experience an appreciation. However, in the case of money supply, the appreciation is very short-lived. Then the exchange rate overshoots before the effect of the shock is eliminated. With a rise in monetary policy, the appreciation lasts for three months and it takes 5 months to get the effect of the shock eliminated. This result of monetary policy's effectiveness is similar to Pattanaik and Mitra (2001), Pattnaik, Kapur & Dhal (2003), but on different specifications.

Figure 1: Impulse Response Functions (up to 10 months):



Source: Authors' estimation using the E-views software.

Here, we should note that even though we find money supply and monetary policy's effect on the exchange rate, the underlying reduced form VAR estimates (results are not shown here) are not robust in the sense that only the CPI-inflation and IIP-growth have become significant at 5 and 10 % level of significance respectively in the equation for the changes in the exchange rate. Also, no effect of changes in the exchange rate is found on any other variable. So, as noted earlier we would like to estimate the determination of the exchange rate in the short-run monetary approach framework in the single equation framework, as indicated by equation (4). For this purpose, we have used the ADRL model to allow for the usual lag adjustments underlying macroeconomic relations.

From Table 3 we find no effect of the domestic or foreign money supply as well as domestic and foreign CPI-inflation on the changes in the exchange rate. This finding is consistent with the negation of PPP holding. However, the interest differential measured as a difference between MPS and Federal funds rates has a significant effect on the exchange rate. Domestic IIP growth appreciates the exchange rate significantly. The US IIP growth was also found to be significant.

The lag positive effect of interest differential on the changes in exchange rate corroborates in the long run the uncovered interest parity condition which states that the expected rate of depreciation will be equal to the nominal interest differential. If the interest parity conditions hold, then it becomes difficult for the monetary authority to affect the exchange rate via the interest channel (Flood and Rose, 2002). In this regard, as the expected rate of depreciation is difficult to measure, following the literature we find some evidence of covered interest parity which states that the nominal interest differential is equal to the forward premia. Here we assume forward premia to represent the expected change in the exchange rate. In Appendix II we have presented this result of forex market efficiency in more detail.

We have experimented with several models and found that incorporating the interest differential improves the model. Based on the portfolio approach to exchange rate determination when we include capital inflow and also RBI's net sale and purchase of forex, the model improves significantly (see Model 2). Capital inflow makes the short-run effect of interest differential insignificant.

Due to the paucity of space and also to make the presentation easily comprehensible, we have not shown all the results of all the specifications we have tried. Some important observations from those experiments are including crude oil neither improves the model nor is becoming significant. Including the lag values of exchange rate changes significantly improves the R-square value but only the coefficient of lag 4 is becoming significant. This may indicate the importance of the random walk model against the macro fundamentals found in Meese and Rogoff (1983).
In the lower panel of table 3, we have presented the models 3 and 4 for two different sub-periods. Based on the structural breaks and casual observation of the data of the changes in exchange rate we select these truncated periods. Model 4 can be considered as the post-financial crisis model while model 3 captures the whole period which includes both the high and decelerated phase of foreign capital inflow. We could not estimate models for different regimes we found from structural break analysis because of the short span of the regimes.

Table 3: ARDL Estimates*

Dependent Variable: D(LNUSD)

Model 1

Sample (adjusted): 1996M05 2022M06 (314 Observations)

Variable	Coefficient	Prob.
D(LNUSD(-1))	0.25	0.00
D(LNBROAD__MONEY)	-0.04	0.64
D(LNUS_M3_)	-0.08	0.73
D(LNUS_M3_(-1))	-0.44	0.07
D(LNUS_M3_(-2))	0.07	0.76
D(LNUS_M3_(-3))	0.39	0.07
D(LNIIP_G_)	-0.02	0.27
D(LNIIP_G_(-1))	**-0.08**	**0.00**
D(LNIIP_G_(-2))	**-0.05**	**0.01**
D(LN_US__IIP_)	-0.05	0.66
D(LN_US__IIP_(-1))	-0.06	0.58
D(LN_US__IIP_(-2))	**-0.25**	**0.02**
D(LN_US__IIP_(-3))	**0.21**	**0.04**
D(MPS_FED_)	0.01	0.06
D(MPS_FED_(-1))	**-0.02**	**0.00**
D(MPS_FED_(-2))	-0.01	0.33
D(MPS_FED_(-3))	**0.02**	**0.01**
C	0.00	0.12
R-squared	0.19	0.00
Adjusted R-squared	0.15	0.02
F-statistic	4.15	
Prob(F-statistic)	0.00	
Durbin-Watson stat	1.97	

Model 2

Sample (adjusted): 1996M05 2022M06 (271 observations)

Variable	Coefficient	Prob.
D(LNUSD(-1))	0.19	0.00
D(LNCPI__US_A)	-0.39	0.26
D(LNNEW_CPI_IW_G)	0.02	0.76
D(LNIIP_G_)	0.00	0.83
D(LNIIP_G_(-1))	**-0.07**	**0.00**
D(LNIIP_G_(-2))	**-0.05**	**0.00**
D(LN_US__IIP_)	-0.11	0.31
D(LN_US__IIP_(-1))	**0.30**	**0.01**
D(LN_US__IIP_(-2))	**-0.25**	**0.02**
D(LN_US__IIP_(-3))	0.17	0.07
D(MPS_FED_)	0.01	0.24
D(MPS_FED_(-1))	-0.01	0.13
D(MPS_FED_(-2))	-0.01	0.18
D(MPS_FED_(-3))	**0.02**	**0.00**
LNSALE_PURCHASE	**-0.03**	**0.00**
LNSALE_PURCHASE(-1)	**0.02**	**0.00**
LNCAP_INFLOW	-0.001	0.48
LNCAP_INFLOW(-1)	**0.002**	**0.05**
LNCAP_INFLOW(-2)	0.000	0.93
LNCAP_INFLOW(-3)	**-0.002**	**0.10**
C	0.13	0.02
R-squared	0.34	0.00
Adjusted R-squared	**0.28**	0.02
F-statistic	6.31	
Prob(F-statistic)	0.00	
Durbin-Watson stat	1.99	

*Model selection method: Akaike info criterion (AIC)

Table 3B: ARDL Estimates*					
Dependent Variable: D(LNUSD)					
Model 3			**Model 4**		
Sample (adjusted): 2004M03 2022M06 (177 observations)			Sample (adjusted): 2012M02 2022M06 (119 observations)		
Variable	Coefficient	Prob.	Variable	Coefficient	Prob.
D(LNUSD(-1))	0.25	0.00	D(LNUSD(-1))	0.16	0.10
D(MPS_FED_)	0.01	0.37	D(MPS_FED_)	0.00	0.86
D(MPS_FED_(-1))	0.00	0.90	**D(MPS_FED_(-1))**	**0.02**	**0.07**
D(MPS_FED_(-2))	-0.01	0.20	D(LNBROAD__MONEY)	0.10	0.53
D(MPS_FED_(-3))	**0.02**	**0.00**	D(LNUS_M3_)	0.01	0.98
D(LNBROAD__MONEY)	-0.04	0.74	D(LNNEW_CPI_IW_G)	0.12	0.52
D(LNBROAD__MONEY(-1))	-0.17	0.17	**D(LNNEW_CPI_IW_G(-1))**	**0.35**	**0.03**
D(LNUS_M3_)	**-0.62**	**0.04**	D(LNCPI__US_A)	-0.55	0.34
D(LNNEW_CPI_IW_G)	-0.04	0.76	D(LNIIP_G_)	-0.03	0.36
D(LNNEW_CPI_IW_G(-1))	**0.27**	**0.05**	D(LN_US__IIP_)	0.15	0.36
D(LNNEW_CPI_IW_G(-2))	-0.12	0.37	**D(LN_US__IIP_(-1))**	**0.33**	**0.03**
D(LNCPI__US_A)	-0.59	0.18	**LNSALE_PURCHASE**	**-0.04**	**0.00**
D(LNIIP_G_)	-0.03	0.24	**LNSALE_PURCHASE(-1)**	**0.02**	**0.04**
D(LNIIP_G_(-1))	**-0.07**	**0.03**	**LNCAP_INFLOW**	**-0.01**	**0.04**
D(LNIIP_G_(-2))	-0.04	0.14	LNCAP_INFLOW(-1)	0.00	0.88
D(LNIIP_G_(-3))	0.04	0.04	**LNCAP_INFLOW(-2)**	**0.01**	**0.02**
D(LN_US__IIP_)	-0.12	0.38	**LNFORWARD_PREMIA_US_$__6**	**-0.05**	**0.03**
D(LN_US__IIP_(-1))	0.26	0.09	LNFORWARD_PREMIA_US_$__6(-1)	0.05	0.16
D(LN_US__IIP_(-2))	**-0.35**	**0.02**	LNFORWARD_PREMIA_US_$__6(-2)	-0.06	0.07
D(LNSALE_PURCHASE)	**-0.03**	**0.00**	**LNFORWARD_PREMIA_US_$__6(-3)**	**0.06**	**0.00**
D(LNCAP_INFLOW)	**-0.003**	**0.01**	C	0.20	0.05
D(LNCAP_INFLOW(-1))	**-0.004**	**0.03**			
C	0.01	0.01			

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		*Model selection method: Akaike info criterion (AIC)	
R-squared	0.41	R-squared	0.39
Adjusted R-squared	0.32	Adjusted R-squared	0.26
F-statistic	4.80	F-statistic	3.10
Prob(F-statistic)	0.00	Prob(F-statistic)	0.00
Durbin-Watson stat		Durbin-Watson stat	

Source: Author's calculation.

Here, interestingly we find US money supply to have an appreciating effect on the exchange rate in model 3. This signifies the buoyant phase the world witnessed before the financial crisis and the squeeze it faced after that. In both models, 3 and 4, we find CPI inflation to have a positive relation with the exchange rate depreciation. Capital inflow becomes more significant as expected during these phases. We also found expectations, captured by the 6-month forward premium, to become important in model 4. Due to the data unavailability, we could not include this variable in the other models. The forward premium of 3 month or 1 year did not become significant (results not shown).

V. Conclusion

From our analysis, we find the monetary approach to the exchange rate is not operative in the Indian economy. However, in both, the simultaneous and single equation framework of VAR and ARDL respectively we find the monetary policy to have a significant effect on the exchange rate in the short run. However, this interest rate channel does not show any improvement over time. Regarding money supply, we only find US money supply growth to be effective from the later part of our analysis. The domestic money supply growth has no major role in determining the exchange rate dynamics. We find a significant effect of domestic inflation in exchange rate depreciation for the latest years. So, monetary policy by containing domestic inflation may prevent excessive depreciation. We would like to explore this channel in further detail in future.

The significant effect of capital inflow, market expectations proxied by forward premia etc. signifies the importance of the portfolio approach to the exchange rate over the monetary approach. The importance of market expectations often makes the monetary policy difficult to operate through the interest rate channel. Exploring this channel also in more detail is our future research agenda. This analysis provides a basic understanding of India's exchange rate determination over the last two and half decades.

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Appendix-I: Data

We have considered the Exchange Rate of the US Dollar as a representative measure of the exchange rate.

Forward premia of US$ for 1,3,6 months are also used as a proxy of market expectation which is treated as an exogenous variable. It is considered an important determinant of the spot exchange rate in the portfolio-balance approach of exchange rate determination.

Based on the monetary approach to exchange rate determination, as a measure of price level, output and money supply we have used are the Consumer Price Index (CPI), Industrial Index of Production (IIP) and broad money respectively. For India, the CPI of General Index for Industrial Workers and the new series available from 2014 as CPI-Combined are used for CPI and for the USA we have used the CPI of All Commodities. For both countries, broad money and IIP-general are used in this analysis.

As a measure of interest rate, we have used different interest rates like monetary policy stance, call money rate, treasury bill yields etc. We have constructed the monetary policy stance as a weighted average of CRR, Bank rate, Repo rate and SLR, where the weights are calculated based on the number of changes in each of the monetary policy instruments that occurred during our study period. For the US economy, we have used the Federal Funds Rate for this purpose. We have used the weighted average call money rate for India, the call money rate for the USA and 3 months, 6 months and 1 year Treasury Bill yield for both, India and USA as different other interest rates.

As important determinants of exchange rate under the portfolio approach, we have also used Foreign direct investment (FDI in US Million Dollar), Foreign investment inflow (FII in US Million Dollar), RBI's net sales and purchase of US dollars (in US million), and Crude Oil Prices ($ per barrel).

This study covers the period from 1996 to 2023 using monthly data. The data are culled from the Federal Reserve Bank of St. Louis and RBI (Reserve Bank of India).

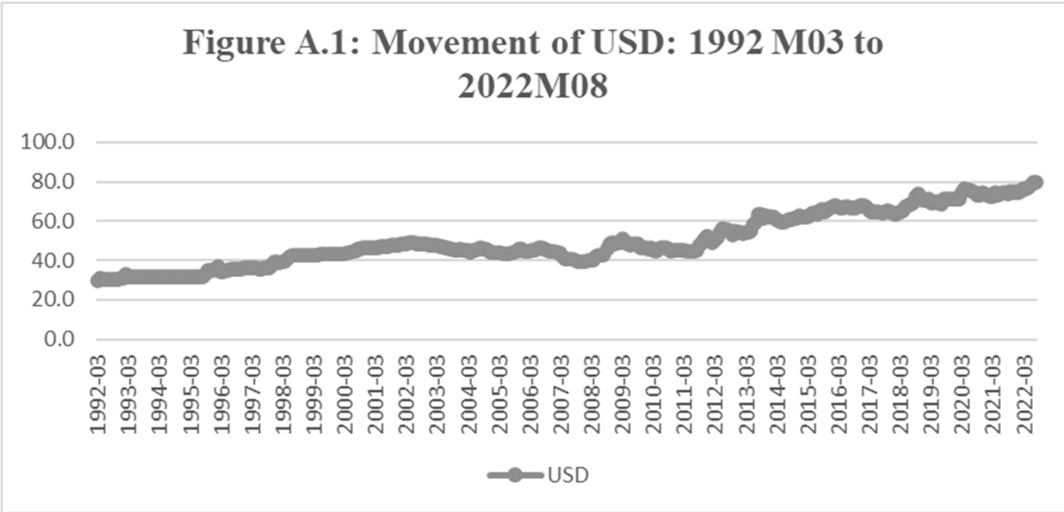


Table A.1: Structural Break Analysis

Bai-Perrons's Multiple Break Point Tests: 1991M01 to 2023 M06
Breaking Variable: C; Trimming 0.15; Max. break 5; Sig. level 0.05
Udmax determined breaks: **3**; 1997M12, 2012M05, 2018M08 **Udmax statistic: 2082.349* (8.88)**
Wdmax determined breaks: **5**; 1997M12, 2004M02, 2008M10, 2013M06, 2018M08 **Wdmax statistics: 3227.151* (9.91)**
*implies 5% level of significance Note: Bai-Perron (2003) critical values are given in the parenthesis. Source: Authors' calculation.

Appendix II

Table A.2: Unit Root Test Results

	ADF Test Results						PP Test Results					
variable	constant		trend		1st diff. constant		constant		trend		1st diff. constant	
	T value	P value	T value	P value	T value	P value	T value	P value	T value	P value	T value	P value
lnWACR	-4.69	0.00					-5.85	0.00				
lnUSD	0.78	0.99	-1.29	0.88	-12.52	0.00	0.46	0.98	-1.36	0.87	-12.64	0.00
Ln CPI-G	-1.06	0.72	-1.74	0.72	-4.12	0.00	-1.77	0.39	-2.07	0.55	-25.80	0.00

lnIIP	-1.64	0.45	-1.22	0.90	-7.63	0.00	-1.57	0.49	-6.21	0.00		
LnBroad Money	-2.32	0.16	0.52	0.99	-3.55	0.03	-3.56	0.00	0.82	0.99	-18.72	0.00
lnCrude oil	-1.88	0.34	-2.95	0.14	-15.15	0.00	-1.47	0.54	-2.68	0.24	-14.75	0.00
LnIIP_US	-3.27	0.02	-3.39	0.05	-13.59	0.00	-3.30	0.01	-3.42	0.05	-14.93	0.00
LnBroad Money_US	-0.26	0.92	-2.38	0.39	-9.08	0.00	-0.20	0.93	-2.38	0.39	-9.08	0.00
LNCPI-All (US)	0.42	.98	-1.08	.93	-12.12	0.00	0.43	.98	-1.26	.90	-12.29	0.00
lnFDI	-2.30	0.17	-10.0	0.00			-8.08	0.00				
lnFII	-1.20	0.67	-4.53	0.00			-3.79	0.00				
Ln 3m TB yield rate	-1.40	0.58	-1.56	0.80	-10.39	0.00	-1.25	0.65	-1.51	0.82	-10.27	0.00
Ln 6m TB yield rate	-1.31	0.62	-1.38	0.86	-10.46	0.00	1.26	0.65	-1.46	0.84	-10.38	0.00
Ln 1yr TB yield rate	-1.07	0.73	-1.17	.91	10.91	0.00	-1.29	0.63	-1.51	.82	-10.93	0.00
Ln call money rate(US)	-1.86	0.35	-1.57	0.80	-11.87	0.00	-1.84	0.36	-1.48	0.83	-11.87	0.00
Ln 3m Tb(US)	-1.78	0.39	-1.48	0.83	-13.91	0.00	-1.86	0.38	-1.50	0.83	-14.62	0.00
Ln 6mTb(US)	-2.13	0.23	-1.95	0.62	-6.26	0.00	-1.86	0.35	-1.56	0.80	-13.96	0.00
Ln 1 Yr Tb(US)	-1.91	0.33	-1.85	0.67	-9.35	0.00	-1.72	0.42	-1.51	0.82	-9.85	0.00
New MPS	-1.39	0.59	-2.95	0.15	-4.68	0.00	-1.15	0.69	-2.55	0.30	-11.47	0.00
Ln federal fund rate	-1.47	0.55	-1.94	0.63	-8.60	0.00	-1.17	0.69	-1.65	0.77	-8.49	0.00
Ln forward premia 1M	0.38	0.98	-2.21	0.48	-2.22	0.20	-0.20	0.94	-3.41	0.05	-18.84	0.00
Ln forward premia 3M	0.15	0.97	-3.12	0.11	-10.19	0.00	0.10	0.96	-3.17	0.09	-10.81	0.00
Ln forward premia 6M	0.40	0.98	-3.14	0.10	-10.83	0.00	0.34	0.98	-3.25	0.08	-10.93	0.00

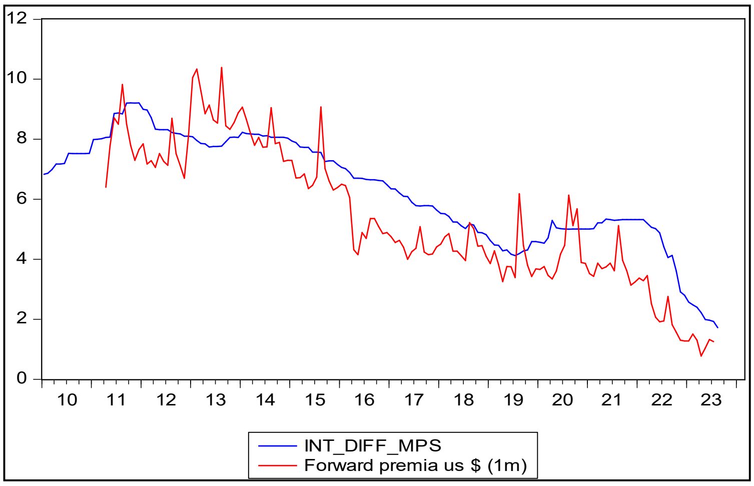
Covered Interest Parity Condition

If the forward premia are found to be cointegrated with the interest differentials and the long-run coefficients of the β and a of the following equation become 1 and 0 respectively then we can say the covered interest parity holds:

$$(forward\ premium)_t = a + \beta(\mathrm{i} - \mathrm{i}\,*)_t + e_t$$

In the following table we present the Johansen and Engle-Granger cointegration results for 1 month forward premium and two different interest differentials. The first one is based on MPS and Federal funds rate and the 2nd one is based on call money rates of India and the USA. In both the cases we find the series are cointegrated. However, the coefficients for a and β are not very close to zero and 1. In the following, we have also presented a figure showing the correlated movement of the 1-month forward premium and the interest differential based on the policy rates.

II. A. Johansen Cointegration Tests									
Sample (adjusted): 2011M11 2023M07 Series: INT_DIFF_MPS FORWARD_PREMIA_US_$__1M_					Sample (adjusted): 2011M09 2023M05 Series: FORWARD_PREMIA_US_$__1M_ INT. DIFF_CMR				
Hypothesized No. of CE(s)	Trace Statistic	Prob.**	Max-Eigen Statistic	Prob.**	Hypothesized No. of CE(s)	Trace Statistic	Prob.**	Max-Eigen Statistic	Prob.**
None	15.93	0.04	15.88	0.03	None	39.38	0.00	31.02	0.00
At most 1	0.05	0.82	0.05	0.82	At most 1	8.35	0.43	7.72	0.41
					At most 2	0.63	0.43	0.63	0.43
II. B. Engle-Granger Test									
Dependent Variable: FORWARD_PREMIA_US_$__1M_					Dependent Variable: FORWARD_PREMIA_US_$__1M_				
Variable	Coefficient	Std. Error	t-Statistic	Prob.	Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.85	0.29	-6.28	0.00	C	1.17	0.19	6.26	0.00
INT_DIFF_MPS	1.17	0.05	25.60	0.00	INT_DIFF_CALL	0.82	0.03	25.40	0.00
R-squared	0.82				R-squared	0.82			
Null Hypothesis: RESID02 has a unit root									
			t-Statistic	Prob.*				Adj. t-Stat	Prob.*
Augmented Dickey-Fuller test statistic			-3.4	0.0	Augmented Dickey-Fuller test statistic			-4.8	0.0
Test critical values:	1% level		-2.6		Test critical values:	1% level		-2.6	
	5% level		-1.9			5% level		-1.9	
	10% level		-1.6			10% level		-1.6	
*MacKinnon (1996) one-sided p-values.									
**MacKinnon-Haug-Michelis (1999) p-values									



Experiments with 3-month, 6-month and 1-year forward premia with 3-month, 6-month and 1-year treasury bill yield differential give similar results.