# Modelling Rupee-Dollar Exchange rate using the Monetary Approach: Some Issues and Evidence

**A thesis submitted during 2020 to the University of Hyderabad in partial fulfillment of the award of a Ph.D. degree in School of Economics.**

By

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# CERTIFICATE

This is to certify that the thesis entitled **"Modelling Rupee-Dollar Exchange rate using the Monetary Approach: Some Issues and Evidence"** submitted by **Topunuru Kaladhar** bearing Reg. No.**15SEPH22** in partial fulfillment of the requirements for the award of Doctor of Philosophy in **Economics** is a bonafide work carried out by him under my supervision and guidance. The thesis has not been submitted previously in part or in full to this or any other University or Institution for the award of any degree or diploma. The candidate has satisfied the UGC Regulations of publications and conference presentations before the submission of his thesis. Details are given below.

A. Publications:

1. Manuscript ID IJFE-20-0919 entitled *"Modelling Rupee-Dollar exchange rate using the monetary approach in the times of financial innovation: does measurement of money matter?"* which is submitted to *International Journal of Finance and Economics*, has been reviewed. This publication is the part of third chapter of thesis, which is under revision at present.

B. Presentations in conferences:

1. Presented a paper: "Revisiting monetary approach to exchange rate determination with Divisia money: Some Indian evidence" in the 22$^{nd}$ Biennial Conference of Association of Indian Economic and Financial Studies (AIEFS) during 31$^{st}$ July-1$^{st}$ August 2017 held at NCDS, Bhubaneswar.

2. Presented a paper: "Forecasting Rupee/US dollar exchange rate with Divisia monetary aggregates: Some evidence in Indian context." in the 55$^{th}$ Annual conference of The Indian Econometric Society (TIES) held during 8-9 January, 2019 at the NISM campus, Patalaganga.

Further, the student has passed the following courses towards fulfillment of coursework requirement for Ph.D./was exempted from doing coursework (recommended by Doctoral Committee) on the basis of the following courses passed during his M.Phil program and the M.Phil degree was awarded.

| Course Code | Course Title | Credits | Pass/Fail |
|---|---|---|---|
| LA6030 | Qualitative Research Methods | 3 | Pass |
| LA6040 | Financial Markets & Institutions | 3 | Pass |
| LA6050 | Basic Econometrics & Forecasting | 3 | Pass |
| LA6060 | International Finance | 3 | Pass |
| LA6120 | Advance Econometrics | 3 | Pass |
| LA6130 | Advance Macroeconomics | 3 | Pass |
| LA6210 | Special Topics in Economic Research | 3 | Pass |

(Dr. Debashis Acharya)
Professor, Department of Economics
Signature of the Supervisor

Dean of the School

# DECLARATION

I **Topunuru Kaladhar** hereby declare that this thesis entitled **"Modelling Rupee-Dollar Exchange rate using the Monetary Approach: Some Issues and Evidence"** submitted by me under the guidance and supervision of Professor **Debashis Acharya** is a bonafide research work. I also declare that it has not been submitted previously in part or in full to this University or any other University or Institution for the award of any degree or diploma.

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# Motivation, problem setting and objectives of the study

## 1. Introduction

Exchange rate is one of the crucial macro-economic variables to determine trade, inflation, and investment in a full or partial open economy environment. Hence, the exchange rate movements are the manifestation of stable macroeconomic conditions and efficient production of the country, which have macroeconomic policy implications. In integrated economies, these movements do carry significant weight in conducting monetary and fiscal policies as their success depends on the existence of impossible trilemma among monetary policy autonomy, capital account openness, and fixed exchange rates. This indicates that the monetary policy could be effective under the arrangement of floating exchange rates unlike the fixed regime as it has more room to adjust the interest rate and regulate capital mobility. Thus, the assessment of exchange rates from time to time is essential for better policy design for the macroeconomy.

The modeling of exchange rate dynamics is a complex and challenging task. However, various theoretical models have been developed in international finance such as monetary models of exchange rate (MMER), uncovered interest rate parity (UIP), and purchasing power parity (PPP). In particular, monetary exchange rate models assumed empirical significance following the Bretton Wood system collapse in 1971. After that, many countries adopted a regime of flexible exchange rates and there was huge volatility in the foreign exchange markets across the globe. Exchange rates are modelled using time series models like AR, ARIMA, GARCH, and neural networks (see e.g., Boleslav (1987), Brooks (1996), Najand and Bond (2000), Hu et al. (1999) and Maitra (2015). However, the significance of exchange rate modeling in the macroeconomic theoretical framework remains important. It is precisely because of the significant role of money market adjustments among countries in affecting the exchange rate. The origin of monetary modelling can be taken back to times of great depression. However, the revival of monetary models was seen with the collapse of the Bretton Wood system in 1971 and the beginning of floating/flexible exchange rate era across the globe. India also transited to a floating regime in March 1993. Hence, monetary models became relevant empirical models even for the Indian Rupee exchange rates to analyze the impact of their movement on other sectors of the economy. Given the above, this study empirically investigates monetary exchange rate models in the Indian context by taking Rupee-Dollar rate.

### 1.2.1. Bretton Wood system (1947-71)

In the global scenario, International Monetary Fund (IMF) was established in December 1945 with a meeting of 45 economies in the town of Bretton Woods, New Hampshire, in July 1944, where 29 countries agreed-upon international cooperation in the IInd world war period and signed its article of the agreement. Thus, one sees the birth of the Bretton Woods. In the later years, many other countries joined IMF between 1945 and 1971 and agreed upon par value system in which their exchange rates were fixed at a rate that could be corrected in line with a fundamental disequilibrium in the balance of payment. At the core, a member's exchange rate value was pegged against the US dollar and in return US dollar's exchange rate was pegged in terms of gold in this system.

During this regime, the "par value system" of exchange rate was followed by India, where RBI used to peg rupee currency value fine gold worth 4.15 grains. However, its external value was maintained within ±1 percent margin of using the pound as the anchor/intervention currency. The value of rupee in terms of gold, dollar and other currencies were obligated to be stable indirectly with the efforts of US monetary policy measures to keep sterling-pound dollar exchange rate stable. Thus, throughout this regime, the exchange rate of rupee remained stable except in two cases of devaluations of rupee i.e., in September 1949 and in June 1966. As a result, rupee values reduced to fine gold worth 2.88 and 1.83 grains, respectively.

In this fixed regime, the foreign exchange market was inoperative or restricted for all practical purposes. The requirement of banks was to undertake cover operation only and maintain at all times a near-square or square or position to regulate the demand of foreign exchange as per limit set by available supply. The Reserve Bank of India (RBI) and in some instances, the central government exercised control and regulated international transactions related to current and capital accounts such as payments of foreign exchange abroad and export and import of notes and bullion, transfer of securities as per then enforced Foreign Exchange Regulation Act of 1947 (FERA).

### 1.2.2. Bretton Woods system and the floating regime (1971-91)

With the advent of overvalued US dollar in terms of gold and the growth of US's sizable domestic spending and military spending as a result of the Vietnam War in early 1960, the US President Richard Nixon declared the temporary suspension of the dollar convertibility in August 1973. Thus, it led to the difficulty for the Bretton Woods system by March 1973 to survive, and the major currencies started floating. Since the fall of Bretton Woods system, members in IMF were allowed to follow any form of exchange rate arrangement i.e., floating currency freely, one currency pegged to another or a basket, adopting a foreign currency, following of common currency with the bloc or monetary union.

After the 1971 breakdown of Bretton Woods and free-floating adopted by of major currencies, fluctuations in currency provided enormous prospects for market players through trade in currencies in forex markets worldwide. Consequently, the conduct of exchange rate policy turned out to be a severe challenge for all central banks across the world. Thus, despite the exchange of rupee being linked to pound sterling in 1971, it was fixed to a basket of currencies effective from September 1975 to overcome the risk relating to a single currency peg and ensure exchange rate stability. The RBI decided on the selection of currencies and their respective weights.

During this period, significant developments left an everlasting impression on the forex market and exchange rate system in India. One of those was to allow banks in 1978 to do intraday trading in the forex market. However, banks were required to maintain stipulated near square or square positions daily at the close of business hours. The extent positions were left uncovered overnight. The limit for trading (during the day) was decided by the management of the bank. Also, Authorized Dealers (ADs) were permitted to trade cross currencies for merchant transactions with a spread difference of 0.5 percent. Thus, opportunities to trade and make profits began to emerge for the banks and ADs in this regime. However, due to FERA, 1947, control on the foreign exchange market continued until 1990 with checks on external transactions, barriers to entry, low liquidity, and high transaction cost. It led to the emergence of one of the most efficient parallel unofficial market for forex at the global level. The exchange rate policy was directed predominantly by conserving foreign exchange and protecting India's competitiveness in the international market during this regime, along with tight capital control.

### 1.2.3. Exchange rate policies and forex market developments in the post-reform in India

As the Indian economy gradually opened, its policy on exchange rate also underwent changes. This formed a significant part of the wider macro reforms and liberalization policies of the early 1990's (Dua and Ranjan, 2011). India's policy on exchange rate policy has undergone several changes in terms of three different regimes since its independence, i.e., first a par value system, then a basket-peg and finally a dirty float that one sees today.

The post-reform regime witnessed significant developments and reforms in the forex market and exchange rate policy, institutions, and regulations. These reforms are the outcome of the balance of payment crisis of 1991, preceded by adverse macroeconomic and structural conditions of the 1990's. By 1991 India had arrived at a situation or point where it was on the verge of defaulting on foreign repayment installments and carried insufficient foreign exchange reserves to pay its import bill for two weeks. Borrowing capacity from the market was low due to the junk Indian bonds as rated by the rating agencies. Given such circumstances, the Reserve Bank of India (RBI) in July 1991 had to pledge its gold stocks at Bank of England and Bank of France to avail of a short loan worth $ 405 million. However, in search of other financial avenues, it resorted to IMF for financial assistance under conditions popularly known as Washington Consensus for implementation of policies aimed at liberalization and structural economic reforms. Thus, the Government of India led by the then Prime Minister P.V. Narasimha Rao instituted an effective macroeconomic structural and stabilization program. These programs involved reforms in several areas such as public finance, industry, trade, exchange rate, foreign investment, and the financial sector to create a conducive climate for the expansion of trade and investment.

Regarding the foreign exchange market, RBI had gone for a downward adjustment of the rupee by depreciating or devaluing it by 9 and 11 percent in two installments as an immediate response of the BOP crisis of 1991. This move was to offset the massive downfall in forex reserves, restore confidence among investors, and increase domestic competitiveness. This led to abandoning the pegged exchange rate system followed by a transitional mechanism called the "Liberalized Exchange Rate Management System (LERMS)" in the beginning of 1992. It involved a dual type exchange rate system under which all forex receipts on transactions in the current account, such as export remittances needed to be surrendered to the authorized dealers (ADs) in full. Out of those, 60 percent of the proceeds of transactions were exchanged at rates quoted by ADs. The remaining 40 percent were converted at RBI's official rate. The ADs surrendered 40 percent of their purchase of foreign currency to the RBI and 60 percent balance of foreign exchange were retained by them for sale in the free market. The LERMS and its dual-rate system emerged as a single exchange rate system in March 1993. All foreign exchange rate transactions could be converted at a market-determined exchange rate with recommendations of the Higher Level Committee on BoP under the chairmanship of Dr.C.Rangarajan. Subsequently, the restriction on the current account transaction was fully eased. Thus, India achieved full current account convertibility in August 1994. Further, India had to accept the obligations *vide* "article VIII of Articles of Agreement of the IMF". Partial capital convertibility is allowed through FDI and FII. Consequently, the foreign exchange market developed to be efficient with more robust micro-market structures, depth, and liquidity.

### 1.2.4. Rupee exchange rate volatility and intervention by the RBI

The structural macroeconomics reforms in general and exchange rate policy changes resulted in substantial changes in the rupee exchange rate behaviour. Specifically, the external sector changes included full current account convertibility in August 1994, the gradual opening of capital account for foreign direct investment, foreign institutional investment, external commercial borrowing and allowing bank and ADs for currency trade in the forex market. Thus, the exchange rates and the macroeconomy ware exposed to external shocks over the years. The result was, for instance, the South East Asia crisis of 1997 and the Great crisis of 2008. Consequently, the India rupee exchange rates turned to be more volatile, impacting inflation and interest rate via international trade and capital flow that, in the end, affected growth rate GDP and employment. Thus, exchange rate volatility emerged increasingly as a concern of macroeconomic policy. RBI was required to intervene in the foreign exchange market from time to time to ensure orderly conditions. The IMF's exchange rate classification treated India's exchange rate regime as managed floating. This is also reflected in Jalan's (1999) statement that "RBI, as a central bank of India, pursues foreign exchange market intervention to mitigate exchange rate uncertainty or volatility, promote export competitiveness, accumulate foreign exchange reserves, and develop orderly market conditions". Further, to avoid the disruptions created by exchange rate volatility on financial and real sector, RBI intervened in the market with monetary and administrative measures to manage financial stability. At the same time, communication through speeches, press releases have also been used as complementary measures (Reddy, 2006). For instance, foreign exchange volatility was tackled by RBI with the introduction of "Liquidity Adjustment Facility (LAF)" in June 2000 as an additional tool to influence the liquidity conditions. RBI also introduced the Market Stabilization Scheme (MSS) in April 2004 under G-sec dated securities/Treasury Bills are issued to sterilize the liquidity effect of RBI intervention. Therefore, these measures also partly helped India to withstand several external shocks rooted in exchange rate volatility. Since intervention is a key measure to tackle volatility in the foreign exchange market, the relation between RBI intervention with the amount of net purchases of dollars in millions and monthly Rupee-Dollar rate movement is shown in figure 1.1. It is clear from the figure that whenever there is depreciation of rupee against the US dollar, RBI intervenes by purchasing US dollars to arrest its volatility and smoothing out demand and supply gap of US dollars by market participants and speculators. It sells the US dollar in case of an appreciation of the rupee. It is indicated by the variation in the amount of net US dollars purchase by the RBI and Rupee-Dollar rate in the below figure 1.1. Even empirical evidence reinforces that intervention serves potent as an instrument in reigning in volatility of the rupee (Pattanaik and Sahoo, 2001; Kohli, 2000). Moreover, intervention operations can be also observed through the accumulation of foreign reserves over time. According to RBI data, since structural reforms in India, RBI's accumulated foreign reserves have grown up to 3,64,259 US million dollars in February 2017 from 21,721 million US dollars in August 1994. Thus, RBI effectively uses its intervention policy to curb exchange rate volatility to minimize the impact of external shocks i.e., short-run capital flows, oil prices hike in the international market, and financial crisis.

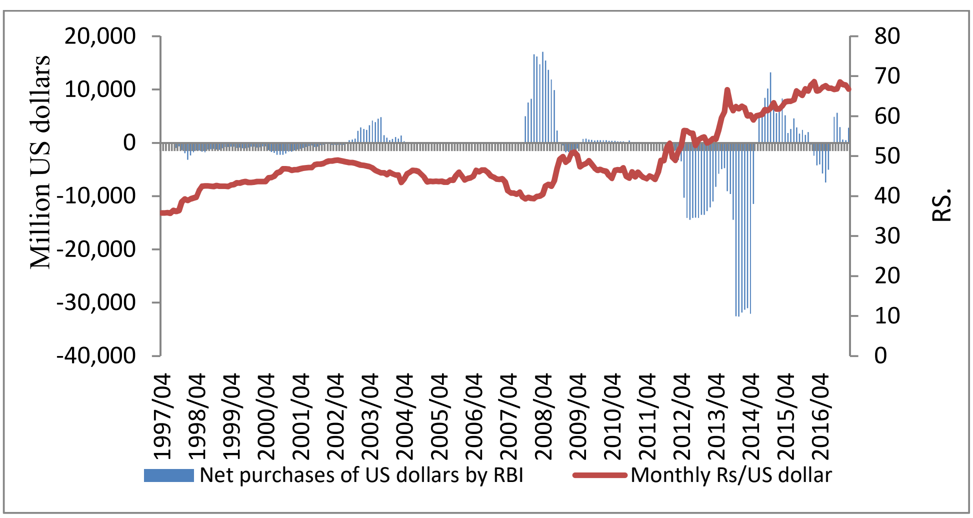



**Figure.1.1** Rupee-Dollar exchange rate and RBI intervention

## 1.3 Theoretical background: monetary models of exchange rates

An overview of monetary models is presented here. Over four decades, the monetary models have been reshaped from time to time as they are confronted with empirical and theoretical challenges. The flexible price version developed by Frankel (1976) was predominant in the modelling of the exchange rate. However, subsequently, excessive volatility in the environment of short-term capital flows across borders has resulted in the advancement of the sticky-price variant by Dornbusch and Frankel (1976). It succeeded in observing exchange short term volatility due to capital flows with the help of the concept of overshooting of exchange rate phenomena. Thereafter, Frankel (1979) augmented the model with real interest rates. He included both "sticky prices (in the short run)" and their convergence to the inflation differential between the domestic and foreign economies in the long run. Further, Hooper and Morton (1982) model of exchange rate has been extended to real shock originating from current account.

In the monetary model of exchange rates (MMER), exchange rate is considered as an asset (Dornbush1976a). The PPP is assumed to hold continuously indicating flexible prices and capital to be perfectly mobile as well as perfectly substitutable between domestic and foreign assets. Therefore,

$$e_t = p_t - p_t^* \tag{1.1}$$

where "*e*", the exchange rate in natural log, (defined as the price of domestic currency per unit of foreign currency): $p$ and $p^*$ denote domestic and foreign price variables measured in natural logarithms. As monetary equilibrium conditions, in the domestic and foreign countries jointly determine the exchange rate, the respective money demand functions are given in equations (1.2) and (1.3) as:

$$m_t\text{-}p_t = \beta_2 y_t\text{-}\ \beta_3 i_t \tag{1.2}$$

$$m_t^*\text{-}p_t^* = \beta_2 y_t^*\text{-}\ \beta_3\ i_t^* \tag{1.3}$$

By rearranging equations (1.2) and (1.3) given above one obtains the expressions for domestic and foreign price levels as:

$$p_t = m_t\ \text{-}\ \beta_2 y_t\text{-}\ \beta_3 i_t \tag{1.4}$$

$$p_t^* = m_t^*\text{-}\ \beta_2 y_t^*\text{-}\ \beta_3\ i_t^* \tag{1.5}$$

By substituting equations (1.4) and (1.5) in equation (1.1) the following reduced form equation is obtained

$$e_t = (m_t\text{-}m_t^*) + \beta_2\,(y_t\text{-}y_t^*) + \beta_3\,(i_t\text{-}i_t^*) \tag{1.6}$$

Where "*m, p, y* denotes money supply, income, and interest rate of domestic country respectively and the variables with an asterisk (*) denote counterparts of the foreign country". In (1.6) above ,$\beta_2$ and $\beta_3$, denote elasticity of each variable with respect to exchange rate *e*. t denotes time. Except interest rate all the other variables are given in their natural logarithm. First-degree homogeneity is exhibited by exchange rate in the relative money supplies in this model. Further, the assumption for the sake of simplicity is that interest rate elasticities and income elasticities for two countries are the same. As this model assumes flexible prices, any interest rate change reflects the changes in the variable, the expected inflation. Consequently, the higher the interest rate relative to that of the foreign, domestic currency depreciates because of reduction in the demand for money. Therefore, a positive relationship is expected between interest rate differential and exchange rate. A domestic money supply increase relative to that of the foreign leads to an increase in domestic price levels and the lower demand for domestic currency results in depreciation of domestic currency. Thus, a positive relationship is anticipated to hold between exchange rate and the money supply differential between domestic and foreign country. Further, the relationship between exchange rate and income differential between the domestic and foreign countries is expected to be negative. This is because with the increase in domestic income level relative to that of foreign, domestic currency appreciates with higher demand for money. However, in reality, PPP does not hold continuously, which leads to rigidities in the goods market results in the slow adjustment of the goods exchange market than the forex market in the short run. Thus, any increase in the money supply causes to depreciation such extent more than its long run depreciation in anticipation of future currency appreciation. This is referred to as overshoot phenomena. Dornbusch (1976) explains this through the sticky price version.

$$e_t = (m_t - m_t^*) + \beta_2 (y_t - y_t^*) - \beta_3 (i_t - i_t^*) \tag{1.7}$$

where one sees a negative relationship between the  interest rate differential and exchange rate. Frankel (1979) combines both “sticky prices in the short run and flexible prices” by incorporating inflation rate differentials (expected inflation rate differentials) between domestic and foreign countries in long run. Consequently, it leads to the real interest rate differential model. The expected inflation rate differentials between domestic and foreign countries is added equation (1.7) to allow for slow domestic price adjustments which is positively related with the exchange rate.

$$e_t = (m_t - m^*{}_t) + \beta_2\left(y_t - y^*{}_t\right) - \beta_3(r_t - r^*{}_t) + \beta_4(\pi_t - \pi^*{}_t) \tag{1.8}$$

Where $\pi_t$- $\pi^*{}_t$ is the inflation rate differentials between domestic and foreign country

Later, the portfolio balance approach emerged based on the assumption of imperfect substitution between domestic and foreign assets. This new model accounts for the effect of domestic assets *versus* foreign assets portfolio choice in the above monetary models to analyze the dynamic interaction among the "exchange rate, current account, and the level of wealth for exchange". This interaction implies an increase in the domestic money supply raising price *via expectation*. This price impact passes to declining net exports and thereby changes the current account of the balance of payments. Consequently, the changes in wealth level are caused by the possible portfolio adjustment among domestic and foreign assets in the capital account. Thus, the assets and exchange rate behavior are altered. This means that under the flexible system, any deficit (surplus) in the current account is offset by accommodating transactional changes in the capital account i.e., capital account surplus (deficit). Overall, this implies that the gap between currency demand and currency supply in the foreign exchange determines a deprecation or appreciation of the exchange rate. Therefore, the differential in current accounts is included to exchange equation (1.8) and its coefficient is positively related to exchange rate.

$$e_t = (m_t - m^*{}_t) + \beta_2(y_t - y^*{}_t) - \beta_3(r_t - r^*{}_t) + \beta_3(\pi_t - \pi^*{}_t) + \beta_4(CA_t - CA^*{}_t) \quad (1.9)$$

Where $CA_t$ - $CA^*{}_t$ is the current account differential between domestic and foreign country

**1.4. Review of literature**

In the late 1970s and early 1980s these monetary models received empirical support until 1978 by studies like Frankel (1976), Bilson (1978) and Hodrick (1978). Later, a few papers by Rasulo and Wilford (1979), Driskill and Sheffrin (1981) demonstrate that the monetary models are not held once they expanded the data series beyond 1978 (Chin et al., 2009). However, Meese and Rogoff (1983) concluded that monetary models forecasted exchange rates poorly relative to the random walk model in the out-of-sample case. This is popularly known as "Meese and Rogoff Puzzle." Subsequently, the large amount of effort of empirical researchers is devoted to reverse the conclusion of Meese and Rogoff (1983). To a large extent, the empirical studies on monetary model have been directed towards investigating the long-run validity and forecasting of the exchange rate. They have addressed the issues such as econometric, small sample size, instabilities and structural breaks in the exchange rate equations, measurements of variables and the empirical and theoretical misspecifications.

MacDonald and Taylor (1994) suggest that “monetary models when unrestricted are appropriate for analysis in the long run when done in a cointegrating framework”. Further, applying cointegration methods, Diamandis and Kouretas (1996), Tawadros (2001), Reinton and Ongena (1999), Hwang (2001) also support “the long-run validity with evidence of better out-of-sample forecasting performance of monetary models. Using the variants of monetary models of the exchange rate”; Chin et al. (2007) find evidence for long-run validity for the monetary model for the Malaysian-ringgit-USD exchange rate, particularly in the sticky-price monetary model. However, Baille and Selover (1987) attribute the monetary model's poor performance to absence of cointegration underlying the exchange rates-monetary fundamental relationship. Similarly, Burns and Moosa (2017) and Moosa and Burn (2014) investigate cointegration issues and include structural breaks in the monetary model. They have found that irrespective of cointegration and the presence of structural breaks does not solve the Meese and Rogoff puzzle if the magnitude measures forecast accuracy by measures like root mean squared errors (RMSE) only. However, the results show that the monetary models beat the random walk when forecast accuracy is assessed by the change of direction accuracy and profitability.

Further, Moosa and Vaz (2016) demonstrate that error correction model (ECM) does not have much value addition improving the forecast of the monetary models compared to the first difference VAR model because of their similarities in the dynamics structure. Several studies address small sample size issues like Mark (1995) Mark and Sul (1998), Groen (1999), and Kalian (1999). However, their empirical conclusion is mixed on the performance of monetary models. A few studies analyze monetary models with time varying coefficients and find that the long run validity and forecast of monetary models are improved (see e.g. Schinasi and Swamy (1987); Plasman et al. (1998), Ross (2004) and Park and Park (2013)). Further, when instabilities are considered in the model, the empirical studies support the significance of monetary fundamentals in determining the exchange rates (Goldberg and Frydman, 2001; Rossi, 2005; Beckmann et al., 2011; Panopoulou and Pantelidis, 2012).

Literature in the exchange rate field deals with volatility in exchange rates or second moments of the exchange rate from the macroeconomics perspective. To this end, Friedman (1953) argues that volatility in exchange rates indicates instability or volatility of macroeconomic structure. He states that instability in flexible exchange rates is attributed to the underlying instability of economic conditions. Conversely, Flood and Rose (1995, 1999) empirically show that choosing exchange rate regimes as policy variable essentially affects exchange rate volatility but not the volatility macro variables. Therefore, they assert "absence of a clear trade-off between exchange rate volatility and macroeconomic volatility (stability). Also, they have found fixed exchange rates to be less volatile than floating exchange rates and thus volatility in macroeconomic fundamentals are not determinants of exchange rate or volatility". Similarly, Duarte (2003) supports these findings further empirically. He also found the substantial exchange rate volatility during countries switching from pegged to floating exchange rate regimes without having much similar the volatility in other macro variables such as output, consumption and trade flows. Kempa (2002) and Morana (2009) provide further evidence for Flood and Rose (1999) in the case of G7 countries.

However, Balg and Metcalf (2010) find that volatility in exchange rate is decided by macro fundamentals in the case of countries such as Canada, Germany Japan and United Kingdom (UK). However, the different fundamentals play vital roles in the exchange rate volatility in different countries. Grossmann et al. (2014) show that exchange rate volatility is significantly responsive to macroeconomics and financial variables with any difference between high frequency and low frequency volatility data. Adusei and Gyapong (2017) attempt to explain the variance in exchange rate by macro fundamentals using partial the least square structural equation model for Ghana's cede exchange rate with US. Their results show that the variance of macroeconomic fundamentals explains 82% of the exchange rate variance.

The empirical literature explores the nexus between rupee exchange rate volatility and macro fundamentals by taking account of macro factors such as growth rate of GDP, inflation, trade, interventions, FDI and financial openness in the case of India (Ghosh, 2011; Ghosh, 2014; Goyal and Arora, 2012; Kohli, 2015: Saha and Biswas, 2014; Panda and Kumar, 2014 and Mahanty and Bhanumurty, 2014). Goyal and Arora (2012) have studied central bank intervention's impact on the conditional mean and volatility of exchange rate by accounting its communication and news impact using monthly and daily frequency. They have mainly confirmed that central bank intervention with its effective communication influences the exchange rate level despite the fact that the RBI is to not commit to targeting the level of exchange rate. A similar study by Kohli (2015) found a significant impact of reserve advocacy in reducing the exchange rate volatility irrespective of the exchange rate regime after controlling the effect of macroeconomic variables. This study implies that the impact of foreign exchange reserves operates through market sentiments and confidence rather than the actual intervention alone.

### 1.5. Research gap

Over time the empirical issues of exchange rates for monetary models have been addressed through the various methodologies i.e., econometric models and forecasting methods,, data sets and specification issues. But the focus on major building blocks of monetary approach of exchange rates i.e., PPP, UIP and money market equilibrium is inadequate. These conditions are hardly held empirically (Engel, 1996, 2000). However, a few efforts have been made through the "sticky price monetary model (Dornbusch, 1979) and Frankel (1984) by relaxing the PPP and UIP assumptions to analyze the exchange rate dynamics". However, less attention is devoted to the equilibrium condition in the money market or money demand instability. One of the reasons cited for such failure is the lack of the long-run relationship or cointegration between the exchange rate and monetary fundamentals (Baillie and Selover, 1987; Neely and Sarno, 2004). This could also possibly be due to instability in the money demand functions and the instability being a result of using simple sum money measures in the estimation of monetary models. Such instability caused by simple sum aggregates is called as the "Barnett critique" by Chrystal and MacDonald (1994). Subsequently, Chrystal and MacDonald (1995) examine "the relevance of aggregation theoretic monetary aggregates" i.e. Divisia money relative to simple sum monetary aggregates for the monetary models during financial deregulation period for two exchange rates namely the Sterling-Dollar and the German-Mark rates. They suggest that the use of aggregation Divisia monetary aggregates make a significant difference in modelling of the Sterling-Dollar exchange rate both in short and long runs. The Divisia monetary aggregates as originally proved by Barnett (1980) and his collaborators in a number of papers in the 1980s, internalize the substitution effects following portfolio adjustments among monetary components or assets held by economic agents in response to changes in the interest rate i.e. the process of these assets in the economy. Monetary assets as potential components of monetary aggregates published by the central banks in general are found to be imperfect substitutes since they yield both transaction and investment services in different degrees. Nevertheless, almost all the central banks publish simple sum monetary aggregates with equally weighted components that are assumed to be perfect substitutes of each other. Since the 1980's, Divisia monetary aggregates started receiving empirical support for their superior performance in demand for money functions and other areas of macro-economics. To mention a few among others, Barnett (1980, 1990) and the most recent ones by Fuente et al. (2020) and Belongia and Ireland (2019) have proved the superiority of Divisia money in terms of its relationship with real macro variables such as income, inflation, and also in yielding stable money demand functions. Since money demand functions play crucial role in the MMER, appropriate measurement of money merit attention too.

In the Indian context, a few studies are found on empirical verification of the monetary model of exchange rates. These studies (e.g. Ghosh, 1998; Klezmer and Kohli, 2000; Due and Rajan, 2011; Bhanja et al., 2015) have used simple sum monetary aggregates in empirical modeling of the monetary models. India being an emerging economy, has been witnessing financial innovation in several dimensions since the 1990s. This requires a new investigation since financial innovation in terms of introduction of new assets at the least, render simple sum monetary aggregates to be less meaningful in capturing liquidity in the system. Therefore, money not appropriately measured may yield unreliable results in the MMER via its bearing on money demand stability. Acharya and Kamaiah (2001) found money demand functions in India to be unstable with simple sum money whereas the functions with Divisia money were stable. Therefore, a significant research gap in the Indian context is not using Divisia aggregates in estimating monetary models of exchange rates. It may also be noted that the Reserve Bank of

India had set up the third working group named "Working group on money supply, analytics and methodology of compilation", chaired by Y.V. Reddy (RBI, 1998) to examine the adequacy of simple sum money stock published by the Bank in view of the developments in the financial system and the global developments in money measurement. The working group examined the adequacy of existing measures of money in view of emergence of new instruments in the financial market and came up with a set of new simple sum monetary aggregates and liquidity aggregates. The group in their report also acknowledged the rationale underlying possible introduction of the Divisia type aggregates advocated by Barnett (1980). However, in case of India, studies using Divisia aggregates are limited to demand for money and inflation only. These studies provide theoretically consistent results and better information content. Some of these studies include Acharya and Kamaiah (2001), Ramchandran et al. (2010) and Paul and Durai (2019). However, Barnett et al. (2016) examine monetary policy impact in a SVAR model to examine the fluctuation in exchange rate, output and price level using simple sum and Divisia money for the Indian economy. They find that exchange rate fluctuations are well explained and predicted when money is defined by Divisia aggregates compared to simple sum aggregates.

### 1.5.1. Financial innovation:

Fundamentally, financial innovation involves new financial services, financial instruments, products, technologies, financial institutions, and markets. White and Frame (2002) classify financial innovation into four types. Those are the new products (e.g., exchange traded index funds (ETFs)); new production process (e.g., electronic record for securities and organizational changes (e.g., electronic exchange, internet-only bank). In the past five decades, credit and debit cards, ATMs, subprime mortgages, mutual funds index funds, ETFs, options, and plain vanilla swaps and forward are well-known financial innovations globally and Indian scenario.

The major aim of financial innovations is to reduce transaction costs for financial transactions and reduce and diversify risk through new instruments and products at the economics agent level. At the market and economy level, it is to enhance depth and liquidity, efficiency, and price discovery in financial markets and efficiency in the allocation of economic resources for production through credit and loans at the cheaper interest rate. Financial innovation is motivated and mainly driven by market participants or financial firm's efforts in capturing more market power, profits and its size, infrastructure and opportunities in technology, computation in the financial market, changes in the regulatory environment and volatile financial and macroeconomic conditions, demand for new financial products and services (Ramakrishnan, 2015).

**1.5.2. Financial innovation in India:**

Schumpeter (1911) supports financial innovation and well-developed financial markets that stimulate economic growth in efficiently mobilizing savings, evaluating projects, managing risk, monitoring managers, and facilitating transactions through services of financial intermediaries. Goldsmith (1969) also affirms that finance development causes growth and there is a positive relationship between the two. In fact, in India, financial innovation has been taking place in tandem with the phase of financial liberalization since 1991. Since then, India has embarked on the financial sector reforms and policies to build a resilient financial system with institutions, markets, instruments, and services. Consequently, financial liberalization has driven up financial innovation in India. Prior financial liberalization policies, excessive control on administrated interest rates have impeded financial innovation and increased transaction cost that paved the way for developing poor debt, money and capital markets, and stalled technological and weaken financial system (Pandey and Banwet,2018). However, the roots of financial innovation in India is traced back in the 1980s with the digitalization of financial institutions and markets with the inception of ATM which has turned banks as centralized settlement risk management system. Also, the banking system has been gone through modernization in recent decades intensively with the widespread use of the internet that enables to connect the large network of individuals and institutions to communicate, process and access information among them. On one hand, it leads to an increase of users for internet banking, ATM, credit and debit cards, e-wallets such as PayPal, Paytms, and PoS sale machines for business and consumer transactions. Consequently, it is anticipated that the relationship between the money supply and its components have changed. Pandey and Banwet (2018) observed the significant correlation between M3 and monetary components due to POS and IMPS transactions in India. On the other hand, it also results in the creation of an e-commerce market such as Flipkart and Amazon and digitalization of many business and service.

A consequential financial innovation in the asset or capital markets has come up with the existence of the first digital exchange i.e. "National Stock Exchange of India Ltd.(NSE) in 1994". This breaks the monopoly power of the Bombay Stock Exchange market, some 100 years old (Pandey and Banwat, 2018). Subsequently, derivative and forward markets in the asset, commodity and currency have been developed with new financial products and instruments i.e., Derivatives and options, mutual funds in the equity, money, and foreign exchange markets. These innovative products and instruments have further strengthened the financial markets later.

All the above together in the process of financial innovation leads to decreased cost of transactions, i.e., cost of transferring funds from lower-yielding avenues to higher-yielding alternatives and also enable the market participants to minimize risk and to maximize returns. With the widespread use of new financial products and services, their impact on financial and monetary markets is thus profound in the last three decades that lead to change in their structure. The resultant structural changes have challenged the stability of financial markets. Because capital and money markets are integrated deeply and become indistinct because of financial innovation and market sensitive financial information flows that lead to huge market volatility (Ramakrishnan, 2015).

Financial innovation has changed a landscape of monetary policy transmission mechanism and effectiveness over the previous two decades with new payment technologies and electronic trading platforms. Particularly, it has the potential to alter the components of money in India through introduction of new financial instruments or changes in old instruments in the financial markets, new payment technologies, new electronic platforms as well as the terms and conditions of debt/ credit arrangements. In this backdrop, the monetary aggregates that measure their monetary components with service costs rendered do have a basis. Therefore, redefining monetary aggregates with Divisia aggregates is rationale because of its ability to capture the financial innovation and its resultant changed macro conditions or monetary informational flows in line with financial innovation. Moreover, as mentioned above, the failure for monetary models in the exchange rate rests in unstable monetary demand functions. So it is believed that money demand function is likely stabilized with Divisia aggregate compared to simple sum aggregates in the empirical monetary model specification of exchange rate that may improve the long run and short run dynamics in tracing dynamics of Rupee-Dollar exchange rate, its forecast, and volatility.

### 1.6 Objectives of the study

In view of the above background the following objectives are formulated.

1. To examine Rupee-Dollar rates and monetary fundamentals relationship in the long run by employing simple sum and Divisia money and compare their performance in monetary model.

2. To evaluate and compare the short run forecast accuracy of monetary model with "simple sum and Divisia money".

3. To examine the Rupee-Dollar rate volatility and volatility in monetary fundamentals where money is measured by both simple sum and Divisia money.

Therefore, the usage of Divisia money for Rupee-Dollar exchange rate in the monetary approach, attempting forecasting and modelling volatility are the three core contributions of the present study to the empirical literature.

### 1.7 Data and methodology

#### A) Nature and sources of data:

To pursue this study, monthly data of secondary nature is used. Exchange rate and monetary variables data are extracted from the "Handbook of Statistics on Indian Economy" for India published by the RBI. For US, data is drawn from Federal Reserve Bank of St.Louis database (FRED). Divisia money components and their assumed returns for India are sourced from SBI database and the Handbook of Statistics on Indian Economy. US Divisia money is sourced from the Centre for Financial stability.

**B) Methodology:**

This study employs various methodologies to estimate the above three objectives and analyze relations among variables. They are described in brief below. The details of the methodologies employed are discussed in respective chapters.

- To estimate the long validity of the Rupee-Dollar exchange rate and monetary fundamentals with different monetary aggregate, Johansen (1988) method is applied to see the long run cointegration among variables. Further, error correction models are used to analyze short run changes in the exchange rate.
- A set of time series models of univariate and multivariate types are employed to evaluate the forecast exchange rate accuracy. Such as ARIMA (p, q, r), GARCH (p, q) are univariate models and vector auto regression (VAR) in levels and first difference, and vector error correction model (VEC) are multivariate models. These models are estimated in the in-sample and then using estimated coefficients, the exchange rate forecasts are obtained for out-of-sample. In this out-of-sample, using RMSE and MAE forecast errors at 1 to 24 months ahead forecasts, the accuracy of the exchange rate is analyzed among monetary aggregates and across time series models.
- For the investigation of the "long-run relationship between Rupee-Dollar exchange rate volatility and macro fundamentals' volatility", a standard linear ARDL (p, q) cointegration model is applied (Pesaran and Shin, 1999 and Pesaran et al., 2001). This model analyses both long run and short run dynamics between exchange rate volatility and volatility in the fundamentals.

### 1.8 Structure of the thesis

The rest of this thesis contains five chapters. Chapter 2 reviews the empirical studies on the long validity of MMER, forecast and volatility. Chapter 3 examines an empirical analysis of the long run validity of the monetary model for the Rupee-Dollar exchange rate. Chapter 4 evaluates exchange rate forecast accuracy with different monetary aggregates and times series. Chapter 5 analyzes the Rupee-Dollar exchange rate volatility and volatility in fundamentals. Finally, chapter 6 presents summary, conclusion, and limitations of the study.

# Chapter 2

# Review of Literature

## 2.1. Introduction

An extensive body of empirical literature on the MMER is found in the field of exchange rate research area. This empirical literature attempts to deals with pertinent issues such as long-run validity of monetary models and their ability to predict exchange rates. In pursuing so, the full range of issues from econometric modeling to data small sample size and instabilities in parameters to structural breaks are addressed. As mentioned earlier, most of the studies on monetary model till today have tried their best to "overturn the findings of Meese and Rogoff (1983) that the monetary model is poor at forecasting of exchange rate compared to the random walk". Thus, this chapter majorly covers a review on the first two empirical issues that are concerned with the main objectives of this thesis, i.e., the long-run validity of monetary models and their forecast of the exchange rate, where their related issues are discussed thoroughly. After that, it presents a review on the problems of exchange rate volatility that is concerned with the third empirical objective. In addition to empirical analysis related to monetary models, the studies on purchasing power parity (PPP) and time series methodologies such as univariates and multivariate models (ARIMA and VAR models) for the exchange rate are discussed to understand their importance. This chapter is organized as follows; section 2.2 reviews studies on the long-run validity of monetary models and their forecast of the exchange rates in both international and Indian contexts. Section 2.3 discusses exchange rate volatility literature from a mostly macroeconomics perspective. Section 2.4 describes the research gap and objectives of the study.

## 2.2 MMER, its validity in the long-run and forecasting of exchange rates

To begin, the seminal work by **Meese and Rogoff (1983)** questioned the validity of monetary models and prompted considerable research in this area of exchange rates over three decades. This study primarily compares forecasting accuracy (out-of-sample) of various structural and time series models using time series data spanning from March 1973 to June 1981 for the exchange rate of dollar currency *vis-a-vis* the pound, mark, and yen. They have applied ordinary least square (OLS), generalized least square VAR, and autoregressive models to estimate empirical specification of the structural model of the exchange rate. The results demonstrate that the monetary structural models of exchange rate underperform than that of the random walk model in the out-of-sample forecast exercise. This study's findings are regarded as Meese and Rogoff puzzle in other empirical studies.

**Diamandis and Kouretas (1996)** reexamine "the long-run validity of monetary model" for Dutch mark, British pound, and Japan yen against dollar currency over floating exchange rate period using Johansen-Juselius cointegration methodology. It is found in the empirical results that two significant cointegrating vectors among the money supplies exchange rate, short-term interest rates, and industrial output. They have found in the identification test that forward-looking monetary model is rejected. However, the unrestricted type monetary model is found to be a solid framework for explaining the long-run movements of three exchange rates. Further, the results show that the dimensions of cointegration space are sample dependent, and no significant instabilities in the estimated coefficients of the recursive estimation are found in the parameter instability test.

**Tawadros (2001)** attempts to examine the predictive power in addition to cointegration, in the monetary model for the Australian dollar currency against US Dollar during period from January 1984 to January 1996. Unlike most other studies, this study investigates a separate domestic and foreign variable in the empirical specification of monetary model by applying Johansen cointegration technique (1988) and error correction model. In his cointegration results, "a single long-run relationship is found between the exchange rate, money supplies, real income, and short-term interest rates". The monetary model has performed well in in-sample and out- of-sample analysis. Even the monetary model beats the random walk in exchange rates forecast with the increase of forecasting horizons from the short to longer horizons in the error correction analysis. Overall, this study shows the importance of monetary model in determining exchange rate in the long-run and its forecast.

In the case of India, **Kletzer and Kohli (2000)** investigate the long-run exchange rate behavior of Rupee-Dollar using various monetary aggregates and inflation measures. Such measures used for money are broad money (M3) and narrow money (M1). In addition, relative price differential of tradable to non-tradable and consumer price index differentials between India and US are used for inflation. Authors have applied Johansen cointegration test and error correction model (ECM) on quarterly data. Their results show multiple cointegrating vectors among money supply, income, interest rates, and inflation, which are robust to different money and price measures. The inflation rate plays an important role in process of adjustment to long-run exchange rate disequilibrium. They have also found the PPP to hold in the long run.

Similarly, **Dua and Ranjan (2011**) examine the forecasting ability of the MMER for the Rupee-Dollar exchange rate by extending them with the "exchange rate forward premium, volatility of capital flows, order flows and central bank intervention". For this purpose, "two variants of

VAR, i.e., vector autoregression (VAR) and Bayesian vector autoregression (BVAR) are applied to estimate forecasts using monthly data set spanning from July 1996 through June 2008". Out-of-sample forecasting exercise results show that monetary models perform well compared to the random walk models except in few cases. Monetary models based on information on exchange rate forward premium, capital flows, the volatility of capital flows, order flows do beat monetary models that have not included them in the forecast of Rupee-Dollar exchange rate. It also finds that the inclusion of central bank intervention has enhanced forecast accuracy at long horizons. In a comparison with VARs, BVAR models yield forecast of higher accuracy than that of VAR at longer horizons.

Using the same Bayesian VAR in the panel of 33 exchange rates against US Dollar by considering of useful information concerning cross dynamics and co-movement among them, **Carriero et al., (2009)** have tried to forecast exchange rate. To this end, Bayesian VAR with a driftless random walk prior is applied. The forecasting result shows that Bayesian VAR model forecasts better than random walk for most of the countries for at all forecast horizons. This study affirms the significance of VAR models in the exchange rate forecasting

**Fritsche and Wallace (1997)** attempt to forecast the exchange rates of four industrial countries such as United Kingdom (UK), Japan, German and Canada with the error correction model applied on purchasing power parity (PPP). This study supports PPP partially in terms of theoretical signs. However, in the case of two out of four exchange rates, PPP with either unrestricted or restricted error correction model has shown a better performance than that of random walk models in an exercise of out-of-sample forecasting.

Some studies analyze factors underlying failure of monetary models empirically. Of those, **Smith and Wickens (1986)** investigate “the leading causes for failure of the monetary models and the random walk hypothesis for the sterling and Dutch mark exchange rate against US dollar”. In this regard, a new methodology is employed that involves the modeling of the misspecification of sources by time-series techniques. The results reveal that, to a larger extent, invalid of PPP in the short run and misspecification of the money demand are the primary reasons for the failure of monetary models. Further, “it is shown that lagged information can be the potential to improve upon the random walk model of the exchange rate”. This study suggests that through monetary model is incorrect, in some respects, it is quite a good approximation.

Using the permanent and transitionary decomposing method, **Chen and Chou (2015**) attempt to explain the failure of monetary models using the exchange rate of six countries, i.e., “Finland, Italy, Portugal, France, and Switzerland”, against the US Dollar. They have used the long span of annual data from 1880 to 2011. The empirical analysis shows that transitory shocks largely explain exchange rates. But the permanent shocks seem to dominate the fluctuations in the fundamentals. Therefore, this study suggests that the monetary models have failed to explain or predict the exchange rate in short run since they do not account for the transitionary shock on the exchange rate.

**Baillie and Selover (1987)** explain why cointegration techniques lack for monetary models in studying nominal exchange rate movements. They have estimated monetary model by applying various dynamics models such as ordinary least square (OLS), OLS with autoregression (AR) on residuals and seemingly uncorrelated regression equation vector auto regression (SURE VAR) for time series from March 1979 to December 1983. It is found in results that the differences in trends of fundamental variables and lack of cointegration among them are the leading causes of lack of the long-run relationship in the monetary model. Therefore, they suggest that the results of Meese and Rogoff (1983) are quite visible so that these models are not worthwhile for the forecast of the exchange rate.

**Moosa and Burns (2014)** reappraise the “Meese-Rogoff Puzzle”. They argue that “the random walk model can be outperformed in terms of other than matrix of root mean square errors (RMSE) such as the forecast accuracy direction and profitability”. Following the Meese-Rogoff methodology, they find that result of Meese and Rogoff have not changed much even when the model is estimated with time-varying parameter approach (TVP). Therefore, this puzzle is not resolved by mere use of time-varying coefficients. However, the result gets overturned or reversed that when forecasting evaluation is done in terms of direction accuracy, MMER can out-perform the random walk model with drift in the forecasting exchange rate. Overall, they conclude that time-varying coefficient approach and forecast accuracy measure i.e., RMSE alone, cannot invalidate findings of Meese-Rogoff.

In another study, **Moosa and Burn (2017)** address if cointegration matters for monetary models to forecast the exchange rate accurately. To this end, they examine the relationship between “stationarity and size of the forecasting errors” of estimated variants of monetary models. The results reveal that monetary models do not strongly support for the proposition that cointegration does matter for forecasting accuracy. The simulated results find that the smaller stationary errors under cointegration than that of non-stationary errors under non cointegration is not a universal rule. Interestingly, again this study also supports that monetary models cannot out-perform the random walk in the out-of-sample forecasting if their accuracy is judged by the magnitude-only measures i.e., RMSE and MAPE irrespective of the presence or absence of cointegration.

However, the monetary model beats the random walk using accuracy measure, the direction of change, and profitability accuracy measures.

**Moosa and Vaz (2016)** compare forecasting power between the error correction model (ECM) and the first differenced model for monetary model of exchange rate. Their study sample spans from January 1995 to December 2014 covering countries such as "Chile Sweden, Switzerland, Korea, U.S., Japan, U.K., Canada, Brazil, Mexico, Singapore, Malaysia, and Israel". The results show that the error correction model does not have much value addition to enhance the forecasting power of exchange rate compared to the first difference models due to their similar dynamic structures. This provides a plausible explanation, suggested by Bekiros (2014) that fundamentals may be imperative of exchange rates. To quote, "there may be some other unobservable variables driving the currency rates that current asset-pricing models have not yet accounted". Further, they do not support that the need for restriction due to economic theory to augment the forecasting power.

On the contrary**, Bhavani and Kadiyala (2010)** have found that the exchange rate model that includes both short and long-run dynamic changes (adjustment process) simultaneously forecast the exchange rate more accurately than that model includes only long-run(level) changes. However, they still support the Meese and Rogoff (1983) findings that random walk out-performs monetary models in forecasting in the exchange rate even in case of developing countries rates i.e., Indian rupee/$,Mexican peso/$ and Pakistan rupee/$. They have concluded that the exchange rate model that includes both short and long-run dynamic changes (adjustment process) simultaneously forecast exchange rate more accurately than that model includes only long-run(level) changes. However, they still support the MR findings that random walk out-performs monetary models in forecasting in the exchange rate even in the case of developing countries.

We find in literature such studies that analysis monetary models with help of time varying coefficients and regime switching approaches. **Schinasi and Swamy (1987**) examine the forecasting performance (out-of-sample) of the monetary model using fixed and variable coefficients in monetary models for the exchange rates of US Dollar against Dutch mark, Japan Yen and European Union Euro. To this end, they employ a wide range of stochastic coefficients and three alternative fixed coefficients estimates. The results show that the variable coefficient model for all exchange rates performs better than the random walk models. However, the fixed coefficient version of monetary models provides support for the findings of Meese and Rogoff.

**Rossi (2005)** also examines macro fundamentals - exchange rates nexus using time-varying parameters/coefficients in the rolling window out-of-sample. Optimal tests, namely, Andrew's QLR test and the optimal Nyblom (1989) test, are applied for testing for model specifications and time-varying parameters. The result shows that though the optimal test rejects the hypothesis that random walk forecast better monetary model, the rolling out-of-sample test does not reject the same hypothesis. Thus, this study has concluded that the failure of monetary models is due to unstable monetary fundamentals and exchange rate relationship, which is hard to capture by Granger causality test or forecast comparison not embedded with information in the fundamentals related to exchange rate changes.

**Beckmann et al. (2011)** investigate "the time-varying relationship between the Dutch mark/US Dollar exchange rate and macro fundamentals". They use monthly data for the period from January 1975 to February 2007. This study employs "Bai-Perron (1998,2003) test for detecting breakpoints in the sample and the fully modified (FM–OLS) method for testing cointegration between exchange rate and fundamentals along with a regime sensitive framework". It is found that there exists no stable long-run relationship among the exchange rate and its fundamentals and no single regime without which fundamentals have an insignificant impact on the exchange rate. Lastly, this study concludes that fundamental are the critical determinants of the exchange rate, but their impact is varied significantly across different sub-period in time. A similar finding is obtained by **Park and Park (2013**) find that cointegration between exchange rate and fundamentals is time varying. And time-varying coefficients model produce a better exchange rate forecast than that constant coefficients model for monetary models in both the in-sample and the out-of-sample forecasting exercise.

Another study by **Plasmans et al. (1998**) investigate variant monetary models in artificial neural network (ANN) framework and see the importance of linear and non-linear specifications for them. This study has found any significant non-linearity in the monetary and univariate models. However, in the out-of- sample forecast exercise, some extent forecast is improved upon the random walk with ANN method for monetary model. But it is not reliable due to unclear methodological procedures.

By including structural breaks due to policy changes or the occurrence of events such as financial crisis, the empirical studies have been attempted to study the monetary models. **Burns and Moosa (2017)** investigate if structural breaks can solve the Meese and Rogoff Puzzle that monetary model can out-perform the random walk model in the out-of- sample forecast. Bai-Perron (1999, 2003) structural break test is used to identify the multiple structural breaks. They find that structural breaks cannot explain the failure of the monetary model. Again as their previous studies **Moosa and Burn (2014, 2017),** it is attributed to conventional magnitude only measure to assess forecast accuracy i.e., root mean square errors (RMSE), adjusted root mean squared errors (ARMSE). But with alternative measures like directional accuracy, the monetary model can out-perform the random walk model regardless of the presence or otherwise of structural breaks.

Further, **Goldberg and Frydman (1996)** examine the temporal instabilities in the cointegration between US Dollar/Dutch mark exchange rate and fundamentals in sub-sample analysis over a period spanning from March 1973 through March 1983, which is used by Meese and Rogoff (1983). The results show that cointegration between fundamentals and exchange rate within the sub-sample regimes are relatively stable than that of the entire sample regime. In the out-of-sample forecasting exercise, the forecast accuracy of exchange rate is improved at a large margin in terms of RMSE and RMS (root mean squares) compared to the result of Meese and Rogoff (1983) when the breaks in the cointegration vector are accounted for. They have attributed the cointegration vector shifts to the expectation channel in which the different sets of variables are matter during different periods. Further, **Godberg and Frydman (2001)** reexamine the determination of US Dollar/Dutch mark exchange rate in the monetary model framework in the presence of temporal instability. To this end, they employ monthly data spanning from March 1973 through December 1998. The result of the structural breaks test confirms four structural breaks in the full sample. When a full sample is used for estimation, error terms of cointegrations in monetary models are found to encounter issues of non-normality, ARCH, heteroscedastic and serial correlation. However, these issues are solved in two of four cointegration errors when it is estimated with four sub-sample periods.

Also, there are few studies in the case of India that undertake structural breaks in monetary models for Rupee-Dollar exchange**. Ghosh (1998)** examines the MMER for Rupee-Dollar exchange rates in the phase of accelerating inflation. This study employs different cointegration tests such as Engel-granger (1983), Johansen cointegration test and Gregory and Hansen (1992) cointegration test on monetary model. The results indicate no long-run equilibrium among monetary fundamentals and Rupee-Dollar exchange rate, and it is further confirmed by Gangran and Hansen (1996) test result that account shift in the relationship. Finally, this study suggests the lack of stable money function for the failure of monetary model.

On the contrary, **Bhanja et al**. (2015) find the long-run validity of monetary model even when taking into account structural breaks or shifts in the exchange rate of rupee against USD, Pound-sterling, Yen, and Euro for monthly data time series from March 1993 to March 2011. This result is found when they employ LM break test (Lee and Strizicich, 2003, 2004) to detect structural breaks and Geogory-Hansen (1996) cointegration methodology to account for structural breaks endogenously in the cointegration tests. Thus, this study strongly supports "the long-run relationship among the exchange rate of rupee against US Dollar, Pound sterling, Euro, yen, and monetary fundamentals". Similarly, **Sharma and Setia (2015)** attempt to investigate structural breaks in the relationship between the Rupee-Dollar exchange rate and a set of macro variables. Their results mainly infer that the macro fundamentals determine the exchange rate significantly with varied size effects across the sub-sample periods. **Suthar (2009)** analyzes the impact of supply-side determinants on the Rupee-Dollar exchange rate during the period from April 1996 to June 2007. Supply-side variables include foreign exchange rate reserves and money supply, domestic interest rate, both long term and short-term differential between domestic and foreign country. This study finds in the results that change in the domestic interest rate and foreign exchange reserves have a significant impact on the exchange rate. Further, all explanatory variables are in line with the economic theory despite of that, not all variable variables are not significant.

Using Markov switching model framework, many studies have tried to model swings in the exchange rate by linking monetary fundamentals. Applying Markov switching model on US dollar rate against mark, frank and pound, **Engel and Hamilton (1990)** have tried to model the long-run swings and address peso problem for the period between March 1973 to Jamaury 1988. To this end, they use stochastic segmented trend model, which fits well data to characterize the long swings patterns. They also confirm that in the rational expectation framework, these long swings patterns are not explained by forex risk premium that arises due to the pattern of interest rate differential between two countries. **Lee and Chen (2006)** justify the use of Markov switching model by contending that the theoretical process of the exchange rate closely aligns with its empirical counterpart and the implied exchange rate process is state-dependent. They assume that "the central bank's intervention behavior is a Markov chain rather than an independent intervention in which whether central bank intervenes or not depend on a continuously changing economic environment". This study derives the stochastic intervention model. The study also shows that a higher probability of a central bank's future intervention results in discrepancy in rational expectations even though the central bank does not get into the foreign exchange rate market during any period.

**Wu (2015)** examines the dynamics of the exchange rate of Asia-Pacific countries against US Dollar by applying time-varying transitional probabilities (MSM-TVTP) in the Markov switching model for real interest differential model (RID) and compares the result with Markov switching model (MSM). In the result, it is found that coefficients and their significance are different across models and countries as well. But the results confirm the non-linear relationship between exchange rate volatility and fundamentals. Further, the results demonstrate that when the time varying probabilities transition are considered, MSM-TVTP out-performs MSM-RID model in capturing the movements of exchange rates.

**Kanas (2005)** investigates the Dournbush (1978) model of overshooting phenomena by the examining linkage between real interest differential  and US/UK real exchange rate.. This study chooses an extended data set for the period between "1921 – 2002, which is characterized by various exchange rate regime and monetary regime". Thus, the multivariate Markov regime model is applied. The results show that the relation between two variables is characterized by high volatility during the period of floating exchange rate regime while it is low volatility during a fixed exchange rate regime. This indicates distinct volatilities in the exchange rate between these two exchange rate regimes. **Sarno et al. (2004)** "examine the importance of restoring the long-run equilibrium between US exchange rates and fundamentals with the application of Markov switching VECMs across different exchange rate regimes i.e., the gold standard, the Bretton Wood period, exchange rate mechanism and recent float". The result shows precisely that fundamentals have adjusted to restore the long-run equilibrium relationship in the fixed exchange rate regime, whereas during the regime of free float, adjustments to equilibrium are mainly through movements in the nominal exchange rate. They also find the relative importance of fundamentals and exchange rates in restoring the long-run equilibrium vary mostly over time.

**Kempa and Riedel (2013)** study the exchange rate model by incorporating Taylor rule interest function where money supply is endogenously included in nonlinear of Markov switching framework for Candian US dollar rate. This study is conducted for the sample period that starts in February 1991 when the Bank of Canada has adopted an inflation targeting policy and ends in December 2008. The results show that there exist many regimes in the estimation period and the non-linear relationship between the fundamentals and exchange rate. This study attributes nonlinearity to active monetary policy stance and thereby no MMER can explain the exchange rate movements.

**Panopoulou and Pantelidis (2012)** provide evidence for the bubbles collapsing "periodically in the exchange of British pound against US Dollar for the period between January 1973 to January 2011". They have applied PWY test (Phillips,Shi and Yu,2011) to identify the bubble in the sample and Van Nordon (1996) and Brooks and Katsaris (2006) to accounts for two and three regimes to capture collapse, survivals and dormant bubbles. The significant findings indicate that regime switching model is better than that random walk model in term of both statistical and economics evolution criteria for the forecast of exchange rate. Their three-state regime switching model out-performs the two-state model. The short-term interest rate followed by imports is optimal variables among macro fundamentals they considered.

**Mark (1995)** reinvestigates the issue of failure of monetary models by addressing size distortion and small sample bias. In this regard, this study applies bootstrap distribution to draw inference on the null hypothesis that log exchange is unpredictable and test if estimated regression based on monetary model and random walk generates equal forecast using Diebold Mariano (DM) test. This procedure is conducted on quarterly data of US Dollar exchange rate against Canadian Dollar, Dutch Mark, and Swiss Franc for the period between 1973Q2 to 1991Q4. The results suggest that all hypotheses are jointly rejected across all forecast horizons at the standard five percentage level. Biased adjusted slope coefficients and $R^2$ increase with the increase of time horizons increase and point forecasts estimate out-performs the random walk model without drift at longer horizons in the out-of-sample. However, the results are unreliable at a longer horizon forecast due to a small number of observations available.

Similarly, **Kilian (1999)** also deals with biasedness in the estimate of coefficients and asymptotic standard errors due to small sample size for the long-run predictability of the monetary model. But he finds no evidence for high predictability at longer horizons. The bias is corrected by new bootstrap method with the correction of small sample size for vector error correction. There is the possibility for misspecification in the linear VEC model. So this study suggests non-linear data generation process for monetary model.

Further, it also finds fundamental flaws in the bootstrap procedure used by Mark (1995) for constructing critical p values for long-run regression, which may lead to bias. **Groen (1999)** also test further the claims made by studies Chinn and Mess (1995) and Mark (1995) that exchange rate prediction at a longer horizon based on the MMER outperforms the random walk model during the post Bretton Wood period. In pursuing so, this study considers three monetary models and purchasing power parity model. He uses Monte Carlo simulation method to correct the overlapping data. The results do not yield the long-run relationship in the monetary model with corrected persistence or autocorrelation among error terms over time that is generated by overlapping data. These results occur when time series is extended to a longer span than that of previous studies Chinn and Mess (1995) and Mark (1995). This is further confirmed by pooled data model of forecasting exercise where it accounts for the exchange rates interdependency with the same numeraire of different countries. This study also concludes that the failure of monetary model for forecasting the exchange rate may be attributed to the lack of cointegration between exchange rate and fundamentals. **Faust et al. (2003)** analyze the result of long-run predictability of monetary models studied by Mark (1995) using original data release and real time forecasting evaluation. But they show that the results of Mark (1995) would have been otherwise if the originally released data other than two years data around 1992 is used. They also find a better forecast for the exchange rate with monetary model-based original data than fully revised data. Even in some cases, forecast based on real time forecasts of future fundamentals rather than actual future fundamental can perform better. Thus, this study does not support the result of Meese-Rogoff based on the actual future fundamentals.

To address these kinds of small sample issues in the long-run relationship of monetary model, **Mark and Sul (1998)** employ the panel data set of 18 countries during the period January 1993 to January 1997. They apply two-step of cointegration developed by Pedroni (1997) “for testing the long-run relationship between exchange rate and fundamentals. The results of panel cointegration test reveal that the presence of long-run relationship between exchange rate and monetary fundamentals for most of the countries. In the out-of-sample forecast exercise, the forecast of monetary model is superior to PPP and random walk model in terms of RMSE at different horizons for most countries”. Furthermore, these results are found to be robust for using alternate numeraires of countries.

Similarly, **Rapach and Wohar (2002)** address the issue of low power of standard tests for small sample by using a long span of annual data of the late nineteenth for 14 industrial countries. Johansen cointegration test is applied to see the long-run relationship between exchanges rates and monetary fundamentals. The empirical results exhibit “the long-run validity of monetary model in the case of exchange rate of US against France, Italy, the Netherlands and Spain and moderate support for Belgum, Finland, and Portugal and inadequate support for Switzerland. They find no support of monetary model for Canada, Denmark, Norway, and United Kingdom”. In VECM result, the exchange rates adjust to ensure long-run equilibrium rather than the monetary fundamentals for Belgium, Finland, and Italy and conversely, it is fundamentals to adjust the long-run equilibrium for Portugal and Spain. In the case of France and Switzerland, both exchange rate and monetary fundamental adjust to restore long-run equilibrium. Finally, they also find a close link between out-of-sample forecast performance of monetary model and the weak exogeneity test. The inability of monetary fundamental to forecast in some countries is due to the weak exogeneity of exchange rate in those countries.

Applying panel unit root test in the presence of structural breaks for real exchange rate between India and its 16 trading partners, **Hegwood and Nath (2014)** examine the validity of PPP hypothesis. Panel root test suggests for more reliable structural breaks in real exchange rates though it is mean reverting without structural breaks. After correcting small sample and time aggregation biases, the time take to adjust any deviation from its long-run real exchange value is reduced with structural breaks in the half-life in the estimated results. Thus, this study yields "structural breaks in the real exchange rate of India", and it has a transitionary impact with any nominal disturbance.

**Engel and West (2005)** explain near random walk behavior with the PV approach as the exchange rate is the discounted summation of linear combination current and future fundamentals. Thus, if the fundamentals are I (1), then the discount factor approaches one. It means that exchange rate follows some unobserved variables that cause random walk movements or exchange rate movements. This proposition is tested in this study using a quarterly data spanning over 1973Q1 through 2003Q1 for US dollar against currencies of Canada, France, Germany, Italy, Japan, and the U.K. They find that that 40 percent of change in the variance in the exchange rate is attributed to observable fundamentals (money, income, prices, interest rate) in the estimation of the present value model of exchange rate. Further, this finding is reexamined by **Hsin Ko and Ogaki (2015)** by testing the Granger causal relation from exchange rate to fundamentals in the same present value model. This test is conducted by using bootstrap method since results in the Engel and West (2005) study suffers from small sample problem, which uses asymptotic method of inference test. Bootstrap test results show Granger casuality running from exchange rate to fundamentals is weak than that of asymptotic test. The Monte Carlo experiment test results also suggest that Bootstrap test yields fewer size distortions and more power than the asymptotic test. It implies that the relationship from exchange rate to fundamentals is not as significant as previously found in the Engel and West (2005).

One finds the hybrid model in the monetary framework where both macro and microstructure of foreign exchange markets are blended to examine the exchange rate dynamics. **Chinn and Moore (2011)** develop the hybrid model by including macro fundamental with Evans–Lyons microstructure approach. This augmented model is estimated by using monthly observations of 100 and with inter-dealer order flow on dollar/euro and dollar/yen from January 1999 to January 2007. The results show that the hybrid model that includes macro fundamentals and micro variables exhibit better performance than traditional macro fundamentals and random walk model alone in the in-sample and out-of-sample. In a similar way **Bhanumurthy (2006)** analyses the relative importance of macro and microstructure variables in explanation of short term movements of exchange rate in the context of the Indian foreign exchange market. This study uses the primary data collected by a survey of the foreign exchange market dealer (FEDAI) and secondary data with daily frequency. The secondary data regression analysis reveals that order flows proxied by turnover, and the number of transactions explains significantly compared to a macro variable such as interest rate. The primary data analysis suggests that factors such as news, bandwagon effect, speculation, and order flows determine short run exchange rate. Most surprisingly, this study indicates that speculation activities rise volatility, liquidity, and efficiency of the market, whereas central bank intervention reduces volatility and efficiency in the market.

Similarly, **Ranjan et al.** (2008) attempt to analyze if the market microstructure in the Indian foreign exchange market is important. They examine the interdependence among intra- day high, low, and close exchange rate in the trading rule framework. This is conducted by the application of cointegration test along with vector error correction analysis during the period April 1995 to September 2007. They find that there exists the interdependence between close, intra-day high and low exchange rates that indicate demand and supply forces in the market have influenced Rupee-Dollar rate. The closed exchange rates symmetrically reacts to intraday low and high exchange rates in the long run. Furthermore, they also confirm that exchange rate reacts to macroeconomic variables, such as differential between call money rate and repo rate, foreign interest rate and stock market return. These variables reflect domestic liquidity conditions, external financial climate, and capital flow and their respective impact on all closed, intraday high and low exchange rates. This result shows the role of macroeconomic conditions in determining the demand and supply forces of exchange rate.

In the emerging economies context, **Sanchez-Fung (2015)** investigate exchange rate behavior using the hybrid model by adding micros structure dimension to PPP model during the period 2005 to 2013. This study uses monthly data employing the Engle-Granger cointegration with error correction mechanism. This study reveals that augmented PPP model with net purchases in the foreign exchange market play a key role in capturing the dynamics of exchange rate over and above the conventional macro PPP model. Moreover, in their comparison among PPP, augmented PPP AR, and UIP model of exchange, it finds that augmented PPP beats other model over 3-month forecast horizon. However, at the 6 months and 12-month forecast horizon, UIP is found to perform well.

As mentioned in earlier, we also review few empirical studies that investigate merely on exchange rates dynamics without the use of any monetary models or monetary fundamentals. **McCrae et al. (2002**) compare the performance of auto regressive integrated moving average (ARIMA) univariate models in terms of forecasting with multivariate model like cointegration based ECM model. They attempt to see how it makes a difference in including information of integrated components and cointegrated components in the forecast. For this purpose, the time series between January 1985 to February 1997 is chosen for the daily exchange rate of ASIAN countries such as the Thai Baht (TB), the Japanese Yen (JY), the Singapore Dollar (SD), the Malaysian Ringgit (MR) and the Philippine Peso (PP). The relative forecasting accuracy is found to be sensitive to individual exchange rate series behavior and forecasting horizons. ARIMA model yields a more accurate forecast over short horizons with MA terms of order greater than 1. But over horizons of medium time, ECM based cointegration performs better when series has no moving averages. Overall, this study shows the difference between 'synchronous' and 'sequential' and forecasting ability of models. In similar lines, **Diebold et al. (1994**) contend that exchange rate forecasts of cointegrated based ECM are superior to those martingale models. They examine this proposition in case of Canadian dollar, French franc, British pound for by generating forecasts over 1 to 126 days ahead horizons. It is found on the contrary that martingale model is superior in the forecasting than co-integration models in the forecasting exercise.

**Maitra (2015)** looks at the univariate model's power involving Rupee-Dollar rate, and rates against British pound, European union euro, and Japanese yen for sample spanning from August 1994 to April 2014. ARIMA model and GARCH based ARIMA model are estimated in the in-sample and the out-of-sample to assess their performance with the benchmark model random walk model. He finds that the random walk model beats ARCH/GARCH and ARIMA models in forecasting Rupee-Dollar rates.

As our primary focus is on Divisia aggregates in the monetary framework, there are also such studies that try to explain exchange rate using Divisia aggregates and examines the sensitivity of monetary model between simple sum aggregates and Divisia aggregates. **Chrystal and MacDonald (1995)** discuss how useful are the Divisia aggregates relative to simple sum ones for MMER during financial deregulation period of UK and US. Additionally, they compare UK estimates with German where relative stable environment presents in monetary market. So the exchange rates of sterling and mark against US Dollar are taken for empirical investigation over the period 1972Q1 to 1990Q2. In the estimated results with Johnson cointegration test and error correction models, Divisia money produces significant difference in the modeling of sterling /US Dollar exchange rate in short and long-run dynamics and out-of-sample forecast relative to simple sum aggregates. When these estimated results compared with mark /US Dollar exchange rate, Divisia aggregates have less significance relative to simple sum counterparts. **Barnett (2005**) forecasts exchange rate using Divisia aggregate and user cost in the place of money variable and interest rate in the monetary models. They use quarterly data for US Dollar UK pound exchange rate for the period 1977Q1 to 2002Q3, since Both the Bank of England and the Federal Reserve Bank of St. Louis both have started publishing Divisia monetary aggregate data for that time period. They apply vector error correction model in the rolling regression procedure. This study also shows that monetary model-based Divisia aggregate and user cost are superior to the random walk model in the forecasting exchange rate out-of-sample.

**Chin et al. (2009)** compare the role of "Divisia money relative to simple sum money" in the context of ASEAN countries for quarterly data series spanning from 1981Q01 to 1994Q04.

Johansen cointegration test and vector error correction models are employed to capture long-run and short-run dynamics underlying the MMER. The results reveal that Divisia aggregates help in modelling long-run dynamics significantly compared to simple sum money in the case of the Philippines and Malaysia and. At the same time, it is not a case for “Indonesia, Singapore, and Thailand”. The monetary model with Divisia aggregates outperforms simple sum in forecasting for Singapore, Malaysia, and Thailand. But they do not have any impact on the forecast results of Indonesia and the Philippines. However, the study also supports the empirical significance of Divisia money in times of financial innovation.

A recent study **by Leong et al. (2018**) also reexamine the long-run relationship underlying the monetary model in case of Indonesia by measuring money with Divisia aggregates in the time of its financial deregulation. ARDL cointegration methodology is employed to see the long-run relation in the monetary model for period 1984Q1 to 2017Q1. The results shows that monetary model has acquired cointegration or long-run relation with Divisia aggregates and thus monetary fundamental are critical determinants of exchange for Indonesia. Moreover, Divisia aggregates help enhance the stability of the monetary equation. **Leong et al. (2018)** investigate an unresolved issue of unstable money demand function in the monetary model by using Divisia aggregates in the case of Philippines. They apply ARDL cointegration methodology on monetary model with Divisia and simple sum aggregate alternatively. For this purpose, quarterly data set range from 1987Q1 to 2016Q4 is utilized. During this period, Philippines is encountered with a favorable external economic situation, i.e., accelerated imports and industrial growth because of lower crude oil price. The results show “long-run relation between monetary fundamentals and exchange rate”. This study also confirms that Divisia aggregates perform better than simple sum aggregates in explaining exchange rate in financially innovative times of Philippines.

In the context of India, **Barnett et al. (2016**) examine monetary policy impact in the SVAR model to explain the fluctuations in exchange rate, output and price level with using simple sum and Divisia money alternatively. They find that exchange rates fluctuations are well explained and predicted when Divisia aggregates define money variables compared to simple sum aggregates. With the same spirit, **Bhadury and Ghosh (2018**) look at the ability of Divisia aggregates in explaining the exchange rate fluctuations in the case of India along with other group of countries i.e., UK , Israel, Poland, , and the US. This analysis is carried out for the years of leading up to and following 2007-08 recession, when interest rate is near the zero lower bound or at zero. Because interest rate turns to be lacking information about the monetary policy stance and Divisia money can be alternative policy indicator. Their application of bootstrap Granger causality yields strong causality running from Divisia money to exchange rates.

**2.3. Exchange rate volatility: Studies in the macro context.**

There are numerous empirical studies on exchange rate volatility in various contexts ranging from trade to macroeconomics and firms' level to stock markets for both Indian and global level. However, we confine to issues concerning to the relationship between exchanger rate volatility and macro fundamentals. The basic argument begins **with Friedman (1953)** that "*exchange rate volatility is a symptom of instability or volatility of macroeconomic structure. He states that flexible exchange rates are not necessarily unstable exchange rate. If it is so, it is due to underlying instability of its economic condition".* Several authors have tested the claim of Friedman (1953) through their empirical studies. **Morana (2009)** considers linkages between macro fundamentals and exchange rate volatility in long terms for the G-7 countries. The results show significant long-term inter-linkages and tradeoffs between macro fundamentals and exchange rate for G7 countries in the float period between 1980 and 2006. **Balg and Metcalf**

**(2010)** examine the effect of macro fundamentals volatility on exchange rate volatility using the different monetary models of exchange rate for Canada, Germany, Japan and UK. The findings of results confirm evidence for short run overshooting in the exchange rates. Volatility in money supply differentials is a key factor for volatility in exchange rates. **Grossmann et al. (2014)** investigate high and low-frequency components in the dynamic relationship between exchange rate volatility and macro-financial variables for panel data 29 economies using spectral methodology. They find evidence without much difference between high frequency and low frequency that the more substantial feedback effect from exchange rate volatility to macro and financial variables in the case of developing countries relative to that in the developed ones. **Jabeen and Khan (2014**) discover many sources for the volatility of Pakistan currency against foreign currencies in the different macro fundamentals in the estimated GARCH and EGARCH results.

Conversely, **Flood and Rose (1995, 1999)** argue and show empirically that choosing exchange rate regime as a policy variable consequent into important effect on exchange rate volatility without impacting volatility of macro variables. Thus, they conclude that volatility in macroeconomic fundamentals is not determinants of exchange rate or its volatility. Further, this conclusion has been empirically examined by a few other authors. Even **Duarte (2003)** documents variability in the real exchange rate across floating and fixed exchange rate using the framework of a dynamic equilibrium model with the assumptions of a nominal good price set in the buyer's incomplete asset markets and currency markets. This model finds a drastic increase in the volatility of real exchange rate in the time of switching from pegged to floating. At the same time, the same pattern is not seen for other macroeconomic variables. **Kempa (2002)** provides further evidence for it by showing volatility difference, found in fundamentals with an appropriate identification in the fully identified structural VAR model on quarterly G7 exchange rates. The results find that exchange rate volatility is by large accounted by shocks to purchasing power parity that is originating in the real sector of the economy.

We find plenty of empirical studies that analyze the exchange rate movements on account of real and nominal factors of the economy. In those, **Driskill and McCafferty (1980)** develop "a theoretical model for the exchange rate uncertainty in a small open economy under a flexible regime". This assumes sticky prices, the quick adjustment of asset markets that clear period by period, and rational expectations to see a role of the capital mobility. They assert through model that high capital mobility may lead to an increase in portfolio variability when variability in relative assets return is anticipated. In conversely, higher capital mobility lowers exchange rate volatility if shocks are felt by real factors and is associated with positive exchange rate volatility when unexpected shocks occur within the economy. Similarly, **Grydaki and Funtas (2008)** develop the theoretical approach for determinants of exchange rate and output levels and their volatilities in the context of a small open economy with flexible exchange rate regime. They show that volatility of exchange rate and output are positively related to shocks in monetary, inflationary, trade, output, and government spending. The levels of the exchange rate and output are affected by all these shocks.

**Edwards (1986)** investigates the importance of real and monetary factors (shocks) on the real exchange rate volatility in the case of developing countries emphasizing the possible roles of terms of trade and trade openness. The results show that both real and nominal variables influence the real exchange rate volatility. But the real factors determine significantly real exchange rate volatility in the long term, whereas nominal variables influence real exchange rate volatility in the short run. The result also reveals that terms of trade is found to play a prominent role in the long-run volatility in real exchange rate.

A classic study by **Clarida and Gali (1994)** attempts to investigate the sources of real exchange rate fluctuations using Blanchard and Quah (1989) identification approach for VAR. Their estimated results suggest the nominal shocks explain the more significant amount of variance in real exchange rate relative to real shocks. They stress predominantly that nominal shocks still do matter for explaining real exchange rate fluctuation in the short run. The same study is examined by **Chen (2004)** by estimating structural VAR for an extended long span of data on UK/US real exchange rate. Interestingly, this study also reiterates the conclusion of Clarida and Gali (1994) that monetary shocks do have an impact on real exchange rate with 50 percent of the variation in real exchange rate.

Several studies analyze volatility in the context of trade openness and financial openness. **Calderon (2004**) examines the real exchange rate volatility and its determinants for industrial countries over the period between 1973 -2001 in the context of openness in trade and finance. He observes in the results that volatility in money supply, output and terms of trade are significant sources of fluctuations in real exchange rate in the times of trade openness. The real exchange rate volatility is shown to be highly volatile under more flexible exchange rate regime. **Karras (2006)** finds openness exerting a positive influence on exchange rate variability. But exchange rate variability and trade openness are inversely related on account of economic size. The result of recent study by **Mpofu (2016)** also confirms that trade openness reduces volatility for both nominal and real bilateral exchange rates for South Africa along with the significant impact of macro fundamentals. Conversely, it also finds that switching to a floating exchange system from fixed one does lead to more exchange rate volatility. **Grydaki and Fountas (2010)** show that there is a significant impact of macro fundamentals like money supply and inflation on exchange volatility when financial openness is account in the case of three Latin American countries i.e. Argentina, Bolivia an Chile. Their result also shows that flexible exchange rate tends to lead higher volatility than that under fixed rates for Argentina and Chili. But it is not in case of Bolivia.

**Canales-Kriljenko and Habermeier (2004)** support "evidence on floating exchange rate that is highly volatile than that of fixed based on a cross-section data of 85 developing and transition economies in 2001". Their analysis reveals that higher exchange rate volatility in those countries experiencing high fiscal deficits and inflation and lower in those countries with faster real GDP growth and more open economies. However, the volatility is not significantly affected by terms of trade. In addition, exchange rate volatility is found to be negatively associated with market microstructure factors. They include decentralized dealer markets, regulations on nonresidents' domestic currency use, acceptance of Article VIII obligations, and limits set on banks' forex positions in the IMF survey data on foreign market, organization, and regulation.

Recent literature in the exchange rate explores the exchange rate volatility in using different methods and institutional aspects. **Adusei and Gyapong (2017)** attempt to explain the variance in exchange rate by macroeconomic fundamentals using the partial least square structural equation model for Ghana's cede exchange rate with US the data period spanning 1975-2014. The results show that the variance of macroeconomic fundamentals explains 82 % of the variance of exchange rate. **Cevik et al. (2017)** investigate the impact of soft power aspects on exchange rate volatility. They employ a 115 countries' balanced panel over 1996 to 2015. Their results demonstrate that after account of macroeconomic factors, "the soft power variables such as an index of voice and accountability, life expectancy, educational attainments, fragility of the banking sector, financial openness, and the share of agriculture relative to services are statistically significant impact on the level of exchange rate volatility across the countries".

There are also studies in the case of India that investigate range issues from central bank intervention to trade and inflation to growth and gold and oil prices to the stock market. **Goyal and Arora (2012)** examine impact of central bank intervention on exchange rate conditional mean and volatility by accounting for communication and news using data of both monthly and daily frequency. They mainly confirm that central bank intervention with its effective communication influences exchange rate level despite of the fact that RBI is not committed to target the level of exchange rate. A similar kind of study by **Kohli (2015)** investigates the impact of reserves on Rupee-Dollar exchange rate volatility in the backdrop of the increased financial integration in pre and post- crisis period. It is found in the results that the reserve advocacy shows a significant impact in reducing the exchange rate volatility irrespective of the regime after accounting the effect of other internal and external macroeconomic variables. This study implies that the impact of forex reserves operates through market sentiments and confidence rather than the actual intervention alone.

**Saha and Biswas (2014)** have examined "the long-run relation between real effective exchange rate and macro fundamental variables during the post-reform period. They find evidence for long-run relation among exchange rate and macro fundamentals". The source of exchange rate fluctuations is by lager amount concentrated in interest rate, economic growth, and inflation. Further, a shock to fundamental macro variables bears the long-lasting effect on exchange rate. **Mohanty and Bhanumurthy (2014)** investigate exchange rate stability for inflation management in the framework of "impossible trilemma". It shows in the results that exchange rate regime does not have an impact on inflation in the Indian context. This may be on account of the offsetting sterilization action by Reserve Bank of India (RBI). **Mirchandani (2013)** investigates macroeconomic factors that lead to instability in the Rupee-Dollar exchange when the foreign exchange market was undergoing significant changes in the period 1991-2010. She considers macroeconomic variables such as inflation, interest rate, current account deficit, GDP growth rate and foreign investment and finds the correlation between variations in the Rupee-Dollar exchange rate and change in macroeconomic variables.

Some empirical studies look at the impact of old prices and financial markets, i.e., stock markets, etc. on exchange rate volatility. **Ghosh (2011**) sees the nexus between oil prices and exchange rate for India in the period of higher oil prices using GARCH and EGARCH model on daily data. It is found in the results that the increase in oil prices return leads to deprecation Rupee-Dollar exchange rate, and shocks in oil prices lead to permanent impact on exchanger rate volatility. Further, the results also suggest that both positive and negative shock of oil prices have a symmetric effect on exchange rate volatility. **Ghosh (2014)** investigates "volatility co-movements or spillover from different financial market to the foreign exchange market in India. The results of estimated multivariate GARCH, threshold-GARCH, GJR-TGARCH" show that all these financial market variables are found to have a significant volatility spillover effect on the foreign exchange market. The effect mostly occurs from the domestic stock market followed by other markets, which is quite intuitive in the Indian context because of substantial capital inflows. This study also confirms asymmetric reactions in foreign exchange market volatility.

## 2.4. Justification of the present study

In the above review, we find that the previous studies of monetary models have not dealt much with the relevance of Divisia aggregates in the Indian context. India being an emerging economy has been witnessing financial innovation in several dimensions since the 1990s. This calls for fresh investigation since financial innovation in terms of introduction of new assets at the least, renders simple sum monetary aggregates to be less meaningful in capturing liquidity in the system. Therefore, money not appropriately measured may yield unreliable results in the MMER *via* its bearing on money demand stability. Despite few recent studies, i.e., **Barnett et al. (2016) and Bhadury and Ghosh (2018)** have explored the Rupee -Dollar exchange rate dynamics with Divisia money. However, they have not employed monetary models. Thus, the research on Divisia aggregates for exchange rates of India is far its potential.

Accordingly, as stated in Chapter 1 the objectives are formulated.

# Chapter 3

## Modelling Rupee-Dollar exchange rate in the monetary approach using simple sum and Divisia monetary aggregates

### 3.1. Introduction

As discussed in chapter 1, in March 1993 "a unified exchange rate system" replaced the dual rate and exchange rate of the Indian Rupee began getting determined by supply and demand, the market forces. In the global context, with the breakdown of the Bretton Woods, around 1973 major exchange rates were floating. During this time, the MMER emerged as one of the prominent models explaining determinants of exchange rates and exchange rate behaviour. This chapter deals with the long run validity monetary model of exchange rates. According to this model, monetary fundamentals such as domestic money supply, income, and interest rate relative to those of the foreign country determine exchange rate in the long run. Also, the long run validity is of importance for forecast of exchange rates in the various time horizons on which the accurate forecast depends upon. A few studies like Meese and Rose, 1991; Alexander and Thomas III, 1987; Abbott and Vita, 2002 showed the failure of monetary model in determining exchange rate. One of the reasons cited for such failure has been the lack of long run relationship or the exchange rate-monetary fundamentals cointegration (Baillie and Selover, 1987; Neely and Sarno, 2004). However, this can be mainly influenced by several other empirical issues such as instability in the monetary demand function, parameters instabilities, small data sample size, misspecification and structural breaks arise due to policy changes and economic events. Hence, an examination of long run validity of monetary model provides the crucial information in formulating of exchange rate and monetary policies. Thus, the empirical investigation of the long run validity of monetary model in different prospective contribute to exchange rates literature significantly. Specifically, this chapter of thesis addresses measurement issues in unstable the money demand function on which monetary models depend upon, using simple sum and Divisia aggregate to improve their long run validity in the times of financial innovation. The rest of the chapter is organized as follows. Section 3.2 presents overview on long run validity of the MMER and the research gap. Section 3.3 discusses briefly empirical model; Section 3.4 presents data and methodology used in this study. The results are discussed in the 3.4 section. Finally, section 3.5 offers some policy implications and concluding remarks.

### 3.2. Monetary models and empirical validity: an overview

One finds several studies examining exchange rates and monetary fundamental relationship and forecasting exchange rates. As mentioned earlier, the monetary model's failure has been largely attributed to lack of exchange rate-monetary fundamentals cointegration. In particular, Baillie and Selover (1987) employing various dynamics models such as ordinary least square (OLS), OLS with auto regression on residuals and seemingly unrelated regression (SURE) type vector auto regression(VAR) models for five countries i.e., United States(US),United Kingdom (UK), West Germany, Canada and Japan find no cointegration. However, Moosa and Burn (2017) discover that irrespective of cointegration or no cointegration in the monetary model, monetary fundamentals cannot outperform the random walk, when forecast accuracy is judged by root mean square errors. They also suggest that cointegration is not a sole solution to the Meese-Rogoff puzzle. Applying cointegration, few others including MacDonald and Taylor (1994), Diamandis and Kouretas (1996), and Tawadros (2001) document supporting evidence for the long-run validity and better out-of-sample forecasting performance of the monetary models. In testing of variants of monetary model of the exchange rate, Chin et al. (2007) find evidence on long-run validity of monetary model for Malaysian-ringgit-USD exchange rate and particularly in the sticky price variation of the model. Further, with instabilities and structural breaks in the model, empirical studies support monetary fundamentals in determining of exchange rate (see e.g. Goldberg and Frydman, 2001; Rossi, 2005; Beckmann et al., 2011; Panopoulou and Pantelidis, 2012).

One of the recent studies by Ince et al. (2019) find that random walk is outperformed by monetary model. Also, monetary model estimated in the non-linear framework forecasts better than linear models. Ibhagui (2019) examines the long run relationship underlying the MMER using the panel cointegration approach for 22 sub Saharan Africa countries and finds partial support for long run relation between exchange rate and monetary fundamentals.

In case of India, Ghosh (1998) finds no long-run relation in his study whereas studies by Kletzer and Kohli (2000), Dua and Ranjan (2011), and Bhanja et al. (2015) yield evidence in support of long run relationship between monetary fundamentals and exchange rate. In yet another study, Sharma and Setia (2015) examine the relationship incorporating structural breaks in cointegration analysis. They find that macroeconomic fundamentals determine exchange rate significantly with varied size effect and across the periods. To sum up, "the evidence on long run relationship between exchange rate and monetary fundamentals is thus found to be mixed in nature".

The failure of monetary model could be also possibly due to instability in the money demand and the instability being a result of using simple sum money measures in estimation of monetary models. For the first time, Chrystal and MacDonald (1995) examined the usefulness of aggregation theoretic monetary aggregates i.e. "Divisia money versus simple sum monetary aggregates for the monetary models", during financial deregulation period for two exchange rates namely the Sterling-Dollar and the German-Mark rates. They suggested that the use of aggregation Divisia monetary aggregates made a significant difference in modeling of the Sterling-Dollar exchange rate both in short and long runs Barnett et al. (2006) and Chin et al. (2009) further support the Divisia aggregates in improving long run validity of monetary model and out-of-sample forecast of exchange rate. To mention a few among others, Barnett (1980, 1990) and the most recent ones by Fuente et al. (2020) and Belongia and Ireland (2019) have proved the superiority of Divisia money in terms of its relationship with real macro variables such as income, inflation, and also in yielding stable money demand functions. Since money demand functions play crucial role in MMER, appropriate measurement of monetary aggregates merit attention too.

### 3.2.1. Research gap and objective of this Chapter

In the Indian context, a few studies are found on empirical verification of the monetary model of exchange rates. These studies (Ghosh, 1998; Kletzer and Kohli, 2000; Dua and Rajan, 2011; Bhanja et al.2015) have used simple sum monetary aggregates in modeling of the monetary models. As mentioned before India being an emerging economy has been witnessing financial innovation in several dimensions since the 1990s. This calls for fresh investigation since financial innovation in terms of introduction of new assets at the least, render simple sum monetary aggregates to be less meaningful in capturing liquidity in the system. Therefore, money not appropriately measured may yield unreliable results in the monetary exchange rate model via its bearing on money demand stability. Acharya and Kamaiah (2001) found "money demand functions in India to be unstable with simple sum money whereas the functions with Divisia money were stable". A significant research gap in the Indian context is therefore, not using Divisia aggregates in estimating MMER.

In view of the above, this chapter tries to fill the gap by employing simple sum versus Divisia aggregates in flexible price version of the MMER for the time period in which the Indian economy has undergone changes on account of financial innovation affecting measurement of money. The study, therefore, re-examines the validity of the MMER using simple sum and Divisia monetary aggregate for Rupee-Dollar exchange rate. Also, it investigates the relative performance of Divisia money *versus* simple sum money in the monetary model for Rupee-Dollar rate. Divisia index for India as well as US are employed in the monetary model for Rupee-Dollar exchange rate determination. In this regard it is hypothesized that measuring money supply between India and US with Divisia index or Divisia money during the financial innovation period may be more appropriate in explaining the exchange rate dynamics.

### 3.2.2. Divisia monetary aggregates: construction and empirical evidence

Divisia monetary aggregates were first proposed by Barnett (1980, 1990) integrating aggregation theory, index number theory and monetary theory. In a series of papers, Barnett theoretically proved the superiority of the Divisia monetary aggregates and further Barnett (1982) laid down the steps for arriving at an optimal monetary aggregate. The existing simple sum aggregates practiced by the RBI or any other central bank are simple arithmetic sums assuming the components to be perfect substitutes of each other. For instance in the Indian context, broad money (M3) and narrow money (M1) and New broad monetary aggregate (NM3) are computed simply by arithmetically summing up different combinations of the components; "currency with the public, demand deposits, and different time deposits". The different components of these aggregates are imperfect substitutes of each other. Thus, considering all components as perfect substitute for one other may not appropriately measure liquidity. The Divisia aggregate as mentioned earlier circumvents this problem by assigning different weights to the different components in an aggregate according to the degree of transaction/monetary service provided. Thus, money held for transaction purposes is distinguished from money held for investment services. By considering monetary assets as durable goods Barnett (1978, 1980a) derived the user-cost prices of their services. To quote Barnett (2012), "the user cost price of consuming the services of a monetary asset is its opportunity cost, measured by the interest forgone by employing the services of the asset". Thus, "the user cost, $p_{\mathrm{it}}$ of each component is defined as $(R_t\text{-}ri_t)/(1+R_t)$ , where $R_t$ denotes the benchmark interest rate and $r_{it}$ is the interest on asset *i* at time *t"*. The benchmark interest rate is the rate on the best available pure investment. Thus, one needs to subtract an asset's investment services (nonmonetary in nature) from the benchmark rate to arrive at the user-cost price of the asset's two time periods liquidity services. Further Barnett (2012) defines "A quantity (or price) statistical index number measures the change in the aggregated quantity (or price) of a group of goods between two time periods. The index number must be a formula depending on both the quantities and prices of the goods in that group during the two time periods. The index number cannot depend on any other data or any unknown parameters". To quote two more definitions from Barnett (2012), " The growth rate of the Divisia quantity (price) index is the weighted average of the quantities (or prices) of the component goods over which the index aggregates, where the weight of each good is that good's expenditure share in the total expenditure on all the goods over which the index aggregates". Thus, "the expenditure share of the services of component/monetary asset *i* in period *t* is given by

$$s_{it} = \frac{p_{it}m_{it}}{\sum p_{jt}m_{jt}} \tag{3.2}$$

Where, $m_{it}$ is monetary asset *i* at time *t"*.

Finally, "The Divisia monetary aggregates are produced by substituting into the Divisia quantity index formula, the quantities of individual monetary assets and their corresponding user-cost prices".

Thus, the rate of growth of Divisia monetary aggregate (quantity index) is given by

$$\sum_{i=1}^{n} s_{it}^{*} \left(ln\, m_{it} - ln\, m_{it-1}\right) = lnM_t - lnM_{t-1} \tag{3.3}$$

Where $s_{it}^{*} = 1/2(s_{it}+s_{it-1})$. The Divisia index growth is, therefore, a weighted average of the growth rate of the monetary components where weight of each component is the user cost adjusted expenditure share of that component.

It is evident from this formulation that the components weighted more are those with higher transaction/liquidity services and less interest rate return. Hence, Divisia aggregates internalize substitution effect among components responding to changes in interest rate in the economy. The economies undergoing financial innovation often see introduction of new financial assets that are interest bearing in nature. In such scenario the use of Divisia monetary aggregates assume crucial significance in adequately measuring liquidity in the economy.

The empirical literature examining relative performance of Divisia money over simple sum money is humungous. However, among the most recent studies Barnett and Tang (2016) in case of Chinese economy find that the dynamic factor model including Divisia money yields better informational forecast about GDP than models with simple sum aggregates. Belongia and Ireland

(2019) claim, "…identification of stable money demand functions estimated with Divisia quantity data and their user cost duals is consistent with the idea that instability reported since the early 1990s may be more closely associated with measurement error than shift in the underlying economic relationships themselves".

But studies using Divisia money for the MMER are scanty in international and Indian cases. For the first time, Chrystal and MacDonald (1995) examine Divisia money's usefulness relative to simple sum money for the monetary models during financial deregulation period for Sterling-Dollar and German Mark exchange rates. They suggest, "Divisia money makes a significant difference in modelling of the Sterling-Dollar exchange rate in short and long run". Barnett et al. (2006) investigate the ability of the monetary models in forecasting exchange rate by defining money supply and interest rate variables with Divisia aggregate and user costs respectively, for US and UK. They find the Divisia aggregates and user costs based monetary models to be superior to random walk type of models in forecasting exchange rate movements. Chin et al. (2009) reinforce the evidence for Divisia aggregates in their study for ASEAN countries, in which they find that monetary models with Divisia aggregates are superior in long run modeling of exchange rate for Malaysia and Philippines, whereas it is not significant for Indonesia, Singapore and Thailand.

In case of India, studies using Divisia aggregates are limited to demand for money and inflation only. These studies provide theoretically consistent results and better information content. Some of these studies include Acharya and Kamaiah (2001), Ramchandran et al. (2010) and Paul and Durai (2019). However, Barnett et al. (2015) examine monetary policy impact in a SVAR model to explain the fluctuation in exchange rate, output and price level using simple sum and Divisia money for the Indian economy. They find that exchange rate fluctuations are well explained and predicted when money is defined by Divisia aggregates when compared to simple sum aggregates.

In view of the above, in this chapter an attempt is made to fill the gap by employing simple sum versus Divisia aggregates in flexible price version of MMER for the time period in which the Indian economy has undergone changes on account of financial innovation affecting measurement of money. The study therefore re-examines the validity of the MMER using simple sum and Divisia monetary aggregate for Rupee-Dollar exchange rate. In this regard it is hypothesized that measuring money supply between India and US with Divisia index or Divisia money during the financial innovation period may be more appropriate in describing the exchange rate dynamics.

### 3.2.3. Empirical model: monetary model of exchange rates

Flexible price monetary model[1] developed and discussed by Frankel (1976), Mussa (1976) and Bilson (1978) has been used in this empirical analysis. This model is chosen to see its relevance in determining the Rupee-US dollar rate. For the full details on the flexible prime model are suggested to refer to chapter 1 introduction and section 1.3. In this model, "exchange rate is a function of money supply, income, and interest rate differential between domestic and foreign country". This is specified in the following equation.

$$e_t = (m_t - m_t^*) + \beta_2 (y_t - y_t^*) + \beta_3 (i_t - i_t^*) \qquad (3.4)$$

Where $y$, $m$, $i$ denotes income, money and interest rate of domestic country respectively and the variables with an asterisk (*) denote counterparts of the foreign country. In (3.4) above $\beta_2$ and $\beta_3$,

[1] There are three other variants of the monetary model. They are sticky or fixed price monetary model (Dornbusch, 1976), real interest rate differentials model (Frankel, 1979) and Hooper and Morton model (Hooper and Morton, 1982).

denote elasticity of each variable with respect to exchange rate *e*. Except the interest rate variable, all variables are in natural logarithm form. As this model assumes flexible prices, "any changes in the interest rates reflect the changes in the expected inflation". Consequently, if the domestic interest rate is higher relative to the foreign interest rate, domestic currency depreciates because of reduction in the demand for money. Therefore, the variables interest rate differential and exchange rate are expected to be positively related. An increase in domestic money supply compared to foreign money supply leads to rise in domestic price levels and the lower demand for domestic currency results in depreciation of domestic currency. Thus, a positive relationship is expected between exchange rate and the money supply differential between domestic and foreign country. Further, the exchange rate and income differential relationship between the domestic and foreign countries is expected to be negative. This is because with increase in domestic income level relative to that of foreign, domestic currency appreciates with higher demand for money.

### 3.3. Data and method

The focus of this study is on the period coinciding with financial innovation in the Indian economy and performance of the MMER. Hence, the sample is chosen to be part of the post-reform period of India, after March 1993. This also coincides with the commencement of floating rate regime in the Indian foreign exchange rate market. In view the consistent availability of monthly data on all the variables for both the countries, the time spans over August 1996 to February 2017. In the monetary model, money variables for India and US are measured by alternative sets of simple sum and Divisia monetary aggregates. Those are Broad money (M3), New Monetary Aggregates (NM3)[2], Divisia M3 (DM3) and Divisia NM3 (DNM3) for India and M2[3] money stock and Divisia all for U.S. The calculation of Divisia index for M3 as well as NM3 for India is done by employing their components based on their respective user cost-based weights i.e., expenditure shares. The details on monetary components, choice of their corresponding interest rates and the benchmark rate are given in Appendix A3 of this chapter. Interest rates for various monetary components are sourced from State Bank of India (SBI) and Reserve Bank of India (RBI) databases. Data on Divisia M2 (DM2) for US is taken from Centre for Financial Stability. The reason underlying the choice of M2 for US is guided by similarity in the components of US M2 and Indian M3/NM3 that makes these aggregates comparable. Income for India and US are measured by respective countries' monthly index of industrial productions. Interest rate of India and US are the monthly weighted average call money [4]rate and effective federal fund rates respectively. Money supplies and incomes differentials are seasonally adjusted and except for interest rate differentials, all the variables are in their natural logarithms. Rest of the data is sourced from Handbook of Statistics on Indian Economy (HSIE), RBI for India, and FRED for US. For Divisia NM3 the period is from April 1999 through February 2017 due to lack of linked series on all monetary components for calculation of Divisia NM3.

The variables under consideration in this study are first tested for their order of integration as required before conducting cointegration tests. Then Johanesen (1988)'s cointegration method is employed to test the long run relationship in the MMER. This is not possible with the residuals based cointegration test due to Engle and Granger (1987), because it involves two steps of

[2] According to "working group money supply: Analytics and methodology of compilation chaired by Y.V. Reddy (1998), NM3 is based on residency concept in which non-resident foreign currency repatriable fixed deposits in form of FCNR (B), Resurgent Indian bonds (RIB) and Indian millennium Deposits (IMDs)", which are excluded as they are considered as external liabilities and do not constitute domestic demand for monetary assets as well.
[3] M2 of US is broader in terms of components that as equivalent as components of M3 and NM3 of India.
[4] Monthly weighted call money rate and federal funds rate represent a real market interest rate for India and US. Even they are used by studies by Barnett et al. (2016) for the analysis of exchange rate with Divisia aggregates.

estimation resulting in a single cointegrating vector. Another competing and widely used cointegration method due to Pesaran et al. (2001) though ARDL modelling can be used without worrying about the order of integration of the variables. The present study applies the Johansen (1988) method since the variables are found to be of the same order of integration.

The Johansen cointegration method is briefly given as follows. An Nx1 vector of I (1) or I (d) variables, X, having the following autoregressive representation with Gaussian errors, $\varepsilon_t$, is considered i.e.

$$X_t = \Pi_1 X_{t-1} + \Pi_2 X_{t-2} + \ldots + \Pi_k X_{t-k} + \varepsilon_t \quad , t=1, 2.....,T \tag{3.5}$$

And the corresponding long run equilibrium is given by $\Pi X = 0$, and the long run coefficient matrix is given by

$$\Pi = I - \Pi_1 - \Pi_2 - \Pi_3 \ldots - \Pi_k \tag{3.6}$$

Here, $\Pi$ is an NxN matrix. The rank of $\Pi$ , determines the number of cointegrating vectors that exist between the variables in X. Then there are two $N \times r$ matrices of $\alpha$ and $\beta$ such that

$$\Pi = \alpha \beta' \tag{3.7}$$

Where $\alpha$ represents the speed of adjustment. The rows of $\beta'$ , yield the r distinct cointegrating vectors. Thus, given $\beta'_i$ as the *i*th row of $\beta'$, that $\beta'_i X_t \sim I(0)$.

To test the hypothesis of "*at most* r distinct cointegrating vectors and for testing the hypothesis that there are at most r distinct cointegrating vectors against the alternative of r+1 cointegrating vectors", Johansen (1988) gives two test statistics i.e. trace and maximum eigenvalue. Since both test statistics have nonstandard distribution, approximate critical values for test statistics are given by Johansen (1988) and Johansen and Jesulius (1990). Finally, to see the goodness of fit of each model, Breusch-Godfrey Lagrange Multiplier test (LM) and ARCH heteroscedasticity tests are conducted with null hypothesis of no serial autocorrelation and no heteroscedasticity in the residuals of model, respectively. Also, Ramsay Reset test is conducted with null hypothesis of no nonlinear functional form of specification of model. Finally, cumulative sum (CUSUM) and CUSUM of square tests (Brown et. al., 1975) are applied to see the stability of the long run relationship underlying the models estimated.

### 3.4. Empirical findings

In this section, empirical results including interpretation of the unit root and cointegration tests are presented. First, unit root properties of variables entering the exchange rate equation (3.1) are examined. Before that descriptive statistics for these variables are presented in table 3.1. It is observed in the table that the mean change is higher in all variables except industrial production indices differential between India and US. As expected, standard deviations of simple sum money are higher than those of Divisia money.

**Table 3.1** Descriptive statistics

| Variable | e | M3-M2 | NM3-M2 | DM3-DM2 | DNM3-DM2 | y-y* | r-r* |
|---|---|---|---|---|---|---|---|
| Mean | 3.869 | -2.398 | -2.413 | -2.302 | -2.302 | 0.899 | 4.836 |
| SD | 0.164 | 0.429 | 0.454 | 0.428 | 0.428 | 0.305 | 2.379 |
| Skewness | 0.593 | -0.181 | -0.202 | 0.251 | 0.251 | -0.042 | 0.289 |
| Kurtosis | 2.749 | 1.359 | 1.352 | 1.461 | 1.461 | 1.365 | 2.236 |

**Note**: e is a monthly Rupee-Dollar exchange rate, M3-M2 is the differential between broad money (m3) of India and money stock (M2) of US, NM3-M2 is the differential between New monetary aggregates (NM3) of India and money stock (M2) of US, DM3-DM2 is the differential between Divisia broad money of India and Divisia M2 of US, DNM3 is the differentials Divisia New monetary aggregates of India and Divisia M2 of US, y-y* is the differential between index of industrial production of India and industrial production index of US. r-r* is the differential between monthly weighted average call money rate of India and effective federal fund rates of US.

For testing the variables' order of integration, "Augmented Dickey Fuller (ADF) and Phillips Perron tests (PP) are applied with intercept and with intercept and trend". The results are presented in Table 3.2. All the variables are non-stationary at level and stationary in their first differences[5]. Since all the variables are found to be I (1), the long run relationship underlying the model are tested through Johansen (1988) cointegration method. While doing so, exchange rate equation is estimated alternatively by measuring money with simple sum and Divisia indices. An unrestricted constant as deterministic term is taken in each of the models. The optimum lag length of 2 as found by both the Hannan Quinn (HQ) and Schwarz (SC) information criterion is employed to overcome possible misspecification of models. The estimated results for cointegration test are reported in table 3.3. It is evident from the results that irrespective of the type of monetary aggregates used; each exchange rate equation does have at least one cointegrating vector at 5% level of significance. Therefore, it means that the null hypothesis of no cointegration among Rupee-Dollar exchange rate, the monetary aggregate and other variables is rejected, and their linear combination is stationary yielding a long run relationship. The number of cointegrating vectors with Divisia monetary aggregates is found to be only one while two cointegrating vectors are obtained with the conventional simple sum monetary aggregates. This indicates the presence of the long run relationship between Rupee-Dollar exchange rate, income, money supply, and interest rate differentials between India and U.S irrespective of the type of monetary aggregate being used.

The values of normalized cointegrating vectors with exchange rates are reported under each cointegration test result. They reflect long run elasticity measures for the dependent variable, with which the importance of different types of aggregates can be inferred in the monetary model. In the cointegration equations with simple sum aggregates, M3-M2 and NM3-M2, signs of long-run coefficients contrast with what the flexible price monetary model suggests

[5]The models with DNM3 are estimated for the period beginning March 1999 due to the lack of consistent data and a linked series for DNM3.

(Dornbusch, 1976). The $t$ values in parenthesis indicate that none of coefficients are statistically significant at 5% level of significance except for interest rate. This is suggestive of simple sum aggregates for monetary fundamentals doing little in obtaining the long run relationship with Rupee-Dollar exchange rates. Further, the interest rate differential, if negative, can be interpreted as appreciation of domestic currency (Rupee) in short run in anticipation of future depreciation to adjust to PPP in long run. This is referred to the overshooting exchange rate phenomenon explained by the sticky price monetary model. Moreover, all the coefficients in the equations with Divisia aggregates are statistically significant at 5 % level and the signs are in accordance with the flexible price monetary model. This implies that differentials of money supply, income and interest rate between India and US majorly determine Rupee-Dollar exchange rate. Therefore, it is possible for the central bank to influence exchange rate through its monetary and interest rate policies. Further, the estimated coefficients of money supply and interest rate differentials bear positive signs whereas income differential bear negative signs. This part of the result is explained by flexible price monetary model. The positive coefficients of money supply and interest rate differentials imply depreciation of domestic currency (Rupee) in the long run. The estimated results are consistent with flexible price monetary model when Divisia aggregates are included. The same coefficients, on other hand comply with sticky price monetary model with conventional monetary aggregates. Further, money coefficient with DM3-DM2 is close one that is consistent with coefficient symmetrical assumption between domestic and foreign country. Thus, Divisia aggregates compared to simple sum aggregates seem to have more information content about monetary and macroeconomic conditions ensuring long run relation underlying the monetary model. Moreover, Divisia money could perform better in demand for money function in the times of financial innovation compared to simple sum aggregates in achieving the long run relationship in the monetary model.

**Table 3.2.** Unit root test results

| Variables | ADF | | PP | |
|---|---|---|---|---|
| | Intercept | Intercept and trend | Intercept | Intercept and trend |
| e | -0.7613 | -1.5754 | -0.8668 | -1.7075 |
| M3-M2 | -11.7067 | -2.1695 | -1.5905 | -1.9870 |
| NM3-M2 | -1.1870 | -0.3403 | -1.1579 | -0.4128 |
| DM3-DM2 | -1.5486 | -2.1695 | -1.5905 | 0.6051 |
| DNM3-DM2 | -2.6283 | -2.6067 | -2.2055 | -2.1733 |
| (y-y*) | -0.6355 | -0.8383 | -0.5960 | -1.2302 |
| (r-r*) | -2.2496 | -3.1583* | -2.5344 | -3.7146** |
| Δe | -13.8312*** | -13.8039*** | -13.8205*** | -13.7919*** |
| ΔM3-M2 | -11.6406*** | -13.9931*** | -13.9609*** | -13.9988*** |
| Δ NM3-M2 | -14.3462*** | -14.3863*** | -14.3692*** | -14.4075*** |
| Δ DM3- DM2 | -11.6406*** | -11.6789*** | -11.6665*** | -11.7067*** |
| ΔNM3-DM2 | -6.1974*** | -6.2056*** | -10.1383*** | -10.1329*** |
| Δ(y-y*) | -25.6326*** | -25.5917*** | -25.7179*** | -25.6968*** |
| Δ(r-r*) | -21.2797*** | -21.2359*** | -22.1443*** | -22.0949*** |

**Note:** ***, **,* indicates the level of significance at 1,5 and 10 percent levels, respectively.

The presence of cointegration is further analyzed by the error correction term's sign and significance in different models. The coefficient of lagged error correction term in the error correction mechanism specifically measures the speed of adjustment of exchange rate to its long-run equilibrium. The error correction models with all monetary aggregates are estimated and the results are reported in table 3.4. The $EC_{t-1}$ coefficients, with each variant of monetary aggregate are reported in the first row of each column in this table. The coefficients of $EC_{t-1}$ in each equation with the alternative of monetary aggregate are statistically significant at 5 % level bearing negative signs. This confirms the long run relationship with conventional or Divisia monetary aggregate with short run adjustment. Overall, a long-run relationship between Rupee-Dollar exchange rate, income, money supply, and interest between India and US is thus confirmed. However, each error correction term differs in terms of the magnitude or the speed of adjustment. The speeds of adjustment with M3-M2 and NM3-M2 are than those of DM3-DM2 and DNM3-DM2. Hence, Divisia aggregates exhibit faster adjustment to long run equilibrium compared to the simple sum ones in monetary models. In other words, exchange rate adjustment with conventional monetary aggregates is of lesser speed than that Divisia aggregate in the following month. Therefore, one may conclude that monetary models with Divisia aggregates are faster than convention monetary aggregates in bringing back exchange rate to its long run equilibrium. Thus, these results again substantiate the hypothesis that Divisia money could be a better money measure in times of financial innovation to study the behavior of exchange rate in monetary models. The finding of Chrystal and Macdonald (1995) is somewhat similar. To quote the authors, "Thus in times of financial deregulation, large interest rate swings and substitution between asset classes, Divisia money has superior properties to simple sum money. In contrast, in a stable environment, such as that typically seen in the German money markets, simple sum money works equally well as Divisia money".

Next, Diagnostic statistics pertaining to each model are reported in Table 3.4. As seen in the table, the computed Breusch-Godfrey Lagrange Multiplier test at lag 1 is not statistically insignificant at conventional level and ARCH test for heteroscedasticity at lag 1 is statistically significant at conventional level. Therefore, autocorrelation is not a problem in the estimated models. But there is heteroscedasticity in the residuals. However, Gonzalo (1994)[6] and Rahbek et al. (2002) show that maximum likelihood estimator and Johansen procedure is robust or not much sensitive to heteroscedasticity. Because the rejection at 5 % level significance could be firm evidence in the favor of cointegration. Similarly, calculated statistics of Ramsay Reset test

[6] The same applies in the case of the non-normal distribution of residuals of model

is also not statistically significant at conventional level, which suggests that all the models are correctly specified.

**Table 3.3.** Results of cointegration test

Model estimated: $e_t = (m_t - m_t^*) + \beta_2 (y_t - y_t^*) + \beta_3 (i_t - i_t^*)$

| Monetary aggregate in the model: M3-M2 | | | | | | |
|---|---|---|---|---|---|---|
| Trace test | | | | Eigen max test | | |
| Hypothesis | Trace statistic | 5% critical value | p-value | Max eigen value | 5% critical value | p-value |
| r =0 | 140.1945 | 54.0790 | 0.0000 | 92.3515 | 28.5880 | 0.0000 |
| r ≤ 1 * | 47.8431 | 35.1927 | 0.0013 | 31.1737 | 22.2996 | 0.0022 |
| r ≤ 2* | 16.6693 | 20.2618 | 0.1454 | 13.0549 | 15.8921 | 0.1327 |
| e = 0.36*(m-m*)*- 0.02*(y-y*)* - 0.09 *(r-r*)* + 6.19 | | | | | | |
| 0.711) (1.039) (0.034) (2.604) | | | | | | |
| [-0.598] [ 0.025] [-3.77] [-2.379] | | | | | | |
| Monetary aggregate in the model: NM3-M2 | | | | | | |
| r =0 | 146.3752 | 54.0790 | 0.0000 | 101.3440 | 28.5880 | 0.0000 |
| r ≤ 1 * | 45.0312 | 35.1927 | 0.0032 | 30.76240 | 22.2996 | 0.0026 |
| r ≤ 2* | 14.2688 | 20.2618 | 0.2713 | 10.5985 | 15.8921 | 0.2829 |
| e= 0.53 *(m-m*)*- 0.08 *(y-y*)*- 0.15 *(r-r*)* + 6.89. | | | | | | |
| (0.733) (1.141)) (0.039) (2.747) | | | | | | |
| [-0.732] [ 0.070] [3.813] [-2.510] | | | | | | |
| Monetary aggregate in the model: DM3-DM2 | | | | | | |
| r =0 | 61.6450 | 47.8561 | 0.0015 | 41.3322 | 27.5843 | 0.0005 |
| r ≤ 1 * | 20.3127 | 29.7970 | 0.4018 | 13.1427 | 21.1316 | 0.4392 |
| r ≤ 2* | 7.1699 | 15.4947 | 0.5580 | 6.7100 | 14.2646 | 0.5240 |
| e= 1.10 *(m-m*)* - 1.74 *(y-y*)* + 0.11*( r-r*)* -7.23 | | | | | | |
| (-0.367) (0.471) (0.021) (4.114) | | | | | | |
| [-3.017] [3.692] [-5.370] [-3.362] | | | | | | |
| Monetary aggregate in the model: DNM3-DM2 | | | | | | |
| r =0 | 64.9720 | 47.8561 | 0.0006 | 41.5984 | 27.5843 | 0.0004 |
| r ≤ 1 * | 23.3736 | 29.7970 | 0.2282 | 17.8551 | 21.1316 | 0.1354 |
| r ≤ 2* | 5.5165 | 15.4947 | 0.7515 | 4.0521 | 14.2646 | 0.8538 |
| e = 5.55 *(m-m*)* -11.76 *(y-y*)* + 0.75 *( r-r*)* -22.21 | | | | | | |
| (2.390) (3.6740) (0.148) (0.357) | | | | | | |
| [-2.390] [3.201] [-5.056] [-6.078] | | | | | | |

**Note:** Standard errors are shown in parenthesis and t-statistics are shown in square brackets.
The numbers of cointegrating vectors are denoted by r and critical values for trace statistics and Eigen maximum values are tabulated in Johansen (1988) and Johansen and Juselius (1990).

**Table 3.4.** Results of VECM

| Variable | Models with monetary aggregates | | | |
|---|---|---|---|---|
| | M3-M2 | NM3-M2 | DM3-DM2 | DNM3-DM2 |
| $ECT_{-1}$ | -0.0073*** | -0.0050*** | -0.0228*** | -0.0026*** |
| $\Delta(e)_{-1}$ | -0.1141 | -0.0969 | 0.0925 | 0.083957 |
| $\Delta(e)_{-1}$ | -0.1468 | -0.1360 | -0.1089 | -0.0065 |
| $\Delta(m\text{-}m^*)_{-1}$ | -0.3073*** | -0.2850*** | -0.0379* | 0.0128 |
| $\Delta(m\text{-}m^*)_{-2}$ | 0.1086 | 0.0995 | 0.0015 | -0.0003 |
| $\Delta(y\text{-}y^*)_{-1}$ | -0.0448 | -0.0402 | 0.0265 | -0.1060 |
| $\Delta(y\text{-}y^*)_{-2}$ | -0.1569*** | -0.1543*** | -0.0750 | -0.0022 |
| $\Delta(r\text{-}r^*)_{-1}$ | 0.0005 | 0.0006 | -0.0015 | -0.1071 |
| $\Delta(r\text{-}r^*)_{-2}$ | 0.0007 | -0.0005 | -0.0014 | -0.0005 |
| C | | | 0.0029** | 0.0025 |
| Diagnostic statistics | | | | |
| $R^2$ | 0.062 | 0.055 | 0.095 | 0.076 |
| Adjusted $R^2$ | 0.030 | 0.023 | 0.061 | 0.035 |
| ARCH(1) | 9.404** | 9.261*** | 5.741*** | 6.048*** |
| LM(1) | 1.852 | 1.768 | 0.441 | 0.472 |
| RESET | 2.026 | 2.125 | 1.176 | 0.69 |

**Note:*****, **, * indicate 1%,5%,10% level significance level
LM is the Breusch-Godfrey Lagrange Multiplier test for serial correlation up to 1 lag.
ARCH is ARCH test up to lag 1 for heteroscedasticity
Reset is Ramsay's specification test
F-statistics is reported for LM, ARCH and RESET test.

Finally, the stability underlying the exchange rate and monetary variables relationship is examined by "Cumulative Sum (CUSUM) and Cumulative Sum of Square (CUSUM of square) tests proposed by Brown et al. (1975)". These tests are applied on the residuals of models. Following Brown et al. (1975), "both tests are conducted on the cumulative sum and cumulative squared sum of recursive residuals based on the initial set of 'n' observations. They are updated recursively and are plotted against the break points. If plots of CUSUM and CUSUM of square statistics lie within 5 % level, the estimated coefficients of model are considered stable". The results are shown in the series of plots in the figures 3.1 and 3.2. In the results of CUSUM tests, all the models irrespective of conventional and Divisia aggregate seem to be stable as recursive of residuals in the plots of (a-d) lie within the bands of 5 % level. However, the plots of squared recursive residuals (e-h) in the CUSUM square test results for all models have crossed the bands of 5 % level indicating instability. Since instability is found in the coefficients of error correction model irrespective of monetary aggregates used, we divide the data sample at the points of instability. The error correction models are re-estimated with these sub samples to see whether stability is addressed through monetary aggregates or not. The plots of CUSUM and CUSUM of square test for error correction models with both monetary aggregates do not improve in terms of confirming stability. The figures are not presented in the text. This is a bit perplexing which could be solved probably using time varying models. The instability may be also due to certain limitation or drawbacks in the Divisia construction or the working of the monetary models themselves. Further, the coefficients of monetary model could be unstable because of instability of money demand function based on which monetary model is built (Neely and Sarno, 2002). Further, one may question the ability of Divisia aggregate in ensuring the stability of money demand function. It is possible that Divisia aggregates may not completely internalize the substitution effect owing to changes in asset holding arising out of financial innovation. This may result in instability of money demand and thereby the MMER becomes unstable. The period of this study also includes crisis times such as the 2008 financial crisis and 2012 Greece debt crisis. These volatile periods may also cause instability in coefficients.

Overall, these results provide evidence in support of monetary fundamentals as major determinants of Rupee-Dollar exchange rates in the post reform period because of the underlying long run relationship. Compared to simple sum aggregates, Divisia money could be more useful in holding flexible price version of MMER in the long run in terms of sign and significance. It also suggests that monetary aggregates are appropriately measured *via* Divisia formulations in times of financial innovation. Moreover, it also lends partial support to previous studies such as

Chrystal and Macdonald (1995) and Chin et al. (2009), where long run relation and forecast of exchange rate are improved by Divisia aggregate relative to simple sum aggregates.

### 3.5. Conclusion and policy implications

In this chapter, an attempt is made to investigate the usefulness of simple sum versus Divisia monetary aggregates in modeling long run relationship underlying the MMER for Rupee-Dollar exchange rate. Specifically, the objective has been to examine long run relationship among "Rupee-Dollar exchange rates, monetary fundamentals such as money, income and interest rate differentials between India and US" in times of financial innovation in India. The use of Divisia aggregates for MMER is the primary novelty of this study. Because, in general, the studies on monetary approach of exchange rate determination in the Indian context is scanty and particularly Divisia aggregate based studies for the MMER are almost absent. In the financial innovation period, simple sum aggregates are inappropriate measures in demand for money functions as they assume monetary components to be perfect substitutes and assign equal weights to all components in the aggregates. Unlike simple sum aggregates, Divisia aggregate are supposed to render the right demand for money functions since they internalise substitution effects among monetary assets. Therefore, Divisia aggregates are employed in a set of flexible price monetary models and the long-run relationship is compared with simple sum aggregates. Johansen–Juselius likelihood cointegration test is applied to achieve this objective. The results provide evidence in favour of cointegration for the monetary model that includes either conventional or Divisia monetary aggregates. But as expected in theory, the long run relation between Rupee-Dollar exchange and its fundamentals are found slightly better with Divisia aggregates compared to simple sum aggregates. In the short-run analysis, a more rapid adjustment to its long-run equilibrium of exchange rate is seen in models with Divisia aggregates compared to the simple sum counterparts. These results confirm that the monetary fundamentals are major determinants of Rupee-Dollar exchange rates in the post reform period because of long run relationship among them. This implies that monetary policy could be an effective tool to regulate the fluctuations of Rupee/Dollar exchange rate.

The results also make a case for Divisia aggregates in the MMER relative to simple sum aggregates. Divisia money could be more useful in holding the “flexible price version of the monetary model in the long run” in terms of sign and significance. It is also suggested that monetary aggregates when calculated appropriately with Divisia formulations, could render stable long run relationships in times of financial innovation and help in monetary policy tool. Future research in the Indian context may examine the relative importance of simple sum and Divisia money in monetary models by employing time varying models and other tests of structural breaks. One may also study the aggregates’ comparative performance in forecasting exchange rates.

**Figure 3.1** The plots of CUSUM

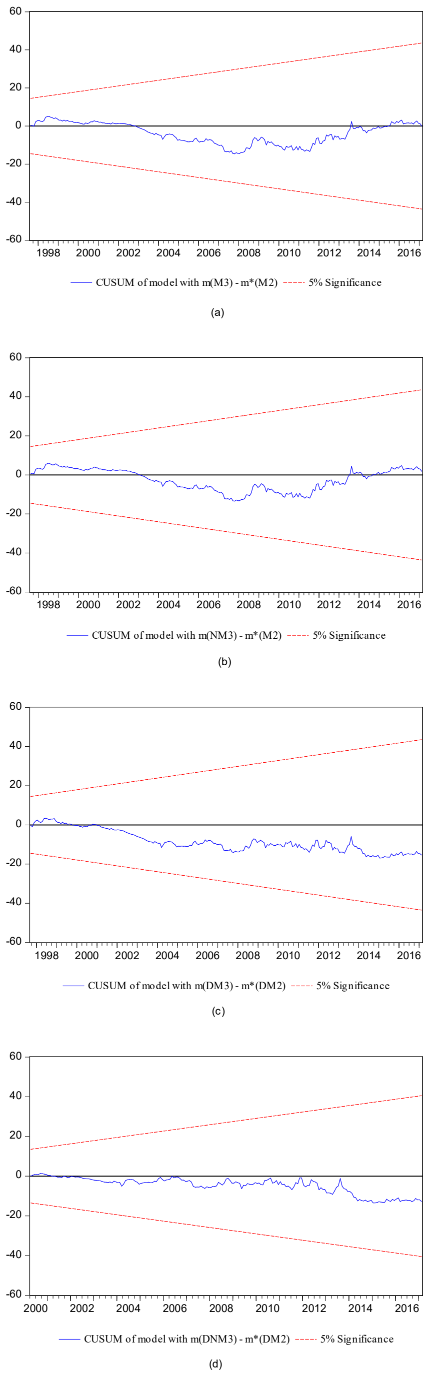
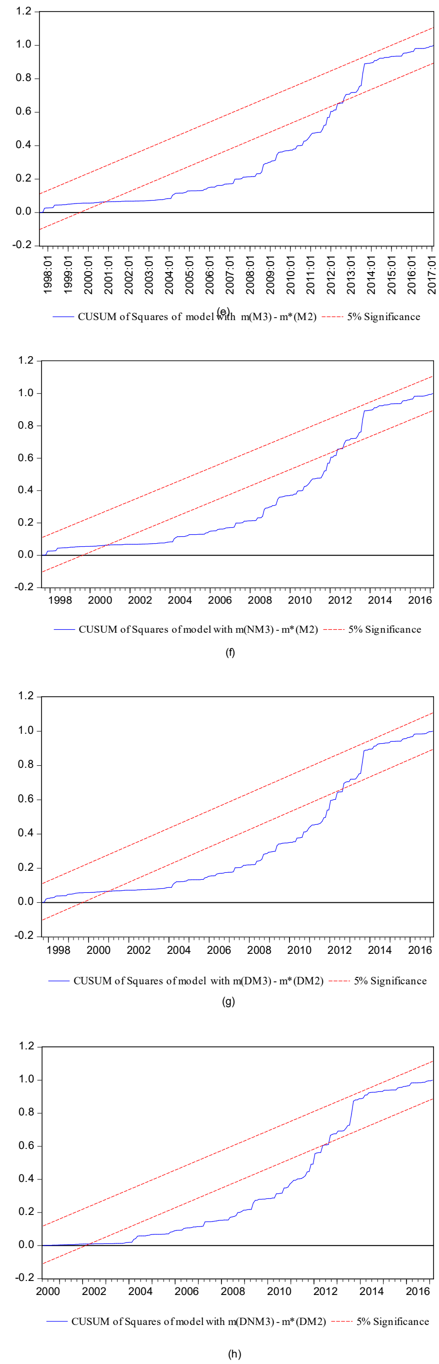



**Figure 3.2** The plots of CUSUM of squares




**Note**: CUSUM indicates the Cumulative Recursive Residuals

CUSUSM of Squares indicates the Squares of Cumulative Recursive Residuals

## Appendix A3

| Monetary aggregates measures used in the study | |
|---|---|
| **Monetary aggregate** | **Monetary components** |
| M3 and Divisia M3 for India | "Currency with the public + demand deposits with the banks + time deposits with the banks + 'other' deposits with the RBI" |
| NM3 and Divisia NM3 for India | "Currency with the public + demand deposits with the banking system + other deposits with the RBI+ short-term deposits of residents (including and up to the contractual maturity of one year)+ certificates of deposits (CDs)+ long-term time deposits of residents + call/term funding from financial institutions." |
| M2 for US | Currency + traveler's checks+ demand deposits+ other checkable deposits (CDs)+savings deposits (which include money market deposit accounts, or MMDAs) +small-denomination time deposits ((time deposits in amounts of less than $100,000) + retail money market mutual funds (MMMFs) |
| Divisia M2 all for US | Currency + travelers' checks + demand deposits +other checkable deposits+ savings deposits+ +money-market deposit accounts +small-denomination time deposits+ retail and institutional money-market funds. |

| Monetary components and interest rate proxies chosen | |
|---|---|
| **Monetary Components** | **Interest rate** |
| Currency with the public | Zero |
| Demand deposits with the banks | Zero |
| Other' deposits with the RBI | Zero |
| Time deposits with the banks | 3 to 5 year deposits rate |
| Short-term time deposits | Call money rate |
| Certificates of Deposits | Call money rate |
| Long-term time deposits of residents | Above 5 years deposits rate |
| Call/Term funding from financial institutions | Above 5 year deposits rates |
| Benchmark rate | SBI Prime Lending rate |
| Refer the Centre for Financial Stability site to know about monetary components and their corresponding interest rates | |

# Chapter 4

## Forecasting Rupee-Dollar exchange rate with different monetary aggregates

### 4.1. Introduction

This chapter focuses on forecasting of Rupee-Dollar rate in the monetary framework employing the monetary model. Usually, a model is developed with two objectives i.e. to explain the phenomenon and to predict the future. The focus is mainly on the forecast or prediction of exchange rate using the MMER. In general forecasting of exchange rate over different time horizons is of crucial significance in today's integrated world economy. Even the effectiveness of monetary policy depends upon accurate forecast of exchange rate. An emerging economy like India has opened in full its current account and the capital account is open to a large extent. Hence, the domestic currency's (rupee) exchange rate with foreign ones in the foreign exchange market exerts immense influence on the macro fundamentals such as inflation, investment, consumption and production through its cross-border trade and capital flows. Therefore, the macroeconomic environment is subject to future movements in exchange rates from time to time. In view of this, forecasting of exchange rate has assumed increased importance in the recent past. In the Indian context, adoption of market determined exchange rate for Indian rupee since March 1993 and subsequently the volatile nature foreign portfolio investment flows (FII) through equity market have added to the significance of exchange rate prediction. Further, the anticipation of exchange rate movements determines firm level profitability of corporates, traders in general and specifically for the information technology industry. Thus, the forecasting of exchange rate assumes significance both at macro level as well at the firm level. This chapter of the thesis concerns to assess the exchange rate forecast accuracy of monetary models for Rupee-Dollar exchange rate using simple sum aggregates and Divisia aggregates. Further, it examines the sensitivity of different month ahead forecasts of exchange rate among the aggregates and across time series models such as ARIMA (p, q, r), GARCH (p, q), VAR and VEC models.

The rest of chapter is organized as follows. Section 4.2 presents the reviews on major studies and the details of the empirical models employed. Section 4.3 explains about methodology and data used for this study. The results are presented in section 4.4. The last section offers concluding remarks along with some policy implications

### 4.1.1. Review of major past studies

The debate on relative ability of different models in forecasting exchange rates dates to the study of Meese and Rogoff (1983). They claim that monetary models are relatively poor compared with simple random walk model in forecasting exchange rate out-of-sample. Most of the studies analyze the relationship between fundamentals and exchange rate in the long-run and their ability to forecast. They include MacDonald and Taylor (1994), Diamandis and Kouretas (1996), Tawadros (2001), Reinton and Ongena (1999) and Hwang (2001), and obtain evidence in support of both long-run validity and better out-of-sample forecasting performance of monetary models. There are few studies that investigate about the significance of cointegration and error correction models for monetary models to assess their forecasting performance. Baille and Selover (1987) attribute the poor performance of monetary model to lack of a cointegrating relationship among exchange rate and monetary fundamentals. A few other studies such as Burns and Moosa (2017) and Moosa and Burn (2014) also include cointegration with structural breaks in monetary model. The results do not solve the Meese and Rogoff puzzle irrespective of cointegration and presence of structural break if forecast accuracy is measured by measure like

RMSE. Their results also show that MMER beats "random walk when forecast accuracy is assessed in terms of the direction of change and profitability". Further, Moosa and Vaz (2016) investigate the importance of error correction mechanism for the monetary model and confirm that error correction mechanisms (ECM) do not add much value to improve forecast of monetary model compared to first difference of VAR model. However, by considering small sample data issues, Mark (1995) and Kilian (1999) support monetary model in forecasting exchange rate with higher accuracy than simple random walk. Studies such as Ross (2004), Park and Park (2013) and Plasman et al, (1998) show the improved exchange rate forecast of monetary model in the time varying coefficient and neural network framework. A recent study by Ince et al. (2019) finds that monetary model beats the random walk. Also, monetary model estimated in the non-linear framework forecasts better than linear models.

Most of the studies including the ones reviewed above have explored issues like structural breaks, time varying parameters and cointegration for forecast. As discussed in the introduction chapter, the MMER depends upon the building blocks such as money market equilibrium, PPP and UIP conditions. In the view of equilibrium condition in the money market or the evidence on unstable money demand, few studies have focused their attention on money measurement in the monetary model for the exchange rate forecast. To this end, Divisia aggregates are employed to account financial innovation and its impact on monetary aggregates. For the first time in exchange rates, Chrystal, and MacDonald (1995) employ Divisia aggregates for modeling sterling –dollar and mark-dollar exchange rates. They attempt to capture instability in money demand function in the case of the UK and US in the data from the 1980's witnessing a period of intense financial liberalization. Interestingly, Divisia aggregates yield a long run equilibrium relation underlying the monetary model and reasonable out-of-sample forecast. Barnett (2005) and Chin et al., (2010) and a recent study by Leong et al., (2018) also show that Divisia monetary aggregates tend to perform better in estimated monetary models that both simple sum aggregates and the random walk model as well. In a similar forecasting exercise for India Barnett et al. (2015) estimate monetary policy impact in SVAR models and find improved forecast of exchange rates by employing "Divisia monetary aggregates relative to simple sum aggregates". But they have not used any monetary model. All these studies at core underscore the significance of information content of Divisia money. Further, Dua and Ranjan (2011) succeed to show superiority of monetary model in forecasting exchange rate of Rupee-Dollar by incorporating forward premium, capital inflows, and capital flow volatility, order flows and central bank intervention. However, they have not paid much attention on type of monetary aggregates and not used Divisia aggregates to capture financial innovation India.

Thus, Divisia aggregates are not explored to check its potential in the context of India in the monetary framework. This is further evident in the studies such as Kletzer and Kohli (2000), Bhanja et al. (2015), Ghosh (1998) and Sharma and Setia (2015) that limit the objective to Rupee-Dollar rate and monetary fundamentals relationship. Even these studies have not attempted any forecasting exercise for Rupee-Dollar exchange rate.

### 4.1.2. Research gap and significance

The major research gap, therefore, may be attributed to lack of studies using Divisia monetary aggregates capturing financial innovation appropriately. India being an emerging economy has been undergoing financial innovation in several dimensions such as emergence of new financial market participants, new instruments, and new payments systems. Simple sum aggregates do not capture such innovation by measuring liquidity adequately in the economy. This calls for fresh investigation since financial innovation is believed to impact measurement of money. As discussed earlier, money if not measured properly may yield unreliable results in the monetary model of exchange rate forecast. Earlier studies have found one of the causes of money demand instability to be use of simple sum money in times of financial innovation. Thus, it is expected that use of Divisia money may improves forecast of exchange rate via monetary models compared to the simple sum ones.

In view of the above background this chapter aims at evaluating the relative ability and performance of Divisia and simple sum money in forecasting Rupee-Dollar exchange rate in the post reform period of India. Accordingly, it is hypothesized that monetary fundamentals forecast Rupee-Dollar rate better than the random walk and Divisia aggregates forecast better than simple sum aggregates. Therefore, this study has two following hypotheses.

- $H_0$1: monetary fundamentals do not forecast Rupee-Dollar rate better than the random walk model
- $H_1$ 1; monetary fundamentals do forecast Rupee-Dollar exchange better than the random walk model
- $H_0$2: monetary fundamentals do not forecast Rupee-Dollar exchange rate better with Divisia monetary aggregates
- $H_1$2: monetary fundamentals do forecast Rupee-Dollar exchange rate better with Divisia monetary aggregates

In addition to above, this chapter also explores the forecasting ability of different univariate and multivariate time series models for Rupee-Dollar exchange and sees what kind difference they make in the forecasts. Towards this, the study employs a battery of time series models, univariate and multivariate including autoregressive integrated moving average (ARIMA (p, d, q)), generalized autoregressive conditional heteroscedasticity (GARCH (p, q)), vector autoregression (VAR) and vector error correction (VEC).

### 4.2. The model

Like the previous chapter, this empirical chapter also employs the flexible price variant of the monetary model developed by Frankel (1976), Mussa (1976) and Bilson (1978). The details of this model are discussed in chapter 1 section 1.3. Here, the basic reduced form equation of the model used for empirical analysis is presented as follows

$$e_t = \beta_1 (m_t - m_t^*) + \beta_2 (y_t - y_t^*) + \beta_3 (i_t - i_t^*) \tag{4.1}$$

Where, $y, m, i$ denote income, money and interest rate of domestic country respectively and with an asterisk (*) denote counterparts of foreign country variables. $\beta_1$, $\beta_2$, $\beta_3$, denote constant and elasticities of each variable with respect to exchange rate $e$. Except for interest rate, all variables are in natural logarithm form. As this model assumes flexible prices, any changes in the interest rates reflect the changes in the expected inflation. Consequently, "the higher rise in the interest rate relative to foreign interest rate, domestic currency depreciates as a result of reduction in the domestic demand for money compared to that of foreign country through inflation effect". Therefore, a positive relation is expected between interest rate differential and exchange rate. Increase in the relative domestic money supply to foreign country leads to rise in domestic price levels and the lower demand for domestic currency result in depreciation of domestic currency. Thus, one expects a positive relationship between exchange rate and the money supplies differentials between domestic and foreign country. Further, we expect relation between exchange rate and domestic and foreign income differential to be negative as domestic income level increase relatively to foreign, domestic currency appreciates with the higher demand for domestic currency. This monetary model is estimated by measuring money supply differential variable alternatively with Divisia and simple sum monetary aggregate between India and US.

In addition to the above monetary model, we also consider two benchmark random walk models i.e., "simple random walk (without drift) and random walk with drift" on exchange rates against which forecast accuracy of monetary model are assessed.

The random walk model without drift is defined with the best prediction of future exchange rate at t+1 through its exchange rate at t along with its predicted random errors at t+1. This is given as

$$e_{t+1} = \delta e_t + \varepsilon_{t+1} \tag{4.2}$$

Where $e_{t+1}$ is the future exchange rate at time t+1,

$e_t$ is today's exchange rate at time t

$\varepsilon_{t+1}$ is future random errors that assumes to have identically independently distribution with zero mean and constant variance

Alternatively, the same future exchange rate is obtained by including drift component c equation. (4.2) which is known as the random walk model with drift.

$$e_{t+1} = c + \delta e_t + \varepsilon_{t+1} \tag{4.3}$$

## 4.3. Data and methodology

A set of monthly data spanning over the period August 1996 to February 2017 is used. The details of data and data source, Divisia money construction and its components are given in Appendix of the last chapter. The exercises have used two samples. The full monthly sample has been split into two sub samples. One is the in-sample starting August 1996 and ending February 2015 for estimating all models mentioned above. Due to lack of data for Divisia NM3 the sample begins with April 1999. The out-of-sample forecasting is conducted with the rest of observations i.e., from March 2015 to February 2017. In this forecasting exercise, one compares the relative performance of alternative monetary aggregates and of the times series models in terms of forecast errors i.e. RMSE and MAE. Forecast errors are generated by recursively estimating models over 1,3,6,9 and 12 months ahead forecast horizons.

A battery of time series models is employed for the forecasting exercises. The univariate ones are the "autoregressive integrated moving averages model (ARIMA (p, d, q)), and generalized autoregressive conditional heteroscedasticity (GARCH (p, q))". GARCH (p, q) helps us to account for the heteroscedastic residuals in the estimated ARMA (p, d, q) and thereby characterize the phenomena referred as a "volatility clustering" in the exchange rate. To understand the relative importance of simple sum and Divisia money in forecasting of exchange rate, multivariate time series technique such as "vector auto regression (VAR) and vector error correction (VEC) models" are applied on the monetary model. Moreover, it allows one to recognize the significance of common stochastic trend or cointegration in monetary models. For comparison of the forecast accuracy among time series models, the benchmark models like random walk model with drift and without drift are utilized. The autoregressive integrated moving average (ARIMA) model has been one of the widely used forecasting models for more than half century. Any time series process, say $y_t$ in this model is built as a linear function of its past observations and predicted random errors at t. Thus, ARIMA (p, d, q) model for a time series process $y_t$ is given in mean adjusted form (μ) as follows

$$\emptyset(B)\nabla d(y_t - \mu) = \theta(B)\varepsilon_t \quad (4.4)$$

Where $y_t$ and $\varepsilon_t$ are the actual observations of $y_t$ and predicted random errors at period t respectively, p and q are auto regressive and moving average orders respectively, d is an order of differencing that are integers. B is a backshift operator. $\emptyset(B) = 1 - \sum_{i=1}^{p} \varphi B^i$ and $\theta(B) = 1 - \sum_{j=1}^{q} -\theta_j B^i$ are polynomials in B of degree p and q. $\emptyset_i (i = 1,2..p) and\ \theta_j (j = 1,2..q)$ are model parameters. $\nabla = (1-B)$, $\varepsilon_t$ are assumed to have identically independently distribution with mean =0 and variance=$\sigma^2$

Here, Box and Jenkins (1976) methodology is followed to identify of the structure of ARIMA (p, d, q). Thus a time series process is refereed to ARIMA (p, d, q) by differencing the series d times, if non stationary and identifying the AR (p) and MA (q) processes appropriately. Usually, "most of economic time series are non-stationary and thus differencing is required for attaining stationarity in the series".

In case of the presence of heteroscedasticity and ARCH effect in the estimated residuals of ARIMA (p, d, q), generalized autoregressive conditional heteroscedasticity (GARCH (p, q)) is applied. Basically, it is applied to model the volatility pooling or clustering in the financial times series. This means, "small changes tend to be followed by small changes". Further, large changes tend to be followed by large changes in the financial time series data. Originally, ARCH model was introduced by Engle (1982) and subsequently GARCH model was developed by Bollerslev

(1986) in the financial time series analysis. The GARCH model is specified for time series $y_t$ as follows

$$y_t = \mu + \varepsilon_t \tag{4.5}$$

$$h_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 \quad + \sum_{i=1}^{q} \beta_i \, h_{t-i} \tag{4.6}$$

$$\frac{\varepsilon_t}{\Omega_{t-1}} \sim iid(0, h_t); \omega > 0; \alpha_1, \ldots, \alpha_p \geq 0$$

Equation (4.5) is the "conditional mean equation", where $\mu$ denotes the mean of $y_{t,}$, $\varepsilon_t$ denotes the error term, conditional on the information set $\Omega_{t-}$, which is normally distributed with zero mean and variance $h_t$. Equation (4.6) represents the conditional variance, $h_t$ that is "a weighted function of a long term average value $\alpha_0$ "and one lagged values of squared residuals $\alpha_i \varepsilon_{t-i}^2$ and one period lagged value of the conditional variance $\beta_i h_{t-i}$".

The above conveys, "that the conditional variance might not be affected by the magnitude of innovations (ARCH) and by past values of the conditional variance (GARCH) only". This specification is like the ARMA specification of times series proposed by Box et al. (1994). "For the GARCH process to be stationary, it is necessary that $\alpha_i + \beta_i < 1$, which implies that conditional variance forecasts converge to the long-term average value of the variance as the prediction horizon increases". The magnitude and significance of $\alpha_{t-1}$ is an indication of the presence of the ARCH process or volatility clustering in the series. This model also renders two advantages over ARCH. One is that it avoids non-negative constrains so that condition variance equation $h_t$>0 is bound to be constrained $\alpha_0$>0, $\alpha_i$>0, and $\beta_i$>0. Second is that it provides more parsimonious specification.

A vector auto regression model is widely used in the forecasting of financial time series. One of the advantages of this model is its flexibility and easiness of use for analysis of multivariate time series. It is proposed by Sims (1980) and applied to understand the mutual influence in the system of multiple time series. Therefore, VAR models are the extension of univariate autoregressive (AR) model, where more than one variable are evolving over time. Thus, each variable in the VAR model has an equation that demonstrates its evolution built upon its own lags and the lags of the other model variables. All variables in the VAR are symmetrical and endogenous in the structural sense (Enders, 2003).

Let $Y_t = (y_{1t} + y_{2t} +, \dots \dots, y_{nt})$ denote an (n x 1 ) vector of time series variables. A VAR model with *p* lags can then be specified as follows:

$$y_t = \emptyset_0 + \emptyset_1 y_{t-1} + \emptyset_p y_{t-p} + \epsilon_t \tag{4.7}$$

Where $\boldsymbol{\epsilon}_t \sim$ iid N (0; $\boldsymbol{\Sigma}$)

In matrix notations, it is expressed as

$$\begin{pmatrix} y_{it} \\ \cdot \\ \cdot \\ \cdot \\ y_{nt} \end{pmatrix} = \begin{pmatrix} \emptyset_1 \\ \cdot \\ \cdot \\ \cdot \\ \emptyset_n \end{pmatrix} + \begin{pmatrix} \emptyset_{11}^{(1)} & \cdots & \emptyset_{1n}^{(1)} \\ \vdots & \ddots & \vdots \\ \emptyset_{n1}^{(1)} & \cdots & \emptyset_{nn}^{(1)} \end{pmatrix} \begin{pmatrix} y_{1,t-1} \\ \cdot \\ \cdot \\ \cdot \\ y_{n,t-1} \end{pmatrix} + \cdots + \begin{pmatrix} \emptyset_{11}^{(p)} & \cdots & \emptyset_{1n}^{(p)} \\ \vdots & \ddots & \vdots \\ \emptyset_{n1}^{(p)} & \cdots & \emptyset_{nn}^{(p)} \end{pmatrix} \begin{pmatrix} y_{1,t-p} \\ \cdot \\ \cdot \\ \cdot \\ y_{n,t-p} \end{pmatrix} + \begin{pmatrix} \epsilon_{1t} \\ \cdot \\ \cdot \\ \cdot \\ \epsilon_{nt} \end{pmatrix}$$

Where $\emptyset_1, \dots \dots \emptyset_p$ is a (n x n) matrix of coefficients, $e_t$ is an (n x 1) unobservable zero mean white noise vector process and $\emptyset_0$ is a constant vector with an (n x 1) and $\boldsymbol{\Sigma}$ is the matrix of variance and covariance in error terms.

It is required to look at the lag operators and the characteristic roots of polynomials for VAR model to be verified if VAR system is stable. The calculation of roots for VAR is specified as

$$(I_n - \emptyset_1 B - \emptyset_1 B^2 - \cdots)y_t = \emptyset(B)y_t$$

And definition of characteristic polynomial is written as

$$\pi(z) = (I_n - \emptyset_1 z - \emptyset_2 z^2 - \cdots)$$

The roots of $|\Pi(z)| = 0$ provide the necessary information about stability condition of VAR process. All characteristic roots lie outside unit circle are a required condition for VAR system to be stable. Therefore, it indicates that $\pi(z)$ is of full rank and being stationary of all variable as well.

Following Johansen (1995) formulation of "an unrestricted VAR model of order p with (n x 1) endogenous, all variables integrated of order one (I(0)), forced by vector of (n x1) independent Gaussian errors, vector error correction model" is specified as follows

$$\Delta y_t = \Gamma_1 \Delta y_{t-1} + \cdots + \Gamma_p \Delta y_{t-(p-1)} + \Pi Z_{t-k} + \delta D_t + \epsilon_t \tag{4.7}$$

Where $y_t$ denotes an (n x 1) vector of variables, $D_t$ is a vector deterministic terms includes constant, trend and seasonality dummies. $\Delta$ is first difference operator. $\Gamma_i$ (i=1,..,p-1) are (n x n) coefficient matrices capturing the short run dynamics. $\Pi$ is an (n x n) matrix and its rank determines significant cointegrating vectors or long run equilibrium solutions. Thus, $\Pi=\alpha\beta'$ where $\alpha$ and $\beta$ are matrices with dimension of (n x r), relating to the speed of adjustment and long run relations, respectively.

As said earlier, all these models are estimated for the in-sample data, then using the estimated models parameters recursively, out-of-sample forecasts of monthly Rupee-Dollar rate at 1, 3,6,9,12,18 and 24 months ahead horizons are generated. To evaluate the relative performance of alternative monetary aggregates and variant time series models, the forecast errors i.e. root mean square errors (RMSEs) and mean absolute errors (MAEs) over the same horizons are computed. Forecast errors are defined as follows

$$Root\ Mean\ Squre\ Errors = \frac{\sqrt{\sum_{t=T+1}^{t+h}(f_t - a_t)^2}}{h}$$

$$Mean\ Absolute\ Errors = \frac{\sum_{t=T+1}^{t+h}|f_t - a_t|}{h}$$

Where $f_t$ is forecasted exchange rate,

$a_t$ is an actual exchange rate,

h denotes h months ahead forecast horizon.

One time series model is deemed to be better in forecasting exchange rate when that model has lower RMSE and MSE relative to its competing models. Similarly, monetary aggregates with the lower RMSE or MAE in the estimated monetary models compared to other monetary aggregates are considered better candidates for forecasting exchange rate in the out-of-sample forecasting. It is worth mentioning that these forecast errors are static in nature in the out-of-sample exercise. This means that future forecast of dependent variable, here Rupee-Dollar exchange rate, is computed by including recursively actual forecasting values of dependent variable in the model. The equation for static forecasting for h periods ahead horizons is given for exchange rate $e_t$

$$e_{t+h} = \widehat{b_0} + \widehat{b_1}x_{1,t+h} + \widehat{b_2}x_{2,t+h} + \widehat{b_3}e_{t+h-1} \tag{4.8}$$

Where $e_{t+h}$ is forecasted exchange rate at h periods ahead from period t

$b_0$ and $b_1$,$b_2$ are estimated constant and coefficients for endogenous variable such as $x_1$ and $x_2$

$e_{t+h-1}$ is the lagged actual exchange rate for periods t+h-1

As in the Meese and Rogoff (1983), actual values of independent variables rather than their forecasting values are used to forecast exchange rate in the out sample exercise.

### 4.4. Empirical results

As required in time series models, unit root rests i.e. Augmented Dicky Fuller (ADF) and Philips Parron (PP) are applied to check the stationarity of the variables considered for estimation of all the models. The unit root test results reported in the previous chapter are used here. The variables in the exchange rate equation (4.1) i.e., monthly Rupee-Dollar exchange rate, money supply differential with alternative definitions by simple sum aggregates and Divisia aggregates (M3-M2, NM3-M2, DM3-DM2, DNM3-DM2), income differential and interest rate differential between India and US are found to be non-stationary and integrated of order 1, i.e. I (1)) at level with either intercept or intercept and trend included in the tests. This means that none of variables in monetary model reject the null hypothesis of unit root. But by first differencing with the same deterministic components, the null hypothesis of unit root is rejected, and all variables are found to be stationary.

Having confirmed the stationarity property of the series, an attempt is made to fit the time series models discussed above. The models are estimated with simple sum and Divisia money for the period August 1996 to February 2015. In the case of DNM3-DM2, the in-sample is from April 1999 to February 2015 as mentioned earlier. Using the estimated coefficients of the model(s), the forecast errors at 1 to 24 months ahead horizons are generated for out-of-sample period between March 2015 to February 2017.

First, univariate ARIMA (p, d, q) model is fitted to monthly Rupee-Dollar exchange rate series. Using Box and Jenkins (1980) methodology, the structure of ARIMA model is identified i.e., autoregressive components (p) and moving average components (q) in the residuals of AR and order of integration of series (d) for the time series. The estimated ARIMA (p, d, q) is be examined through its diagnostics i.e., roots of polynomials, heteroscedasticity and autocorrelation in the residuals. This process is repeated iteratively till the appropriate ARIMA specification is obtained where the best model is chosen by Akaike information criterion (AIC) and Schwartz information criterion (SC). It is shown in table 4.1 of autocorrelation function (ACF) and partial autocorrelation function (PACF) where the correlogram on first difference monthly Rupee-Dollar exchange rate at different time lags with Ljung-Box Q statistics (Q-stat) values are reported. Generally, the correlogram suggests the presence of autocorrelation in a series to identify appropriate AR component. Since it is confirmed that Rupee-Dollar exchange rate is stationary at first difference, a correlogram on its first difference is presented through ACF and PACF up to 8 lags for the null of hypothesis of no autocorrelation in table 4.1. The significance of the null of hypothesis for no autocorrelation in the series is found at 1 and 4 lags and it is further confirmed by the Ljung-Box Q-statistics.

This table indicates autocorrelation in first difference of exchange rate series at 1 and 4. Though coefficient of AR (1) is statistically significant, AR (1, 4) is chosen to be estimated. This specification yields the lower AIC and SC. Therefore, the specification of AR at 1 and 4 lags for Rupee-Dollar exchange rate has been estimated and result are reported in the table 4.2. The results show that the coefficients of AR terms are statistically significant at 5 % level. But its residuals are further examined whether they are white noise or not to identify any moving average process in the series. Again, by using the correlogram of estimated AR model with ACF and PACF at lags 8 the results are reported in table 4.3. It is confirmed that there is no significant

**Table 4.1.** Correlogram of $\Delta e_t$

| lag | AC | PAC | Q-stat | p |
|---|---|---|---|---|
| 1 | 0.117 | 0.117 | 3.4060 | 0.065 |
| 2 | -0.064 | -0.079 | 4.4232 | 0.110 |
| 3 | 0.043 | 0.062 | 4.8914 | 0.180 |
| 4 | -0.144 | -0.167 | 10.147 | 0.038 |
| 5 | 0.138 | 0.198 | 14.978 | 0.010 |
| 6 | 0.180 | 0.108 | 23.175 | 0.001 |
| 7 | -0.071 | -0.073 | 24.479 | 0.001 |
| 8 | -0.009 | -0.011 | 24.498 | 0.002 |

**Note:** $\Delta e_t$ denotes a monthly Rupee-Dollar exchange rate, AC denotes the autocorrelation function, PAC denotes the partial autocorrelation, Q-stat denotes the Ljung-Box *Q*-statistics and p denotes probability values.

autocorrelation up to 5 lags of estimated AR residuals. Therefore, no MA component is required to be added to the AR component. Thus, the best structure for ARIMA (p, d, q) of Rupee-Dollar exchange rate is accomplished with ARIMA ((1, 4), 1, 0).

**Table 4.2.** The estimated results of ARIMA for $\Delta e$ (Rupee-Dollar exchange rate )

| Dependent variable | Parameters | C | $\Delta e_{t-1}$ | $\Delta e_{t-2}$ |
|---|---|---|---|---|
| Δe (Rupee-Dollar exchange rate) | Estimate | 0.0028 | 0.1391** | -0.1511** |
| | Standard errors | 0.0013 | 0.0651 | 0.0655 |
| ARIMA(p, d, q) | ((1,4),1,0) | | | |
| DW=1.924 F-stat=4.459765 AIC=-4.918488 SC=-4.873644 | | | | |

**Note:** ***,**,* indicates the level of significance at 5 and 1 percent levels, respectively. DW denotes Durbin Watson statistics, F- stat denotes F statistics. AIC denotes Akaike information criterion and SC is Schwartz information criterion.

The variance of residuals in the estimation of ARIMA ((1,4),1,0) are assumed to be homoscedastic. But it is likely to be heteroscedastic. So, this homoscedasticity is reexamined by Breusch-Pagan-Godfrey and ARCH-LM tests which test the null hypothesis of homoscedasticity in the residuals of estimated ARIMA model. Those results are reported in the table 4.4. They indicate the variance of residuals generated of ARIMA ((1, 4), 1, 0) are not homoscedastic since these tests have rejected the null hypothesis of homoscedasticity at 5 % significance level. This

**Table 4.3.**Correlogram of estimated residuals of AR model of $\Delta e_t$

| Lags | AC | PAC | Q-Stat | P |
|---|---|---|---|---|
| 1 | 0.039 | 0.039 | 0.3406 | 0.559 |
| 2 | -0.064 | -0.065 | 1.2364 | 0.539 |
| 3 | 0.059 | 0.065 | 2.0170 | 0.569 |
| 4 | -0.028 | -0.038 | 2.1956 | 0.700 |
| 5 | 0.151 | 0.164 | 7.3463 | 0.196 |
| 6 | 0.180 | 0.162 | 14.671 | 0.023 |
| 7 | -0.098 | -0.090 | 16.845 | 0.018 |
| 8 | -0.030 | -0.022 | 17.056 | 0.030 |

**Note**: $\Delta e_t$ is a monthly Rupee-Dollar exchange rate, AC denotes the autocorrelation function, PAC denotes the partial autocorrelation function, Q-stat denotes the Ljung-Box Q-statistic and p denotes probability values.

confirms the necessity of considering time varying variance in the residuals of exchange rate series. To capture this heteroscedasticity and time varying variance in the residuals, GARCH model has been applied on Rupee-Dollar exchange rate series. Further, the presence of heteroscedastic and time variance in the residuals of ARIMA ((1,1),1,0) model can be accounted at best, "with the estimation of ARIMA with appropriate ARCH and GARCH parameters". After alternative estimations with different lags for ARCH and GARCH, GARCH (1, 1) is selected and the results of them are reported in the table 4.5. It shows that coefficients of lagged first differenced Rupee-Dollar exchange rate of conditional mean equations is statistically significant at 1 % level. This means that the return or mean of Rupee-Dollar exchange rate conditionals on its lags or its past period values. In its conditional variance or volatility, the coefficient of ARCH ($\alpha_1$) and GARCH ($\beta_1$) terms are statistically significant at 1 % level. So, there is ARCH and GARCH effect in the exchange rate. This implies, "conditional variance is affected by the magnitude of new innovations or its shocks and past values of the conditional variance. Even GARCH process is shown to be stationary since the sum of $\alpha_i$ *and* $\beta_i$ is less than (< 1). This is an indication of stability of GARCH process because conditional variance in one period forecasts converge to its long-term average value of the variance as its prediction horizon increases”. To demonstrate, the plot of GARCH (1, 1) is presented in the figure 4.1 where GARCH (1, 1) clearly captures volatility clustering’s in the Rupee-Dollar exchange. To verify conditional mean equation is specified correctly, ARCH-LM test on residuals of re-estimated model and Ljung-Box Q-statistics test on squared standardized residuals are conducted whether there is any remaining heteroscedasticity in residuals. Both tests are performed up to lag 5 and results are reported in the below row of table. These tests have rejected the null hypothesis of heteroscedasticity. Therefore, larger extent of heteroscedasticity in the Rupee-Dollar exchange rate series has been captured through GARCH (1, 1). Thus, GARCH (1, 1) could be a best model specification to capture the dynamics in Rupee-Dollar exchange rate.

**Table 4.4.** ARIMA residuals: Homoscedasticity

| | Breusch-Pagan-Godfrey test | | ARCH (5) | |
|---|---|---|---|---|
| Residuals of ARIMA | F-statistics | $\chi 2$ statistic | F-statistics | $\chi 2$ statistic |
| $\Delta e_t$ | 7.4334*** | 7.4334** | 6.7340*** | 12.8818 |

**Note:** ***, **,* indicates the level of significance at 5 and 1 percent levels, respectively.

After estimation of univariate models, the multivariate models are estimated using the in-sample data set i.e., VEC and VAR in first differences and levels on the MMER. These models are estimated underlying the exchange rate equation given in 4.1. As discussed in Sims (1980) and Doan (1992), “the estimation of the VAR in levels is also considered appropriate even if the variables contain a unit root”. They argue against differencing of variables as it may omit information concerning co-movements between the variables such as a cointegrating relationship. In the empirical work, “the usual practice is to estimate the VAR in levels or to estimate error correction in vector error correction model (VEC) in the case of presence of a

**Table 4.5.**

The estimated results for GARCH (1, 1) of ARIMA of $\Delta e_t$ (Rupee-Dollar exchange rate)

| Conditional mean equation | | | |
|---|---|---|---|
| Parameter | Estimate | Standard errors | Probability |
| C | 0.0022 | 0.0011 | 0.0568 |
| $\Delta e_{t-1}$ | 0.2484 | 0.0820 | 0.0025 |
| $\Delta e_{t-2}$ | -0.1552 | 0.0719 | 0.0311 |
| Conditional variance equation | | | |
| $\alpha_0$ | 9.65E-06 | 3.91E-06 | 0.0136 |
| $\varepsilon_{t-1}^2$ | 0 .250891 | 0.057059 | 0.0000 |
| $\sigma_{t-1}^2$ | 0.775037 | 0.036231 | 0.0000 |
| Log likelihood = 605.3228 DW = 2.132972 AIC = -5.211502 SC = -5.121813 | | | |
| ARCH (5) =0.211748 1.08251 Q- stat (5)= 1.1338 | | | |

**Note:** DW stands for the Durbin Watson statistics. ARCH (5) denote the ARCH LM test for up to lag 5 and Q -stat denotes the Ljung-Box Q- statistic test up to 5 lags AIC denotes Akaike information criterion and SC is Schwartz information criterion.

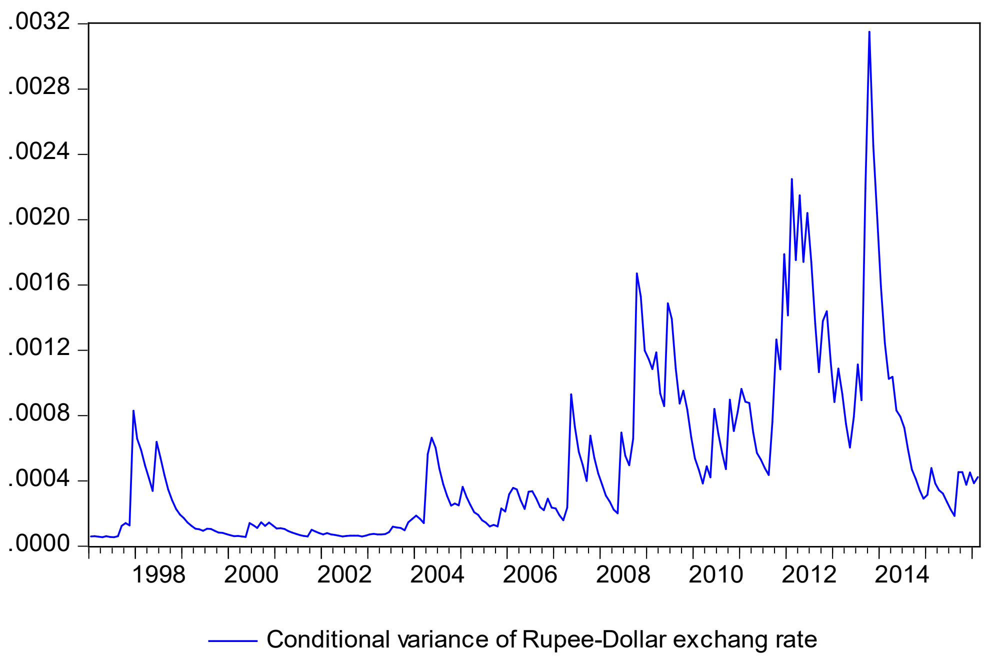



Figure: 4.1 Conditional variance of Rupee-Dollar exchange rate

cointegrating relationship between the variables in a VAR. The VAR in first differences can be estimated when the variables are nonstationary but not cointegrated (Dua and Ranjan, 2011)".

Thus, two types of VARs and one VEC are estimated for this analysis. The VAR in first differences is to ensure stationarity among exchange rate and monetary fundamentals. The VAR in levels and VEC to not lose cointegration or long run relationship among variables are estimated on exchange rate equation (4.1) of monetary model. All these multivariate models are estimated with simple sum and Divisia aggregates separately. Further it may be noted that the following theoretical structure on VARs is imposed to avoid any simultaneous equation bias which indicates the sequence of causality or impact among variables in the empirical monetary model.

$$(m - m*)_t \rightarrow (r - r*)_t \rightarrow e_t \rightarrow (y - y*)_t$$

This sequential structure as per flexible monetary model (Frankel, 1979) indicates the chain of causality among exchange rate and monetary fundamentals that first any change in the domestic money supply have impact on interest rate which in turn have impact on exchange rate. Finally, money impact through interest rate and exchange rate will be passed on real income. The same causation and effect structure is operated for foreign country.

After estimation of VEC, VAR in levels and first differences with simple sum and Divisia aggregates, for each multivariate model four sets of estimated results are obtained. All VARs are estimated at an optimum lag of 2 as suggested by AIC and SC lag length criteria except VAR in first difference with Divisia aggregates where lag 3 is included to avoid autocorrelation in the residuals. Our main objective in this chapter is to assess forecasting accuracy of exchange rate, so that only the results for forecasts of estimated multivariate models are not reported in the table 4.7 for analysis. The diagnostic statistics for VEC estimations are the similar to as summarized in

**Table 4.6.** Specification test results of the VAR estimations

| | | | | |
|---|---|---|---|---|
| VAR in first differences | | | | |
| Multivariate LM (1) test | 22.348 | 21.485 | 10.553 | 12.023 |
| Heteroscedasticity test | 27.902** | 36.020* | 29.247** | 71.133*** |
| Normality test | 79.821*** | 59.505*** | 86.504*** | 27.818*** |
| VAR in levels | | | | |
| Multivariate LM (1) test | 31.170 | 25.240 | 19.351 | 10.833 |
| Heteroscedasticity test | 69.858*** | 73.759* | 74.125* | 38.299*** |
| Normality test | 34.248*** | 25.209*** | 68.382*** | 10.833*** |

**Note:** ***, **,* indicates the level of significance at 5 and 1 percent levels. LM (1) is the multivariate Godfrey Lagrange Multiplier test for serial correlation up to 1 lag. Heteroscedasticity is the multivariate white (1980) test up to lag 1. Normality test denotes the Jarque-Bera (JB) test.

**Table 4.7.** Out-of-sample forecasting

| | **RMSE** | | | | | | **MAE** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month ahead horizon | 1 | 3 | 6 | 12 | 18 | 24 | 1 | 3 | 6 | 12 | 18 | 24 |
| RW | 0.795 | 0.393 | 0.428 | 0.309 | 0.253 | 0.210 | 0.795 | 0.568 | 0.709 | 0.843 | 0.815 | 0.783 |
| RWD | 0.663 | 0.334 | 0.394 | 0.292 | 0.247 | 0.207 | 0.663 | 0.498 | 0.651 | 0.811 | 0.789 | 0.776 |
| ARIMA (1,4,1,0) | 0.728 | 0.412 | 0.432 | 0.297 | 0.249 | 0.207 | 0.728 | 0.243 | 0.121 | 0.061 | 0.040 | 0.030 |
| GARCH (1,1) | 0.768 | 0.420 | 0.437 | 0.313 | 0.260 | 0.215 | 0.768 | 0.708 | 0.807 | 0.874 | 0.867 | 0.834 |
| VEC (M3-M2) | 0.534 | 0.226 | 0.431 | 0.284 | 0.249 | 0.229 | 0.534 | 0.357 | 0.691 | 0.772 | 0.728 | 0.845 |
| VEC(NM3-M2) | 0.587 | 0.244 | 0.434 | 0.287 | 0.250 | 0.225 | 0.587 | 0.378 | 0.705 | 0.785 | 0.741 | 0.836 |
| VEC(DM3-DM2) | 0.452 | 0.284 | 0.419 | 0.299 | 0.244 | 0.208 | 0.452 | 0.394 | 0.640 | 0.772 | 0.781 | 0.791 |
| VEC(DNM3-DM2) | 0.303 | 0.218 | 0.386 | 0.274 | 0.233 | 0.203 | 0.303 | 0.333 | 0.544 | 0.712 | 0.724 | 0.761 |
| VARD(M3-M2) | 0.264 | 0.157 | 0.393 | 0.268 | 0.246 | 0.231 | 0.264 | 0.261 | 0.563 | 0.700 | 0.682 | 0.824 |
| VARD(NM3-M2) | 0.437 | 0.198 | 0.401 | 0.266 | 0.236 | 0.222 | 0.437 | 0.332 | 0.651 | 0.715 | 0.699 | 0.818 |
| VARD(DM3-DM2) | 0.526 | 0.279 | 0.392 | 0.284 | 0.243 | 0.222 | 0.526 | 0.398 | 0.589 | 0.774 | 0.747 | 0.847 |
| VARD(DNM3-DM2) | 0.502 | 0.271 | 0.390 | 0.283 | 0.245 | 0.236 | 0.502 | 0.394 | 0.577 | 0.771 | 0.742 | 0.902 |
| VARL(M3-M2) | 0.751 | 0.379 | 0.509 | 0.361 | 0.290 | 0.242 | 0.751 | 0.612 | 0.933 | 0.946 | 1.000 | 0.954 |
| VARL(NM3-M2) | 0.775 | 0.392 | 0.515 | 0.367 | 0.294 | 0.246 | 0.775 | 0.634 | 0.955 | 0.968 | 1.017 | 0.980 |
| VARL(DM3-DM2) | 0.731 | 0.384 | 0.460 | 0.331 | 0.266 | 0.224 | 0.731 | 0.563 | 0.761 | 0.829 | 0.863 | 0.833 |
| VARL(DNM3-DM2) | 0.867 | 0.457 | 0.524 | 0.384 | 0.306 | 0.263 | 0.867 | 0.718 | 0.958 | 1.018 | 1.061 | 1.029 |

**Note:** VAR (DNM3-DM2) in levels and difference is taken at lag 3.

chapter 3 in tables 3.4 and 3.5. For all VEC estimates with both Divisia and simple sum aggregates are being produced with no autocorrelation up to 1 lag. But these estimates face challenge from the presence of heteroscedasticity in the residual up lag 1. However, this issue of heteroscedasticity is not as much severe as it is thought to be. However, Gonzalo (1994) and

Rahbek et al. (2002) show that maximum likelihood estimator and Johansen procedure are robust or not much sensitive to heteroscedasticity. Because the rejection at 5 % level significance could be firm evidence in the favor of cointegration. The JB test shows non-normal distribution of residuals. However, Gonzalo (1994) shows that non-normal errors do not affect much the performance of the maximum likelihood estimates of the cointegration vector.

The misspecification tests of VAR in first difference and level are given in the table 4.6. In the residuals of VAR in first differences and levels, it is evident in LM and heteroscedasticity test results that there is no autocorrelation and heteroscedasticity with Divisia aggregates. However, these issues are present in the VAR estimates with simple sum aggregates. This indicates the monetary model with Divisia aggregate might be efficient in yielding the best fit for Rupee-Dollar exchange rate. JB tests show non-normal distributed residuals in the case of both VAR estimates.

Thereafter, the random walk model without drift (RW) and random walk model with drift (RWD) are estimated as the benchmark models on Rupee-Dollar exchange rate to compare forecasts with other models. All these time series models and two random walk models are estimated for the in-sample as mentioned earlier. Based on all these estimated models, monthly Rupee-Dollar exchange rates are forecasted for the out-of-sample with variant monetary aggregates and time series models. On those forecasts, forecast errors i.e., RMSEs and MAEs over 1,3,6,12,18,21 and 24 months ahead are generated and presented in table 4.7 that are used for the analysis of the forecast accuracy of Rupee-Dollar in the out-of-sample.

First, the analysis of forecast accuracy begins with the estimates of multivariate models applied on exchange rate equation (4.1) where “simple sum and Divisia money” are included alternatively. Because the core objective of this study is to see the relative importance of simple sum and Divisia aggregates and what makes difference in using them for forecasting monthly Rupee-Dollar exchange rate in the out-of-sample forecast exercise. In the table 4.7, forecast errors of VEC results show that irrespective of monetary aggregates used, monetary model can beat the simple random walk with drift and random walk without drift in terms of RMSE and MAE except at 24 months ahead horizons. This indicates that monetary model beats the simple random walk models. Within the aggregates, Divisia aggregates give more accurate forecasts of exchange rate in the out of sample compared to simple sum aggregates. If these results are compared with forecasts of VAR in first differences, similarly monetary model beats the simple random walks in term of RMSE and MAE except at 24 months ahead horizons irrespective of monetary aggregates included. But in contrary to VEC results, VAR in first differences shows simple sum aggregates perform better than that of Divisia aggregates in terms of, in particular MAE. However, in the terms of RMSE, both aggregates have yielded similar forecasts for Rupee-Dollar exchange rate.

VAR in levels forecasts though not all, yield lower forecast errors compared to the simple random walks. Within the aggregates, simple sum aggregates forecast Rupee-Dollar exchange rate better than that of Divisia aggregates at all horizons. But DM3-DM2 can forecast better than simple sum aggregates in terms of RMSE and MAE at all horizons. This provides a little support further, as in VEC forecast results, for better information content in Divisia aggregates that might help in forecasting Rupee-Dollar exchange rate better.

The major difference in the forecast accuracy also is due to information included in two multivariate models. The VAR in first differences excludes long run dynamics or common stochastic trend among variables. The VEC includes both short and long run dynamics of variables to forecast so that it can forecast more accurately compared to VAR in first differences and levels. It is evident in the results that forecast errors are relatively less for VEC estimates compared to VAR in first differences and levels. Further, Divisia aggregates are more accurate in forecasting exchange rate when the long run information is retained through VEC specifications. Further, VEC and VAR in first differences forecasts based on monetary fundamentals beat not only the random walk models but also ARIMA model in terms of RMSE, but not MAE. Thus, the evidence is in line with the previous studies such as Najad and Bond (2000) where structural monetary model is found to beat univariate time series models like ARIMA and GARCH in forecasting exchange rates. The results of VEC also is also reminiscent of the arguments found in Sims (1980) and Doan (1992) against differencing as it may omit information concerning co-movements between the variables. Also, the VEC results support Bhavani and Kadyala (2010) that when short run and long run dynamics changes are included simultaneously in model specification, the exchange rates forecast is improved better than models with long run changes only. These results are in contrast with Moosa and Vaz (2016) wherein error correction model does not have much value addition to enhance forecast of exchange rate compared first difference VAR model.

If one looks at other forecast errors of univariate models i.e., ARIMA ((1,4),1,0) and GARCH (1,1), one finds the ARIMA to have outperformed GARCH (1,1) and both simple random walks in term of RMSE and MAE at all most every horizon. Even it is more accurate than multivariate models at all horizons except in some cases where VEC with Divisia aggregates forecast better if accuracy is judged in terms of RMSEs.

The plots of out-of-sample forecasts are given in figures 4.2 to 4.17 where the comparisons between forecasted and actual monthly Rupee-Dollar exchange rates are displayed. It is observed that most of turning points of forecast monthly Rupee-Dollar exchange rate coincide with actual exchange rate with Divisia aggregates when estimated by VEC. Even simple sum aggregates forecast better in the VEC estimations which can be seen in their plots. Though VAR in levels forecast better turning points of exchange rates, they are distant from actual exchange rate compared to VAR in first differences with simple sum aggregates. This is the reverse when forecast is generated by VAR in first differences. The deviation between forecasted and actual exchange is smaller with VAR in first differences with simple sum aggregates. However, turning points captured by Divisia aggregates are as much similar as simple sum aggregates. Therefore, the use of Divisia money does have value addition in the monetary models to forecast of Rupee-Dollar exchange rate. Other forecasts of random walk models, ARIMA and GARCH do well in capturing the variations in the exchange rate but their accuracy is surpassed by multivariate models based monetary fundamentals. ARIMA is doing job in capturing actual exchange rate more accurately that that of GARCH (1, 1).

Overall, from this analysis, monetary models outperform the random walk models in the forecasting of Rupee-Dollar exchange rate in the out-of- sample. This confirms the important role played by the monetary fundamentals in exchange rate forecasting. This contradicts with findings of Meese and Rogoff (1983). But this evidence is sensitive to monetary aggregates and the type of time series models used. Divisia aggregate can give enhanced forecast of exchange rate compared to simple sum aggregates in the financially liberalized times of India though, in some cases, simple sum aggregates also do well. This may be attributed to the ability of Divisia aggregates in capturing real monetary information flows such as portfolio adjustment and substitution among monetary assets due to financial innovation. Thus these findings are in general consistent with that of Chrystal and MacDonald (1995). Moreover, the findings support the hypothesis that Divisia money captures all dynamics of monetary changes and forecasts Rupee-Dollar exchange rate in the financial innovation era better than the simple sum counterparts. In addition, monetary models based on simple sum aggregates produce better forecasts than random walk models.

Further, the Rupee-Dollar exchange rate forecasts are also sensitive to time series methodologies applied. The VEC could be the best model since it considers all information regarding monetary fundamentals such as cointegration among variables and forecast better than that of VAR in first differences and levels. The use of cointegration has likely enhanced forecast of monetary models upon random walk. Even this cointegration information has helped Divisia aggregates to forecast exchange rate better than that of simple sum aggregates. Thus, it underscores the importance of cointegration information among variables in forecasting of Rupee-Dollar exchange rate.

### 4.5. The summing up and implications for policy

This empirical chapter predominantly investigates the forecast accuracy of the monetary model with Divisia and simple sum monetary aggregates for monthly Rupee-Dollar exchange rate in the post reform period. In pursuing so, various univariate and multivariate models are employed on the same monthly data used in the chapter 3 that span between March 1996 and February 2017. Using Divisia aggregates for Rupee-Dollar forecast analysis in monetary models constitutes a novelty of study. It is also a contribution to the existing literature. The purpose of Divisia money is to measure real monetary information flows that capture assets portfolio adjustments and substitutability in the monetary model that arise out of financial innovation where such dynamics are hardly accommodated by simple sum aggregates. This is well known in the empirical literature; financial innovation that causes instability in the money demand function may weaken monetary models (Chrystal and MacDonald 1995). The inclusion of Divisia aggregate thus makes money demand function stable and thereby monetary model can improve forecasts of exchange rates. Therefore, this study or empirical chapter's primary objective is to examine the relative importance the variant monetary aggregate measures in forecasting of Rupee-Dollar exchange rate in the out-of-sample exercise. At the same time, this study also looks at forecast ability of the variants of univariate and multivariate time series models i.e., ARIMA (p, d, q), GARCH (p, q), VAR in first differences and levels and VEC models.

To evaluate forecast accuracy among monetary aggregates and across time series models, all the coefficients of models have been estimated in the in-sample dataset and then the estimated coefficients are used in the out-of-sample to forecast monthly Rupee-Dollar exchange rate. The out-of-sample forecasting involves the last 24 observations that spanning from March, 2015 to February, 2017 and forecast errors i.e., RMSE and MAE calculated for 1 to 24 months ahead forecast horizons.

The results show that monetary models irrespective of simple sum and Divisia aggregates outperform simple random walk models in forecast of exchange rate over short to longer horizons in the out-of-sample. Within monetary aggregates, Divisia aggregates are superior in forecasting of Rupee-Dollar exchange rate over simple sum aggregates. These findings are in line with Chrystal and MacDonald (1995) and Barnett (2005). However, the forecast results are sensitive to the econometric and time series models used. In time series models, VEC provides an improved forecast than that of VAR in first differences and levels. Hence, it implies the significance of short and long run dynamics in the modeling and forecasting of monthly Rupee-Dollar exchange rate. This is consistent with Bhavani and Kadyala (2010) that the simultaneous consideration of short run and long run dynamics changes in model specification can improve the exchange rates forecast better than models that includes long run changes only. It is in contrast with Moosa and Vaz (2016) wherein error correction model does not have much value addition to enhance forecast of exchange rate compared first difference VAR model. Further, the results suggest that ARIMA model provides better forecast for Rupee-Dollar exchange rates whereas GARCH model gives poor forecast of exchange rate out-of-sample.

Since monetary models irrespective of monetary aggregates yield better forecast of Rupee-Dollar exchange rate, monetary fundamentals can be considered to frame exchange rate and monetary policies. The findings imply that monetary information flows in the Divisia aggregates could contribute to enhance the out-of-sample forecast of Rupee-Dollar rate in the monetary model. This supports our hypothesis that Divisia aggregates could be considered appropriate measure for money in the monetary models especially in the financial innovation era. Thus, Divisia aggregates are complimentary to simple sum aggregates to observe the liquidity conditions in the economy and to make monetary policy analysis. However these results are subject to structural breaks and parameter in stabilities that might arise due to financial crisis such as South Asian crisis of 1997, financial crisis of 2008 and Greece crisis of 2012. Thus, an examination of forecasting ability of Divisia and simple sum aggregates by including structural breaks or time varying parameters is left for future research.

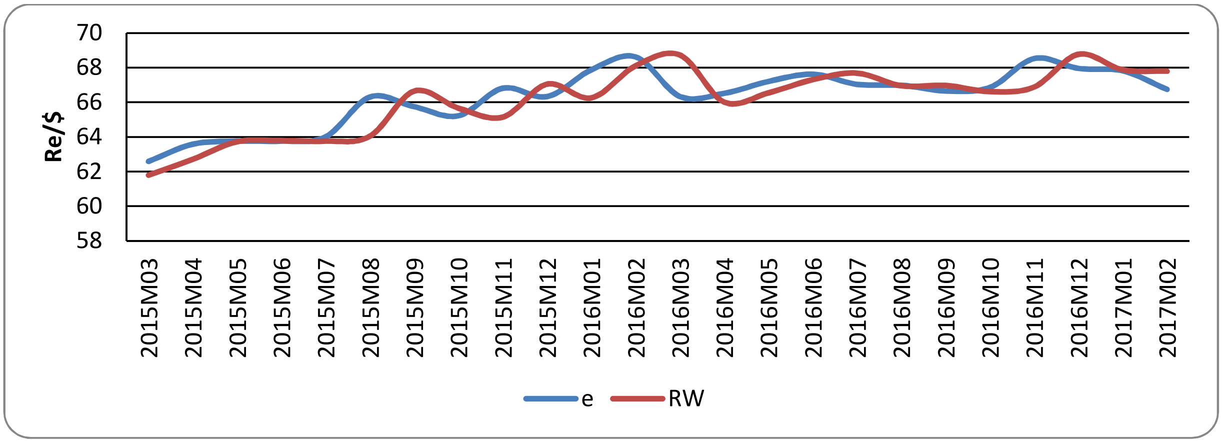



**Figure: 4.2** Forecast of random walk without drift

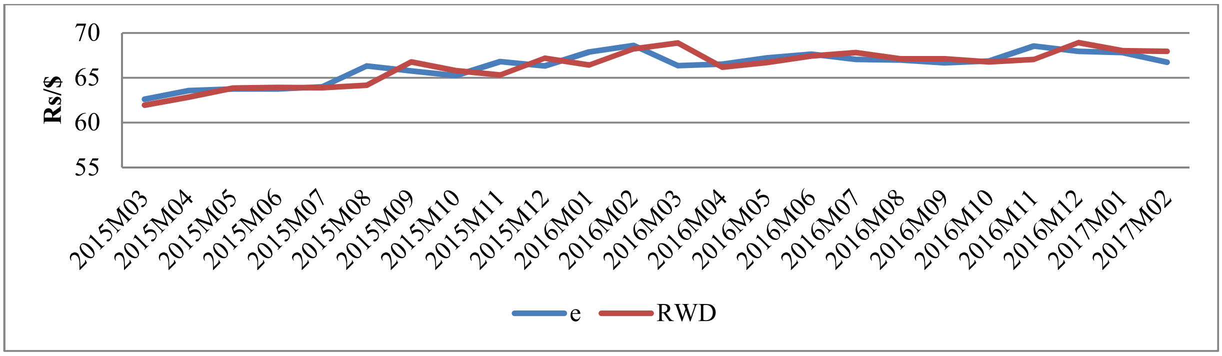



**Figure: 4.3** Forecast of random walk with drift

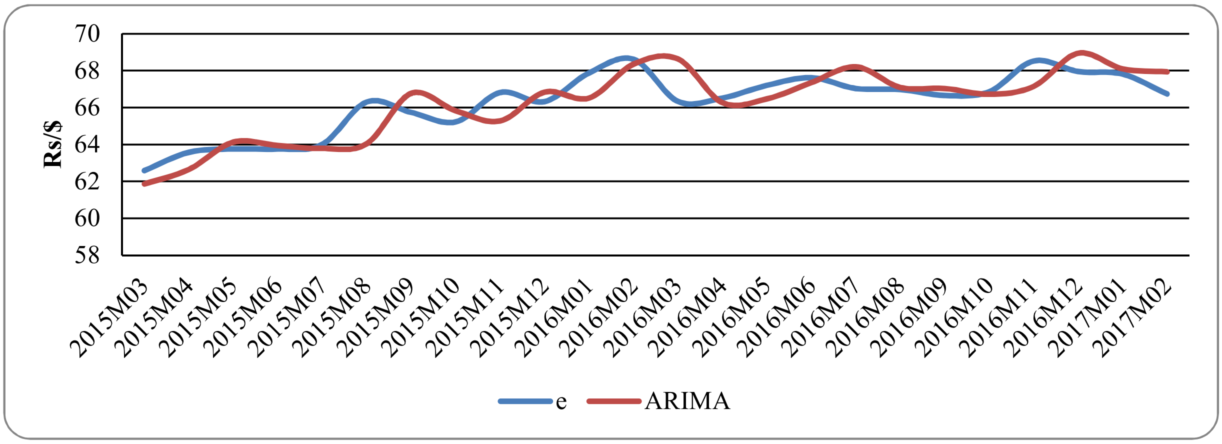



**Figure: 4.4** Forecast of ARIMA ((1,4),1,0)

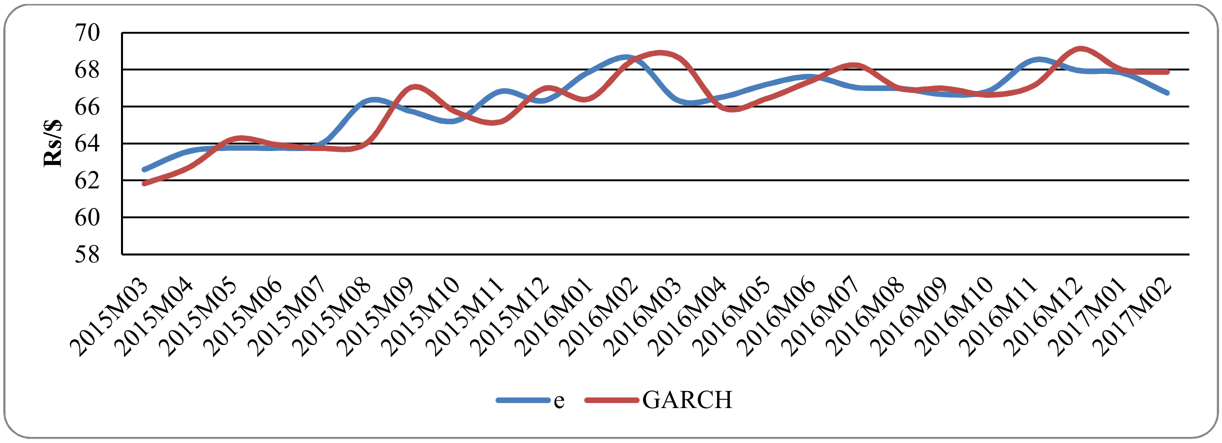



**Figure: 4.5** Forecast of GARCH (1,1)

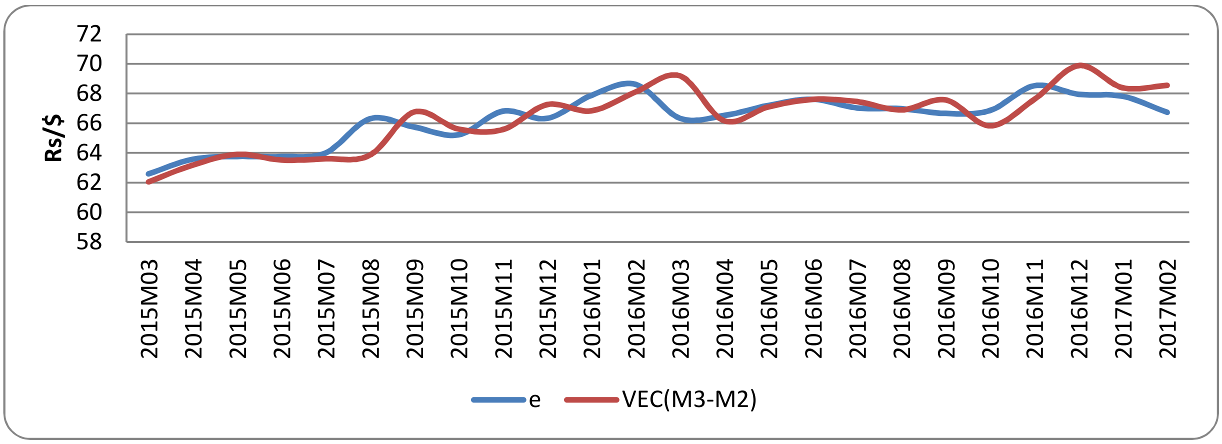



**Figure: 4.6** Forecast of VEC (M3-M2)

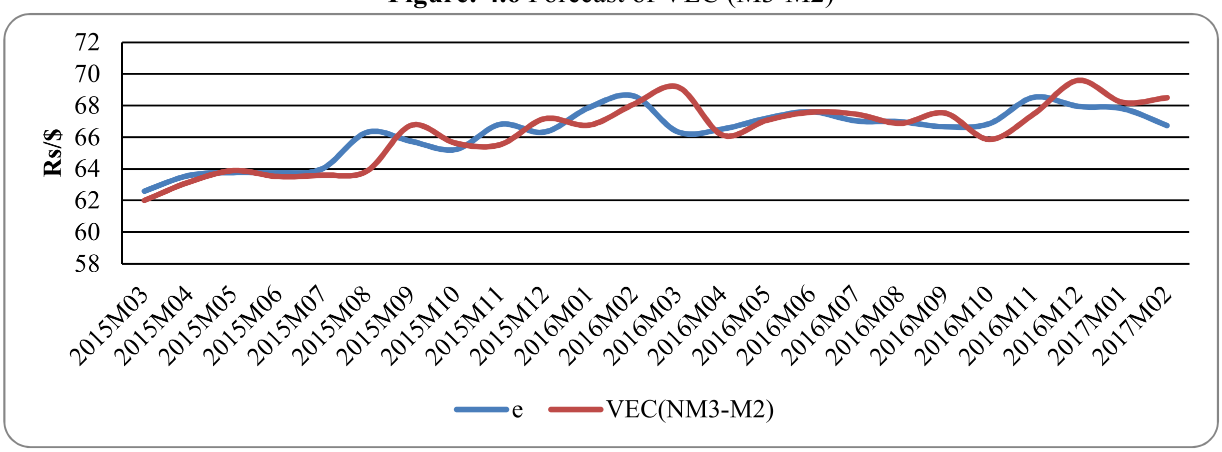



**Figure: 4.7.** Forecast of VEC (NM3-M2)

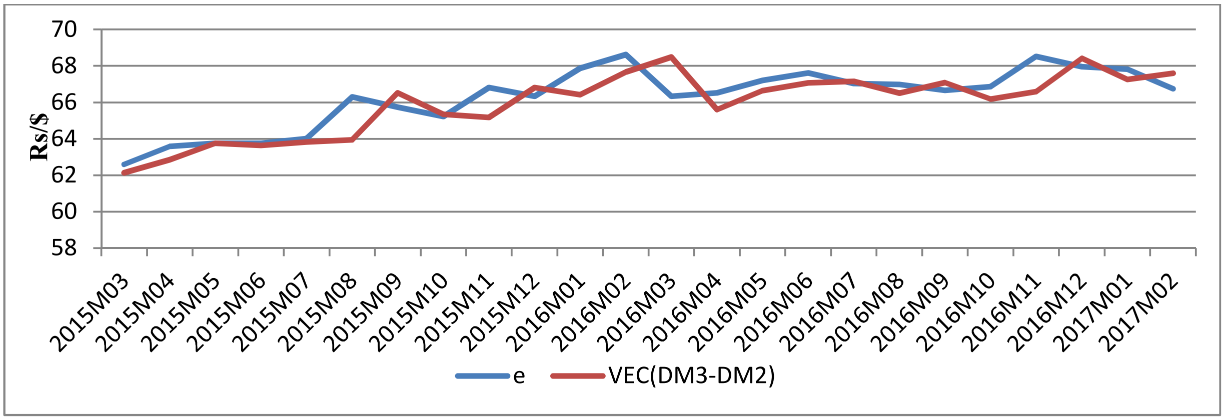



**Figure: 4.8** Forecast of VEC (DM3-DM2)

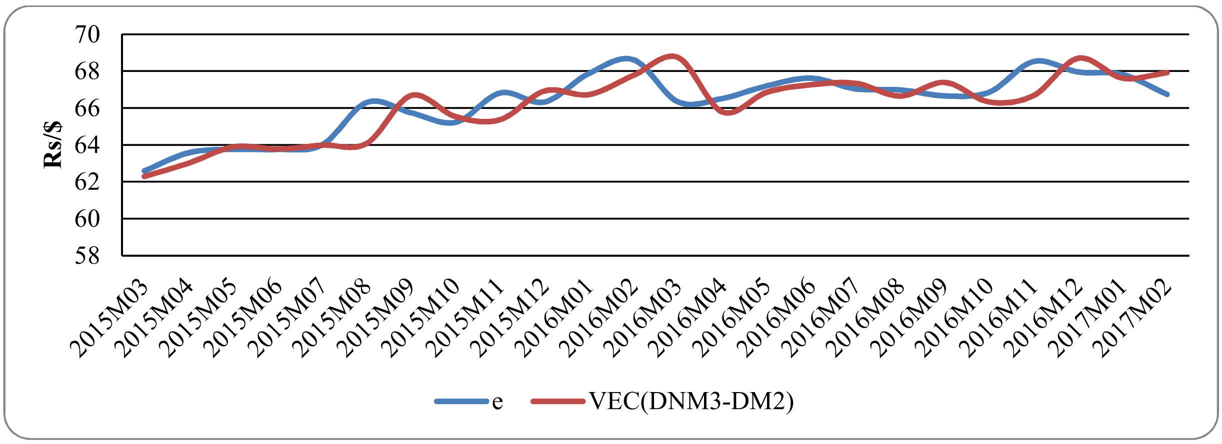



**Figure: 4.9** Forecast of VEC (DNM3-DM2)

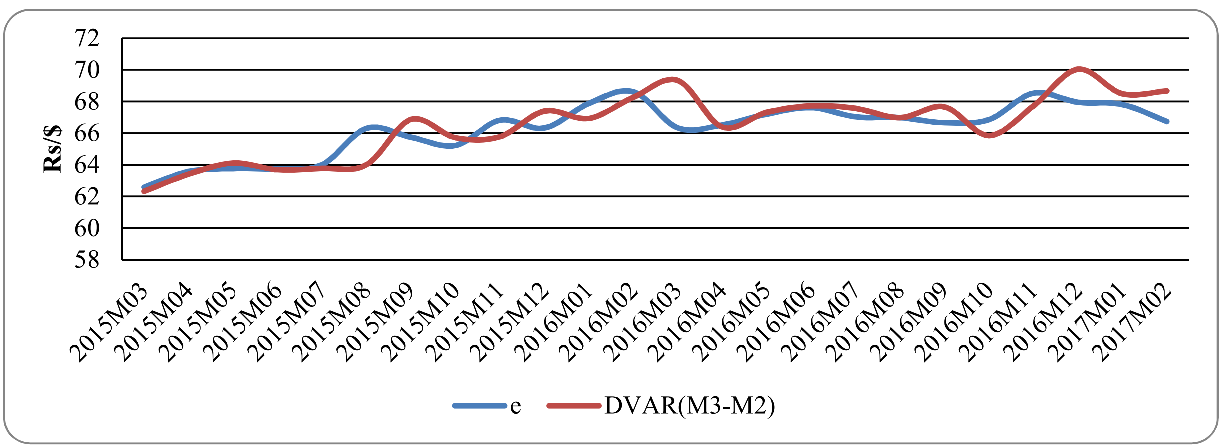


**Figure: 4.10** Forecast of VAR in first difference (M3-M2)

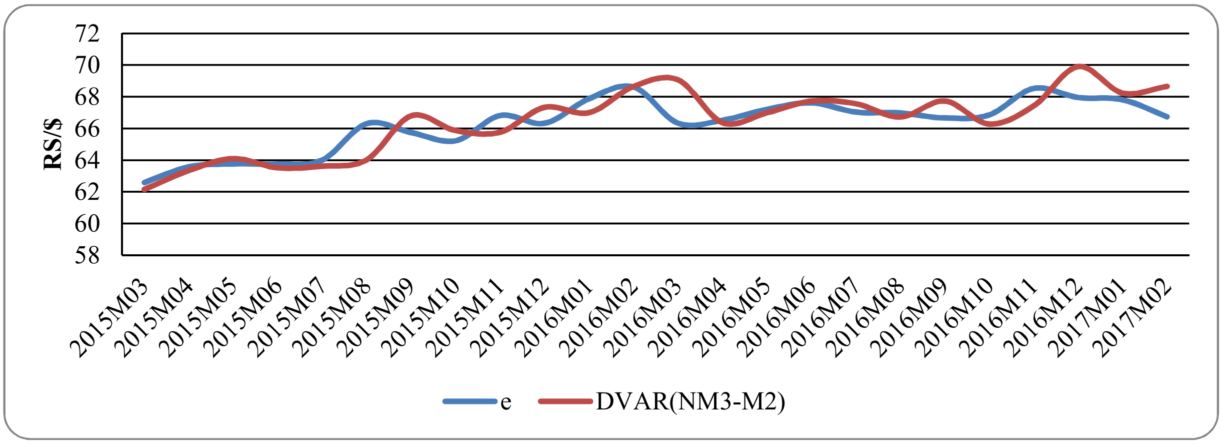



**Figure: 4.11** Forecast of VAR in first difference (NM3-M2)

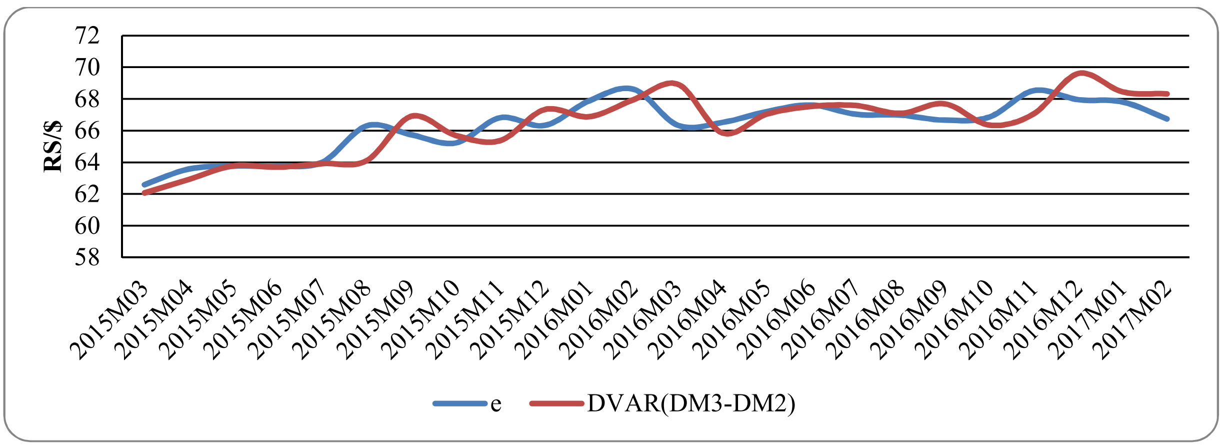



**Figure: 4.12** Forecast of VAR in first difference (DM3-DM2)

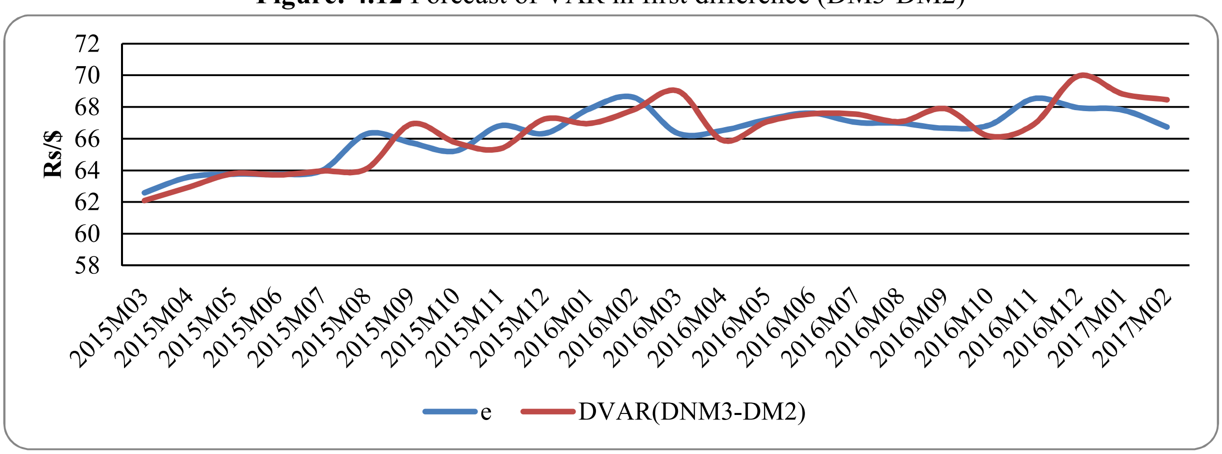



**Figure: 4. 13** Forecast of VAR in first difference (DNM3-DM2)

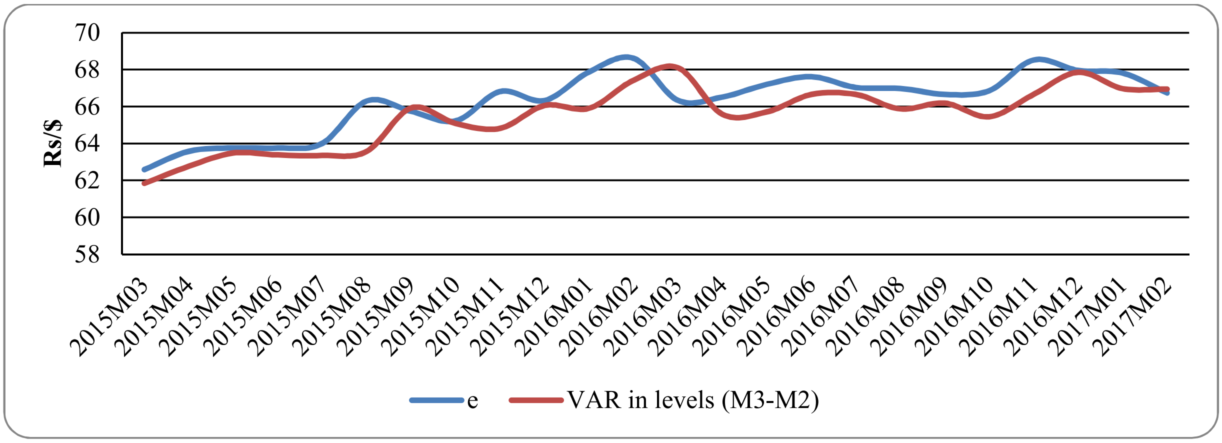



**Figure: 4.14** Forecast of VAR in levels (M3-M2)

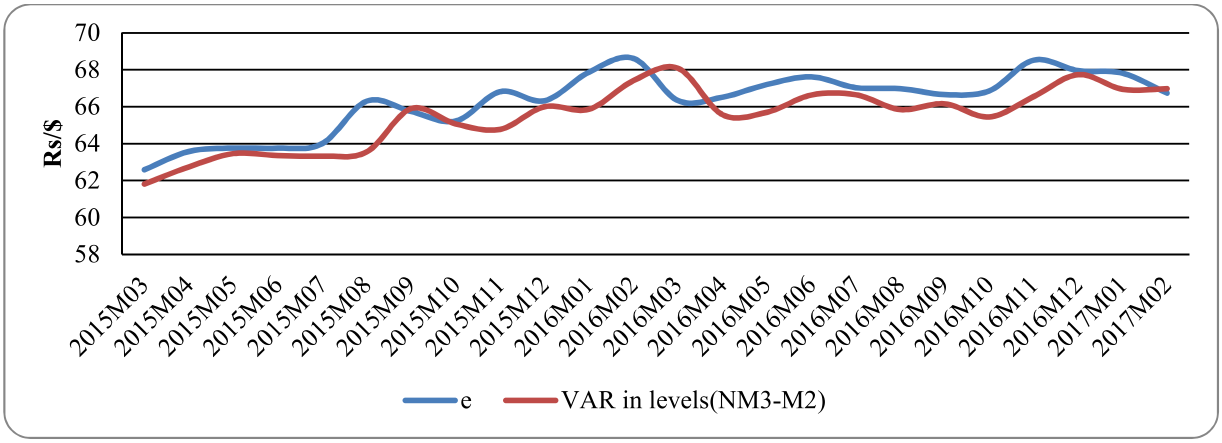



**Figure: 4.15** Forecast of VAR in level (NM3-M2)

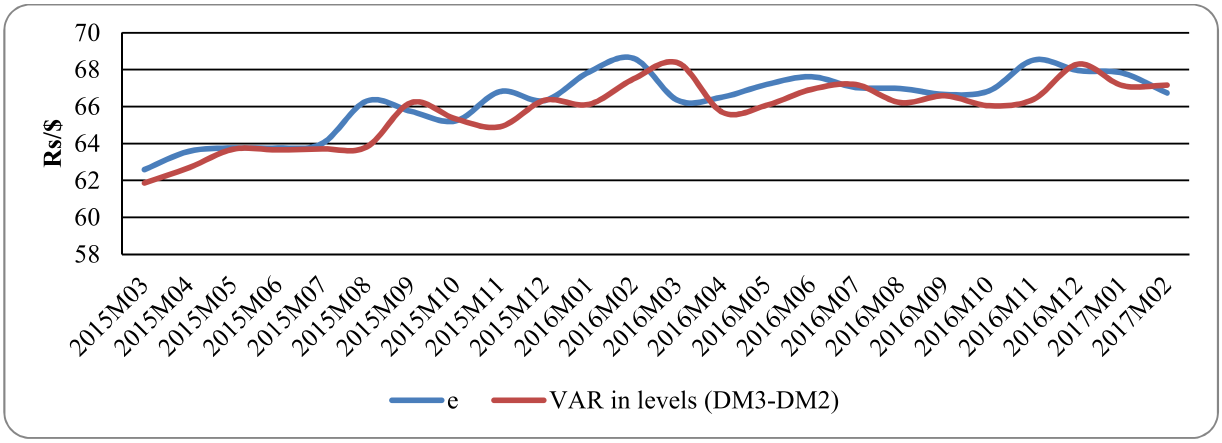



**Figure: 4.16** Forecast of VAR in levels (DM3-DM2)

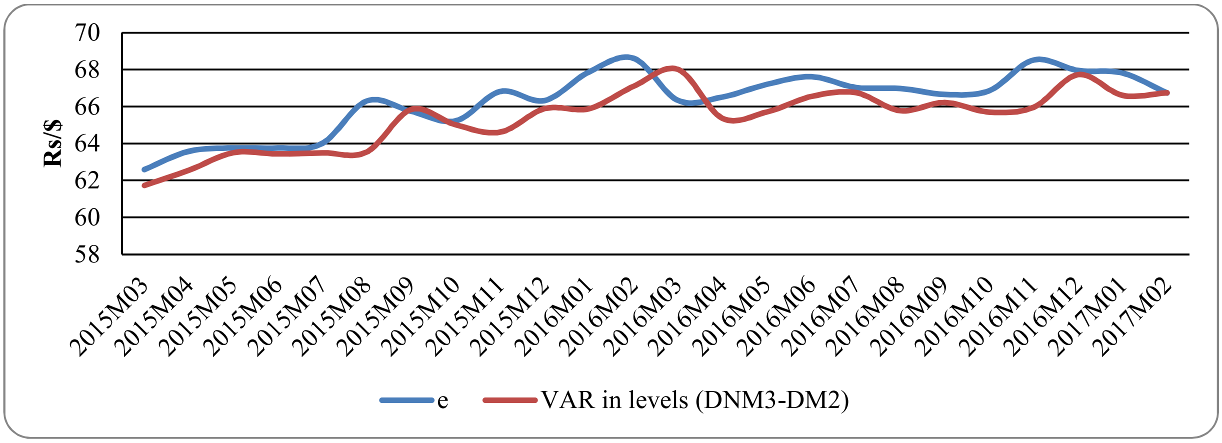



**Figure: 4.17** Forecast of VAR in levels (DNM3-DM2)

**Note:** All forecasts of various models are plotted in anti-logs terms.

e is the actual monthly Rupee-Dollar exchange rate.

VARD is a VAR in first differences.

# Chapter 5

## The volatility of Rupee-Dollar rate and its determinants in the monetary framework

### 5.1. Introduction

With the advent of increased economic and financial integration, exchange rate has emerged as a key factor in the determination of macroeconomic stability of an economy. This is because exchange rate fluctuations have a perverse effect on all economic activities through trade and its pass-through impact indirectly on the domestic price level. More specifically, it impacts trade and thereby domestic production and domestic consumption also are affected. Further, persistent volatility in home currency against major invoice currencies creates destabilizing effects and downgrades export competitiveness. But with the advent of flexible regimes beginning 1973, advanced and developed countries begun to experience large exchange rate volatility in their foreign exchange markets even though flexible exchange rate regime is supposed to protect a country from severe external shocks. Even also developing economies including Asian countries have transitioned from controlled economies to market economies with the implementation of liberalization policies since 1980. Similarly, India also entered into a deregulated regime with linearization policies. As mentioned in the introduction, the exchange rate regime in India also witnessed a major shift in the 1990s with the historic economic reforms. The LERMS came into effect for one-year period starting from early 1992 and early 1993 with a dual exchange rate system. All current account forex receipts needed to be surrendered to the authorized dealers in full under this arrangement. For sixty percent of the transactions' proceeds, the exchange rate was the market rate quoted by the authorized dealers. The remaining forty percent used to be converted at the RBI's official rate. In March 1993, a unified rate system replaced the dual rate system, and all forex receipts began to be converted at market-determined exchange rates. Thus, exchange rate of Indian Rupee was determined in the market and current account convertibility was a reality in 1994. Considering these reforms, Indian forex market has been marked with significant structural changes. With full currency convertibility on current account and partial convertibility in the capital account, trade and capital flows have seen tremendous growth in the last two decades. This is reflected in the respective increased shares of exports and imports of goods and services in GDP to 22.73% and 27.53 % in 2018 from 17.38 % and 18.02 % in 2005. Capital account has witnessed increased foreign direct investment and foreign portfolio investments in the form of equity and debt. However, these developments have come up with both positive and negative repercussions. On the one hand these reforms help enhance foreign exchange rate market efficiency and price discovery, depth, and liquidity over time (Dua and Ranjan, 2011). On the other one sees huge uncertainty in exchange rate movement in the forex market. Goyal (2018) observes that RBI has intervened in the forex market from time to time to dampen the volatility whenever volatility movements in the Rupee-Dollar rate are present before and after great financial crisis 2008. This implies that the central bank intervenes in the forex market to protect export competitiveness in the market and ensure market orderly conditions. Nevertheless, Rupee has been subject to several external shocks like oil prices, international economic circumstances, and financial crisis i.e., the East Asian crisis of 1997, Great Financial crisis of 2008, Euro Debt crisis of 2011 etc. In this background, it is required to study the volatility of Indian rupee empirically. Therefore, this chapter examines the volatility relationship between Rupee-Dollar rate and fundamental macro variables such as the relative money, income, interest rate for India and US using simple sum and Divisia money. The rest of this chapter is organized as the following. Section 5.2 reviews literature on exchange rate volatility in macroeconomics framework and explain research gap. Section 5.3 briefs empirical model. Section 5.4 describes about data and methodology. Section 5.5 presents and discusses the results and finally, section 5.6 provides conclusion and policy implications.

**5.2. Some past studies**

Some of the past studies in the literature have explored a nexus between rupee exchange rate volatility and macro fundamentals in the Indian context by taking into account macro factors such as growth rate of GDP, inflation, trade, central bank interventions, and FDI. In particular, Goyal and Arora (2012), "examine the impact of the intervention by central bank on exchange rate conditional mean and volatility by accounting its communication and news impact using both monthly and daily frequency". They mainly confirm that central bank intervention with its powerful communication influences exchange rate level despite of the fact that RBI is not committed to target the level of exchange rate. A similar study by Kohli (2015) has found that "reserve advocacy has a larger and significant impact in reducing the exchange rate volatility irrespective of the regime after controlling the effect of macroeconomic variables such as liquidity risk, GDP, inflation, interest differentials, and financial openness". This study also implies that the impact of forex reserves operates through market sentiments and confidence rather than the actual intervention alone. However, in the literature, the debate on volatility in exchange rate and macro variables begins with Friedman's (1953) proposition "that volatility in exchange rate is a symptom of instability or volatility of macroeconomic structure". He argues that flexible exchange rates are inevitable to be unstable due to the underlying instability of economic conditions. Balg and Metcalf (2010) investigate the effect of macro fundamentals volatility on volatility of exchange rate for Canada, Germany, Japan, and UK. They find that the different fundamentals have a different impact on exchange rate volatility across countries.

Morana (2009) shows the significant long-term linkages and tradeoffs between macro fundamentals and exchange rate for G7 countries in the float period between 1980 and 2006. Adusei and Gyapong (2017) attempt to explain the variance in exchange rate by macroeconomic fundamentals using the partial least square structural equation model for Ghana's exchange rate with US. Their results show that 82% of exchange rate variance is explained by the variance of macroeconomic fundamentals.

Flood, and Rose (1995, 1999) state that choosing exchange rate regime as policy variable is the sole reason for volatility in exchange rate, but not the macro variables' volatility. Therefore, they assert that "there is no clear trade-off between exchange rate volatility and macroeconomic volatility and fixed exchange rates to be less volatile compared with floating exchange rates". Duarte (2003) documents a drastic increase in the volatility of the real exchange rate in the time of switching from pegged to floating while the same pattern is not observed for other macroeconomic variables. Grossmann et al. (2014) also have found that at both high and low frequencies, the more substantial feedback effect from exchange rate volatility to macro and financial variables in the case of developing countries relative to developed economies. A recent study by Cevik et al. (2017) look at "the impact of soft power aspects on exchange rate volatility employing a balanced panel dataset containing 115 economies for the period 1996–2015". This study demonstrates that after accounting for macroeconomic factors, the variables including different indices of accountability, educational attainments, life expectancy, financial openness etc., show a considerable impact on exchange rate volatility across countries.

### 5.2.1. Research gap and contribution

Given the above discussion, in this chapter, an attempt is made to examine determinants of Rupee-Dollar rate volatility. The possible determinants of volatility could be relative money supply, income, and interest rate with the US. As mentioned in the previous chapters, this thesis has focused on Divisia money as an alternative to simple sum monetary measures in measuring relative money supply in all models estimated. It is probably the first study that incorporates Divisia aggregates in the modeling of Rupee-Dollar volatility. Because most of the studies in the past have used money volatility underlying simple sum money. Further, the analysis of the joint effect of macro fundamentals also makes the exercise distinct from the previous studies. Thus, the focus of the study is to examine the long-run relationship between the Rupee-Dollar exchange rate volatility and volatility in macro fundamentals by measuring money with simple sum and Divisia money. Then the sensitivity of the long-run relationship is examined between the aggregates. So, this study tests the hypothesis that volatility in the macro fundamentals determines Rupee-Dollar exchange rate volatility. Therefore, this study contributes to the empirical literature of exchange rate in two ways. First is to examine the relationship between exchange rate and its fundamentals with simple sum and Divisia monetary aggregates in terms of variance or volatility in the era financial innovation of India. The second is to analyze whether joint or covariance of macroeconomics factors have any effect on exchange rate volatility.

### 5.2.3. Monetary model of exchange rates

The volatility of fundamental macro variables are obtained from flexible price version (Frankel, 1976; Mussa, 1976; Bilson, 1978) for modeling of Rupee-Dollar exchange rate volatility. It assumes that PPP holds continuously, as earlier mentioned. Therefore, it is noted that the same theory as mentioned preceding chapters is reproduced here

Therefore,

$$e_t = p_t - p_t^* \qquad (5.1)$$

Where "*e* denotes the natural logarithm of the exchange rate that is defined as the price of domestic currency per unit of foreign currency: *p* and *p** denote domestic and foreign price variables measured in natural logarithms". As monetary equilibrium conditions in the domestic and foreign countries jointly determine the exchange rate, the respective money demand functions are given in equations (5.2) and (5.3) as:

$$m_t - p_t = \beta_2\, y_t - \beta_3\, i_t \qquad (5.2)$$

$$m_t^* - p_t^* = \beta_2 y_t^* - \beta_3\, i_t^* \qquad (5.3)$$

By rearranging (5.2) and (5.3) given above one obtains the expressions for domestic and foreign price levels as:

$$p_t = m_t - \beta_2 y_t - \beta_3 i_t \qquad (5.4)$$

$$p_t^* = m_t^* - \beta_2 y_t^* - \beta_3\, i_t^* \qquad (5.5)$$

By substituting (5.4) and (5.5) in equation (5.1) the following reduced form exchange rate equations is obtained

$$e_t = (m_t - m_t^*) + \beta_2\, (y_t - y_t^*) + \beta_3\, (i_t - i_t^*) \qquad (5.6)$$

Equation (5.6) can be expressed in the second movement or variance terms by multiplying both sides with variance. It results to the exchange rate in terms of volatility or variance that is a function of the variances of macro fundamentals differentials between domestic and foreign country. This is to form the following equation (5.7).

$$Vs = V\,\widetilde{m} + \alpha 12\ V\,\widetilde{y} + \alpha 22\ V\,\widetilde{r} + 2\ \alpha 2\ Cov(\widetilde{m}\ \widetilde{y}) + 2\ \alpha 2\ Cov(\widetilde{m}\ \widetilde{r}) + 2\ \alpha 2\ Cov(\widetilde{y}\ \widetilde{r}) \qquad (5.7)$$

Where $V$ is volatility and $Cov$ is the covariance

$\sim$ stands for the variable differential between the domestic and foreign country

$\tilde{m}, \tilde{y},$ *and* $\tilde{r}$ denote domestic money supply, income, and interest rate relative to a foreign country. $\alpha 12, \alpha 22, 2\alpha 2, 2\alpha 2, 2\alpha 2$ are elasticities of variance and covariance of fundamental variables for exchange rate volatility. As per prior expectations, these coefficients are expected to be positively linked with exchange rate volatility. However, the covariance of monetary fundamentals is either positive or negative relations with exchange rate volatility. Except for the interest rate, all variables are in natural logarithm form. The volatility for all variables in the volatility equation is measured by three months standard deviations following Balg and Metcalf (2010). These possible theoretical relationships between macro fundamentals volatility and volatility exchange rate are illustrated as follows.

**Money volatility:**

There is a positive relation with exchange rate volatility that means increased volatility in the money is associated with an increase in the exchange rate volatility. Because domestic money supply increases relative to foreign country result into interest rate decline and rise of inflation (Calderon, 2004). It would cause lower demand for domestic money, thereby depreciating the domestic currency and more volatility in the exchange rate.

**Output volatility:**

Income or output volatility is also associated with volatility in exchange rates. As output increases with higher Government spending, increased imports cause exchange rate to depreciate or increase, resulting in higher volatility (Grydaki and Fountas (2008). Income or output effect depends on the share trade in the total output (Morana, 2009).

**Interest rate volatility:**

Volatility in interest rate has an expected positive relation with exchange rate volatility. Because increased interest rate relative foreign country lowers the demand for domestic money, resulting in depreciation of exchange rate and more volatility. Or "the higher difference between domestic and foreign interest rates" leads to a higher speculative capital flows into the economy. This further results in higher volatility in exchange rates (Goyal and Arora, 2012; Grossmann et al., 2014)

**Joint or covariance effect of fundamentals on volatility in exchange rates:**

Grydaki and Fountas (2008) formalize the relationship of covariance with exchange rate volatility. They argue that covariance between interest rate and money supply is either positively or negatively associated with volatility in exchange rates. Because increased interest causes more deposits and an increase in money supply and conversely, increased interest may cause lesser money supply availability. Thus, it could lead to either increasing or decreasing effect.

Similarly, for covariance between income and money supply, as increased money supply lowers the interest rate, the reduced interest rate raises investment that, in turn, causes income or output to grow with the depreciated exchange rate and higher export. This could lead to more exchange rate volatility. Conversely, a growing output may cause the more money demand pressure on inflation and interest rate rise, resulting in negative exchange rate volatility and appreciation of exchange rate and less volatility. As far as the interest rate is concerned, a flexible price monetary model postulates that higher interest rate implies the tighter monetary policy due to higher inflation. Thus, higher interest and higher opportunity cost to hold domestic money lead to exchange rate depreciation and volatility.

## 5.3. Data and methodology

This study employs quarterly data for the Rupee-Dollar exchange and its macro fundamentals. Quarterly observations are generated by calculating three-months end standard deviations from each variable monthly series. A sample data covers the regime of floating exchange rates in India since March 1993 that witness drastic changes in the pattern of Rupee volatility in the forex market. This period also saw significant reforms and financial innovations and changes in the exchange rate policies. Therefore, it can be interesting to study the evaluation and development of Rupee-Dollar rate during this period. The data period 1996:Q3-2016:Q4 is employed depending on the availability of data on all variables in the volatility equation. Due to a lack of data on all monetary components to calculate Divisia for M3 for India, the data period for the volatility equation with DNM3-DM2 used is from 1999: Q2 through 2016:Q4. Data is sourced from HSIE, RBI, and the FRED. Simple sum aggregates M3 and NM3 for India and M2 for US are proxied for money supply between domestic and foreign country. Details of Divisia money for M3 and NM3, their component and assumed returns are given in Appendix A3 based on which Divisia monies for India are calculated. Divisia M2 for the US is extracted from the Centre for Financial Statistics. Income of India is measured by monthly IIP and US's income is proxied by monthly industrial production index. Their interest rates are proxied by monthly weighted average call money rate and effective federal fund rates. Money supplies and incomes are seasonally adjusted, and except for interest rates, all variables are in the form of the logarithm.

For pursuing the above-mentioned objective, OLS linear regression and ARDL cointegration methodology are applied on exchange rate volatility equation (5.7). Pesaran et al. (2001) have developed ARDL cointegration to test the long-run relationship in the empirical model in case of integration of variables at different levels or combinations of I(0) and I(1) or only I(0). In other words, this methodology is developed for such a situation where more than two variables are stationary at either I (1) or (0) or combination of both. Thus, it avoids the pre-testing of the unit root problem associated with conventional methods. Further, the issue of endogeneity is considered as a less problem if the model is free from residual correlation. The "standard linear ARDL (p, q) with two time series $y_t$ and $x_t$ (t=1,2,…..T) for testing cointegration following Pesaran and Shin (1999) and Pesaran et al.(2001)" is given by

$$\Delta y_t = a_0 + a_1 z_t + \sum_{i=1}^{p-1} b_i \, \Delta x_{t-i} + \sum_{i=1}^{q-2} c_i \, \Delta \, y_{t-i} + \delta_1 \, x_{t-i} + \delta_2 \, y_{t-i} + \mu_t \qquad (5.8)$$

"Where $z_t$ denotes a vector of deterministic regression i.e., trend, seasonal and other exogenous influences with a given lags and $u_t$ denotes an *iid* stochastic process".

In this ARDL equation (5.8), it tests "the null hypothesis of no long-run cointegration ($\delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = 0$) against the alternative hypothesis of cointegration ($\delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 \neq \delta_6 \neq 0$) using the F-test. Pesaran et al. (2001) generate two sets of critical values. One assumes that all variables are I (1) whereas the other rests on the assumption that all variables are I (0) that contains a band covering all possible combination for each I (0) and I (1) variable. The null hypothesis of no cointegration is rejected to ascertain a long-run relationship among variables if calculated F statistics is more than critical F value". According to Pesaran et al. (2001), it allows the estimation of following unrestricted error correction model where optimum lags are decided by Akaike information criterion (AIC) or Schwarz Bayesian criterion (SBC).

$$\Delta y_t = a_0 + a_1 z_t + \sum_{i=1}^{p-1} b_i \, \Delta x_{t-1} + \sum_{i=1}^{q-2} c_i \, \Delta \, y_{t-1} + \gamma ECT - 1 + v_t \qquad (5.9)$$

.where $\gamma$ is the coefficient of lags error correction term, which measures the speed of adjustment parameters. ECT is the residuals extracted from the estimated model (5.8).

To see the robustness of the fitted model, the presence of serial correlation and heteroscedasticity in the residuals of the fitted model are examined by Breusch-Godfrey (BG-LM) serial correlation LM test and ARCH tests, respectively. BG-LM test presumes the null hypothesis of no serial correlation in the residuals, while ARCH test has the null hypothesis of no heteroscedasticity in the residuals. Jarque-Bera test tests the normal distribution of residuals of fitted model. Ramsay Reset test is conducted for whether the model is misspecified or not. Further, since the time series models are well known for instabilities so that the CUSUM and CUSUM of square tests are performed (Brown, Durbin, and Evans, 1975) for whether the estimated coefficients of the model are "stable or not" over time.

### 5.4. Results

This section presents and discusses the results of our primary empirical relationship between exchange rate volatility and volatility in fundamentals such as money supply, income and interest rate differentials between India and US. Non-stationary variables are likely to lead for spurious regression and misleading conclusions to generalize findings over time. Therefore, the stationarity of variables in equation 5.7 are tested. Before that, descriptive statistics of the natural logarithms variance for Rupee-Dollar rate and volatility in the fundamentals are presented in table 5.1 below. They suggest that all variable variables are little volatile as standard deviation and Kurtosis indicate. The unit root test results is shown in table 5.2 where the ADF and PP test with the constant and constant plus trend are given on exchange rate volatility and volatility and fundamentals covariance. It is clear from table 5.2 that each volatility and covariance variable is integrated at I (0) that indicates the reject of null of unit root or non-stationary either with the constant and constant plus trend. These unit root test results allow us to apply to two methodologies to estimate the relationship between exchange rate volatility and its fundamentals. One is OLS based linear regression and the second is the ARDL-ECM model. The results of regression for equation 5.7 with different monetary aggregates are reported in table 5.3. It is worth mentioning the strategies used for OLS regression. Since quarterly standard deviation and

**Table 5.1.** Descriptive statistics

| | $Ve$ | $V\widetilde{m}$ (M3-M2) | $V\widetilde{m}$ (NM3-M2) | $V\widetilde{m}$ (DM3-DM2) | $V\widetilde{m}$ (DNM3-DM2) | $V\widetilde{r}$ | $V\widetilde{y}$, |
|---|---|---|---|---|---|---|---|
| Mean | 0.010 | 0.007 | 0.012 | 0.012 | 0.327 | 0.010 | 0.007 |
| Median | 0.007 | 0.006 | 0.010 | 0.009 | 0.181 | 0.008 | 0.006 |
| Std. Dev. | 0.010 | 0.005 | 0.008 | 0.008 | 0.377 | 0.008 | 0.005 |
| Skewness | 1.416 | 1.804 | 1.178 | 1.114 | 2.064 | 1.349 | 1.299 |
| Kurtosis | 4.243 | 8.546 | 4.009 | 3.574 | 7.086 | 4.274 | 5.088 |
| JB | 32.321 | 147.774 | 22.185 | 17.889 | 113.921 | 30.082 | 32.881 |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

**Note:** all the variables are in the natural logarithms variance terms. e is a quarterly Rupee/Dollar exchange rate, M3-M2 is the differential between broad money (m3)of India and money stock (M2) of US, NM3-M2 is the differential between New monetary aggregates(NM3) of India and money stock(M2) of US, DM3-DM2 is the differential between Divisia broad money of India and Divisia M2 of US, DNM3 is the differentials Divisia New monetary aggregates of India and Divisia M2 of US, y-y* is the differential between index of industrial production of India and industrial production index of US. r-r* is the differential between monthly weighted average call money rate of India and effective federal fund rates of US.

covariance for monthly data, it is appropriate to include one to four lags of variance or covariance of each variable alternatively in specifications to avoid any autocorrelation in the residuals of regressions. Also, each fundamental variance is inserted in all specifications to capture the contemporaneous effect on exchange rate volatility. The final model specifications are decided based on the best fit in terms of $R^2$ and lower AIC to draw an interpretation. There is a possibility for misleading results with OLS linear regression in terms of inconsistency with theory and statistical insignificance. As per Granger and Newbold (1974), spurious regression is possible due to missing variables. A remedy for it is to include proper lags in the specification.

Thus, to reexamine the relation between variables, other time series methodology ARDL is further applied on the same equation (5.7).

All the variables are either I (0) or I (1) as seen in the unit root test results, ARDL cointegration

**Table 5.2.** Unit root tests

| Variables | ADF | | PP | |
|---|---|---|---|---|
| | Intercept | Intercept and trend | Intercept | Intercept and trend |
| Ve | -7.746*** | -8.206*** | -7.935*** | -8.324*** |
| $V\widetilde{m}$ (M3-M2) | -8.067*** | -8.423*** | -8.241*** | -8.541*** |
| $V\widetilde{m}$ (NM3-M2) | -5.741*** | -5.758*** | -5.741*** | -5.758*** |
| $V\widetilde{m}$ (DM3-DM2) | -5.705*** | -5.676*** | -5.705*** | -5.676*** |
| $V\widetilde{m}$ (DNM3-DM2) | -8.265*** | -8.921*** | -8.617*** | -8.980*** |
| $V\widetilde{y}$, | -6.610*** | -7.390*** | -6.968*** | -7.672*** |
| $V\widetilde{r}$ | -6.133*** | -6.090*** | -9.820*** | -9.755*** |
| $Cov(\widetilde{m}\,\widetilde{y})$ | -8.552*** | -8.502*** | -8.606*** | -8.548*** |
| $Cov(\widetilde{m}\,\widetilde{r})$, | -5.821*** | -5.976*** | -8.410*** | -8.650*** |
| $Cov(\widetilde{m}\,\widetilde{y})$, | -6.099*** | -6.062*** | - 9.782*** | -9.726*** |
| $Cov(\widetilde{m}\,\widetilde{r})$, | -8.226*** | -8.187*** | -8.200*** | -8.156*** |
| $Cov(\widetilde{m}\,\widetilde{y})$, | -8.678*** | -8.697*** | -8.678*** | -8.693*** |
| $Cov(\widetilde{m}\,\widetilde{r})$, | -8.521*** | -8.577*** | -8.524*** | -8.571*** |
| $Cov(\widetilde{m}\,\widetilde{y})$, | -8.272*** | -8.246*** | -8.270*** | -8.244*** |
| $Cov(\widetilde{m}\,\widetilde{r})$, | -7.221*** | -7.244*** | -7.620*** | -7.639*** |
| $Cov(\widetilde{y}\,\widetilde{r})$ | -5.821*** | -5.976*** | -8.410*** | -8.650*** |
| ΔVe | -8.743*** | -8.693*** | -36.976*** | -37.360*** |
| $\Delta V\widetilde{m}$ (M3-M2) | -8.929*** | -8.887*** | -37.929*** | -41.585*** |
| $\Delta V\widetilde{m}$ (NM3-M2) | -13.58709*** | -13.672 | -14.494*** | -14.550*** |
| $\Delta V\widetilde{m}$ (DM3-DM2) | -13.056*** | -13.077*** | -14.915*** | -14.989*** |
| $\Delta V\widetilde{m}$ (DNM3-DM2) | -8.591*** | -8.529*** | -63.637*** | -64.676*** |
| $\Delta V\widetilde{y}$, | -11.146*** | -11.077*** | -19.958*** | -19.789*** |
| $\Delta V\widetilde{r}$ | -19.151*** | -19.028*** | -90.341*** | -92.159*** |
| $\Delta Cov(\widetilde{m}\,\widetilde{y})$ | -9.509*** | -9.449*** | -37.300*** | -37.218*** |
| $\Delta Cov(\widetilde{m}\,\widetilde{r})$, | -19.163*** | -19.040*** | -91.006*** | -92.800*** |
| $\Delta Cov(\widetilde{m}\,\widetilde{y})$, | -9.988*** | -9.919*** | -39.526*** | -39.979*** |
| $\Delta Cov(\widetilde{m}\,\widetilde{r})$, | -7.805*** | -7.786*** | -31.961*** | -33.652*** |
| $\Delta Cov(\widetilde{m}\,\widetilde{y})$, | -9.258*** | -9.244*** | -47.283*** | -48.317*** |
| $\Delta Cov(\widetilde{m}\,\widetilde{r})$, | -7.310*** | -7.280*** | -35.632*** | -36.020*** |
| $\Delta Cov(\widetilde{m}\,\widetilde{y})$, | -11.382*** | -7.244*** | -25.097*** | -24.397*** |
| $\Delta Cov(\widetilde{m}\,\widetilde{r})$, | -8.599*** | -8.540*** | -37.440*** | -36.019*** |
| $\Delta$ $Cov(\widetilde{y}\,\widetilde{r})$ | -8.591*** | 14.594*** | 9.349*** | 14.464*** |

**Note:** ***, *,*,* indicate significance at 5 and 1 % levels, respectively. Cov for variables are given with simple sum and Divisia aggregates separately.

model is employed "to examine the long-run relationship between exchange rate variance and variance-covariance in the fundamentals". In this procedure, ARDL bounds F test is conducted to see the long-run relationship between volatility in the Rupee-Dollar rate and volatility in monetary fundamentals by employing different monetary aggregates alternatively. The results are presented in table 5.4. Further, the error correction model is estimated to see the impact on the exchange rate volatility due to long-run and short-run dynamics. The results of the ARDL bound test are given in table 5.4. They show that exchange rate volatility and volatility-covariance in the fundamentals are cointegrated irrespective of monetary aggregates included as calculated F statistic at lag 6 in the bound test is more than upper bound critical values. It indicates the rejection of the null hypothesis for no cointegration among variables. Therefore, this result suggests that the volatility in monetary fundamentals determine Rupee-Dollar exchange rate volatility. It implies that a central bank can use the monetary policy to curb exchange rate volatility effectively.

The significant difference between the OLS regression and ARDL results is in terms of coefficients' sign and significance. Most long-run coefficients of ARDL results that presented in tables 5.5 and 5.6 are statistically significant, and theoretically righty signed. Except for the volatility equation with Divisia aggregates (DM3-DM2 & DNM3-DM3), coefficients of volatility in the money, output, and interest rate relative to the US are positively associated with the Rupee-Dollar exchange rate volatility as theoretically expected. It is noted here that the OLS regression results compare with the long-run coefficients of the ARDL model. However, our concern is on the ARDL result only because they are promising in terms of significance and signs.

In both results, money coefficients with simple sum aggregate are statically significant at 5 % levels with a positive sign. It indicates the more money in the domestic economy than a foreign

**Table 5.3.** The estimated equation

*$Vs = V\widetilde{m} + \alpha 12\ V\widetilde{y} + \alpha 22\ V\widetilde{r} + 2\ \alpha 2\ Cov(\widetilde{m}\ \widetilde{y}) + 2\ \alpha 2\ Cov(\widetilde{m}\ \widetilde{r}) + 2\ \alpha 2\ Cov(\widetilde{y}\ \widetilde{r})$*

| Exchange rate volatility equation (5.7) with monetary aggregate | | | | | | | |
|---|---|---|---|---|---|---|---|
| M3-M2 | | NM3-M2 | | DM3-DM2 | | DNM3-DM2 | |
| C | -0.004* | C | -0.004** | C | 0.005** | C | -0.003 |
| $V\widetilde{m}$ | 0.757*** | $V\widetilde{m}$ | 0.622*** | $V\widetilde{m}$ | -0.003 | $V\widetilde{m}$ | 0.324 |
| $V\widetilde{y}$ | 0.127 | $V\widetilde{y}$ | 0.113 | $V\widetilde{y}$ | 0.292** | $V\widetilde{y}$ | 0.391*** |
| $V\widetilde{r}$ | 0.005*** | $V\widetilde{r}$ | 0.003 | $V\widetilde{r}$ | -0.007*** | $V\widetilde{r}$ | -0.004 |
| $Cov(\widetilde{m}\ \widetilde{y})$ | -7.238* | $Cov(\widetilde{m}\ \widetilde{y})$ | -3.430 | $Cov(\widetilde{m}\ \widetilde{y})$ | -14.352 | $Cov(\widetilde{m}\ \widetilde{y})$ | -37.487** |
| $Cov(\widetilde{m}\ \widetilde{r})$ | -0.582*** | $Cov(\widetilde{m}\ \widetilde{r})$ | -0.522*** | $Cov(\widetilde{m}\ \widetilde{r})$ | -0.007 | $Cov(\widetilde{m}\ \widetilde{r})$ | -0.733 |
| $Cov(\widetilde{m}\ \widetilde{r})$ | -0.143 | $Cov(\widetilde{m}\ \widetilde{r})$ | -0.053 | $Cov(\widetilde{m}\ \widetilde{r})$ | -0.385 | $Cov(\widetilde{m}\ \widetilde{r})$ | 0.568 |
| $V\widetilde{y}_{t-1}$ | -0.209** | $V\widetilde{y}_{t-1}$ | -0.234** | $V\widetilde{y}_{t-1}$ | -0.320** | $V\widetilde{r}_{t-2}$ | 0.011*** |
| | | $V\widetilde{r}_{t-2}$ | 0.004** | $V\widetilde{r}_{t-2}$ | 0.008** | $e_{t-1}$ | 0.322*** |
| $Cov(\widetilde{m}\ \widetilde{r})_{t-2}$ | -8.327** | $Cov(\widetilde{m}\ \widetilde{r})_{t-2}$ | 0.569*** | $Cov(\widetilde{m}\ \widetilde{r})_{-2}$ | 1.025*** | $e_{t-3}$ | 0.305*** |
| $Cov(\widetilde{y}\ \widetilde{r})$ | 0.440*** | $Cov(\widetilde{y}\ \widetilde{r})$ | -9.621*** | $Cov(\widetilde{y}\ \widetilde{r})$ | 34.458** | | |
| Trend | 0.0001*** | $Cov(\widetilde{m}\ \widetilde{r})_{t-4}$ | 0.357** | | | | |
| Diagnostic statistics | | | | | | | |
| $R^2$ | 0.65 | $R^2$ | 0.67 | $R^2$ | 0.4 | $R^2$ | 0.45 |
| $AdR^2$ | 0.6 | $AdR^2$ | 0.61 | $AdR^2$ | 0.3 | $AdR^2$ | 0.36 |
| DW | 2.15 | DW | 2.17 | DW | 2.15 | DW | 1.89 |
| LM(2) | 0.53 | LM(2) | 0.58 | LM(2) | 1.85 | LM(2) | 1.81 |
| ARCH(2) | 0.43 | ARCH(2) | 0.54 | ARCH(2) | 0.81 | ARCH(2) | 2.1 |

**Note:** ***, **, * indicate 1%,5%,10% level significance level, respectively.
LM test is Breusch-Godfrey serial correlation LM Test. for serial correlation.
ARCH is heteroscedasticity test for heteroscedasticity.
JB is Jarque -Bera test for non-normality distribution of residuals.
Reset is Ramsay's specification test for correct functional form of model.

country leads to more volatility in the exchange rate volatility. Similar results are obtained with Divisia aggregates except in OLS regression results with DNM3-DM2, where the money coefficient has a negative sign. The magnitude of money coefficients is close to one in ARDL model. This indicates symmetry assumption for money coefficients between India and US. Compared to other variables, the magnitude of money impact is higher that is lie between 0.6 to

1.20 region. It means that a larger part of variance in Rupee-Dollar rate volatility is determined by volatility in money.

The income volatility coefficients bear positive sign with both simple sum and Divisia money specifications in the results of OLS regression and ARDL model, with varied magnitude. With Divisia aggregates, income has more impact than that of simple sum aggregates. Probably, it is because of correctly measuring income volatility's impact when Divisia aggregates are added in the model. This means that the volatility in the output in India relative to US leads to a positive volatility in the Rupee-Dollar exchange rate. The effect of income operates on exchange rate volatility in the two ways. One hand, when investment is higher with low interest rate, the growth of domestic output results in higher exports. Thus, there would be higher exchange rate volatility. On the other hand, as output increases with the higher government spending, the resultant higher imports are likely to lead to the depreciation of the domestic currency and more volatility in the exchange rate (Grydaki and Fountas, 2008). Income or output effect depends on the share trade in the total output (Morana, 2009).

**Table 5.4.** ARDL Bound test results

| Exchange rate volatility equation (5.7) with monetary aggregates | I(0) | I(1) | F-stat |
|---|---|---|---|
| M3 –M2 | 2.63 | 3.62 | 4.60** |
| NM3-M2 | 2.63 | 3.62 | 5.00** |
| DM3 –DM2 | 2.63 | 3.62 | 4.33** |
| DNM3-DM2 | 2.63 | 3.62 | 4.19** |

**Note:***,* indicates 5% level of significance at lag 6 as per AIC.

Regarding interest rate impact on exchange rate volatility, two different results are obtained with simple sum and Divisia money in terms of their significance and signs also. However, their impact is meager in magnitude. In ARDL results, the coefficient of interest rate volatility bears positive sign at 5% level of statistical significance with M3-M2, whereas with both Divisia aggregates, it is negative and statistically insignificant. The positive sign of interest rate with simple sum aggregates, as suggested by the findings of Goyal and Arora (2012) indicates that higher gap between Indian call money rate and the federal funds rate induces capital inflows due to more arbitrage opportunities. Finally, one sees a rise in Rupee-Dollar exchange rate volatility. However, the negative coefficient of interest differentials with Divisia aggregates is attributed to higher interest rate volatility backed by higher equity flows associated with good market sentiments. Further, the confidence in Indian economy leads to lesser Rupee-Dollar exchange rate volatility in the context of financial liberalization, market-determined exchange rate, and macroeconomics imbalances (Kohli, 2015).

Alternatively, it is interpreted as effective sterilized central bank intervention to curb exchange rate volatility also leads to the negative association with volatility in exchange rate. Consequently, the more real interest rate relative to US has yielded a negative relation with Rupee-Dollar exchange rate volatility (Pattanaik and Sahoo, 2001; Kohli, 2000). In the context of India, this is further confirmed by Mahanty and Bhanumurty (2014) that offsetting sterilization action by RBI in case of the resultant expansionary money supply due to its intervention has curbed exchange rate volatility. Thus, interest rate volatility reduces the exchange rate volatility. These results also, in particular, suggest that since increased volatility in money, income, and interest rate are associated with more volatility in Rupee-Dollar exchange significantly, monetary and interest rate policies could influence the uncertainty in Rupee-Dollar exchange rate.

Table 5.3 of regression results show that coefficients of lags and covariance are also statistically insignificant, and their impact is negative on exchange volatility with moderated magnitude impact. However, especially in the result of ARDL model, these estimated covariance coefficients are obtained with similar signs for both simple sum and Divisia money that throws some theoretical implications. Coefficients of covariance between money and interest rate, and covariance between money and income are associated negatively with Rupee-Dollar exchange rate volatility, while covariance between income and interest rate are positively related to Rupee-Dollar rate volatility.

The negative coefficients of covariance between money and interest rate indicate that increased interest rate results in reduction of money supply with higher saving and higher demand for domestic money and thereby appreciation exchange rate that lead to lesser volatility. Similarly, the negative coefficients of covariance between money and income suggest that a rise in income leads to more imports. Further, increased domestic demand for money associated with lesser inflation and higher interest rate may result in exchange rate appreciation and lesser exchange rate volatility. On the contrary, the covariance coefficients between interest rate and income signify that increased income with lower interest rate brought by higher money supply or higher government spending causes the depreciation in domestic currency and positive volatility of exchange rate.

Having established long run cointegration, the error correction models are estimated to analyze the short-run changes in exchange rate volatility. In this model, "coefficients of lagged error correction term ($EC_{t-1}$) measures the speed of adjustment of exchange rate volatility to its long-run equilibrium if it deviates from its monetary fundamentals value in the short run". The error correction model results with different monetary aggregates are reported in tables 5.5 and 5.6 of panels (a). They show some of the lagged variance and covariance of monetary fundamentals significantly affect the Rupee-Dollar exchange rate volatility in the short run despite their signs being theoretically unexpected. It indicates the volatility in fundamentals affects exchange rate fluctuations in the short run. The coefficients of $EC_{t-1}$ with the alternative monetary aggregates are statistically significant at 5 % level and their sign negative. This suggests volatility in monetary fundamentals with both simple sum and Divisia aggregates helps to restore exchange rate volatility to its long-run equilibrium value. This also confirms above the long-run relationship between the volatility in Rupee-Dollar rate and volatility for fundamentals. However, the magnitude of the speed of adjustment between simple sum and Divisia aggregates are not identical. $EC_{t-1}$ coefficients with M3-M2 and NM3-M2 are 1.18% and 1.14%, respectively while they are 0.63 % and 0.61 % with DM3-DM2 and DNM3-DM2, respectively. It means that exchange rate volatility adjustment with simple sum aggregates is higher than that adjustment has brought in exchange rate with Divisia aggregates in the following month. Contrary to the previous empirical chapter 3, this result confirms that monetary fundamentals with simple sum money are faster than that of Divisia money in bringing back exchange rate to its long-run equilibrium values in terms of volatility.

Next, for ECMs with different monetary aggregates, a battery of diagnostic tests are applied. The results of them are reported below part of table 5.5 and 5.6. Both the Breusch-Godfrey LM and ARCH tests show that the computed statistics are statistically insignificant at 5 % level, indicating no autocorrelation and heteroscedasticity in the residuals. The statistics of Jara-Barque tests for each specification are statistically significant at 5 % level so that residuals of all models are non-normally distributed. However, it does not affect our estimates because of our larger sample size. The result of Ramsay Reset test, which is done for the validity of the function form of specification, suggests that all model specifications with power functions are not statistically significant at 5 % level. Therefore, it confirms that the functional forms of all models are correctly specified.

**Table 5.5.** The results of ARDL model

| Exchange rate volatility equation (5.7) with *M3-M2* | | Exchange rate volatility equation (5.7) with *NM3-M2* | |
|---|---|---|---|
| (a) Short coefficients and error correction regression | | | |
| Variable | Coefficient | Variable | Coefficient |
| C | -0.007*** | C | -0.007*** |
| $\Delta V\tilde{m}$ | 0.740*** | $\Delta V\tilde{m}$ | 0.689*** |
| $\Delta V\tilde{m}_{t-1}$ | -0.499*** | $\Delta V\tilde{m}_{t-1}$ | -0.549*** |
| $\Delta V\tilde{m}_{t-2}$ | -0.4817*** | $\Delta V\tilde{m}_{t-2}$ | -0.497*** |
| $\Delta V\tilde{m}_{t-3}$ | -0.293*** | $\Delta V\tilde{m}_{t-3}$ | -0.308*** |
| $\Delta Cov(\tilde{y}\,\tilde{r})$ | -0.002 | $\Delta Cov(\tilde{y}\,\tilde{r})$ | 0.039 |
| $\Delta Cov(\tilde{m}\,\tilde{y})$ | -12.486* | $\Delta Cov(\tilde{m}\,\tilde{y})$ | -12.016*** |
| $\Delta Cov(\tilde{m}\,\tilde{y})_{t-1}$ | 8.655*** | $\Delta Cov(\tilde{m}\,\tilde{y})_{t-1}$ | 9.114*** |
| $\Delta Cov(\tilde{m}\,\tilde{r})$ | -0.652*** | $\Delta Cov(\tilde{m}\,\tilde{r})$ | -0.603*** |
| $EC_{t-1}$ | -1.181*** | $EC_{t-1}$ | -1.143*** |
| (*b*) Long run coefficients | | | |
| $V(\tilde{m})$ | 1.096*** | $V(\tilde{m})$ | 1.103*** |
| $V(\tilde{y})$ | 0.228*** | $V\tilde{y}$ | 0.257*** |
| $V\tilde{r}$ | 0.003** | $V\tilde{r}$ | 0.002 |
| $Cov(\tilde{y}\,\tilde{r})$ | 0.464* | $Cov(\tilde{y}\,\tilde{r})$ | 0.706*** |
| $Cov(\tilde{m}\,\tilde{y})$ | -22.567*** | $Cov(\tilde{m}\,\tilde{y})$ | -23.204*** |
| $Cov(\tilde{m}\,\tilde{r})$ | -0.826*** | $Cov(\tilde{m}\,\tilde{r})$ | -0.950*** |
| (c) Statistics and diagnostics | | | |
| $R^2$ | 0.744933 | $R^2$ | 0.73431 |
| $AdR^2$ | 0.71067 | $AdR^2$ | 0.69862 |
| DW | 1.909345 | DW | 1.954113 |
| JB | 5.452* | JB | 6.175** |
| ARCH (3) | 0.526899 | ARCH (3) | 0.345911 |
| BG-LM (1) | 0.073488 | BG LM(1) | 0.04712 |

**Note:*****, **, * indicate 1%,5%,10% level significance level, respectively.
BG-LM test is the Breusch-Godfrey serial correlation LM test.
ARCH is the heteroscedasticity test for heteroscedasticity.
JB is the Jarque-Bera test for non-normality distribution of residuals.
Reset is the Ramsay's specification test for correct functional form of model.

**Table 5.6.** The results of ARDL model

| Exchange rate volatility equation (5.7) with DM3-DM2 | | Exchange rate volatility equation (5.7) with *DNM3-DM2* | |
|---|---|---|---|
| (a) Short coefficients and error correction regression | | | |
| Variable | Coefficient | Variable | Coefficient |
| $\Delta(V\,\tilde{m})$ | 0.097 | $\Delta(V\,\tilde{r})$ | -0.006** |
| $EC_{t-1}$ | -0.637*** | $\Delta(V\,\tilde{r})_{t-1}$ | -0.008*** |
| | | $\Delta Cov(\tilde{y}\,\tilde{r})$ | 0.519* |
| | | $\Delta Cov(\tilde{y}\,\tilde{r})_{t-1}$ | -0.781*** |
| | | $\Delta Cov(\tilde{m}\,\tilde{y})_{t-1}$ | -31.552*** |
| | | $EC_{t-1}$ | -0.614**** |
| (b) Long run coefficients | | | |
| $V\,\tilde{m}$ | 0.764** | $V\,\tilde{m}$ | 0.658* |
| $V\,\tilde{y}$ | 0.612*** | $V\,\tilde{y}$ | 0.636*** |
| $V\,\tilde{r}$ | -0.004 | $V\,\tilde{r}$ | -0.004 |
| $Cov(\tilde{y}\,\tilde{r})$ | 0.298 | $Cov(\tilde{y}\,\tilde{r})$ | 2.340*** |
| $Cov(\tilde{m}\,\tilde{r})$ | -0.315 | $Cov(\tilde{m}\,\tilde{r})$ | -0.488 |
| $Cov(\tilde{m}\,\tilde{y})$ | -22.639 | $Cov(\tilde{m}\,\tilde{y})$ | -80.870** |
| | | C | 0.002 |
| (c) Statistics and diagnostics | | | |
| $R^2$ | 0.354 | $R^2$ | 0.499 |
| $AdR^2$ | 0.346 | $AdR^2$ | 0.459 |
| DW | 2.036 | DW | 1.978 |
| JB | 53.215*** | JB | 6.024** |
| ARCH(3) | 0.140 | ARCH (3) | 1.152 |
| LM(1) | 0.083 | LM(1) | 0.014 |
| RESET | 1.883 | RESET | 4.526**** |

**Note:** ***, **, * indicate 1%, 5%, 10% level significance level, respectively.
BG-LM test is the Breusch-Godfrey serial correlation LM test.
ARCH is the heteroscedasticity test for heteroscedasticity.
JB is the Jarque-Bera test for non-normality distribution of residuals.
RESET is the Ramsay's specification test for correct functional form of model.

Finally, CUSUM and CUSUM of square due to Brown et al. (1975) are applied to see the "stability of coefficients in the long-run relationship between exchange rate volatility and monetary fundamentals volatility". As mentioned in the earlier chapters, these tests are the residuals based, which are conducted on the cumulative sum and cumulative squared sum of recursive residuals on the initial set of n observations. They are updated recursively and are plotted against the breakpoints. If plots of CUSUM and CUSUM of square statistics lie within 5 % level, the estimated coefficients of the model are considered as stable. Results of these tests are shown in the series of plots in figures 5.1 and 5.2. They show that coefficients of the model with simple sum and Divisia aggregates are stable in the CUSUM plots of (a) to (b), which stay in the limit of 5 % significance level band. But the result of CUSUM of square test shows the coefficient of the model with Divisia aggregates as the plot of CUSUM of square has crossed the 5 % significance level band in plots of (g) to (h). By observing the crossing point of bands, it indicates that the estimated coefficients are turned to be unstable at times of crisis such as financial crisis of 2008 and Greece debt crisis of 2012. As discussed in previous chapters, the coefficients of monetary model could be unstable because of the instability of money demand function based on which monetary model is built (Neely and Sarno, 2002).

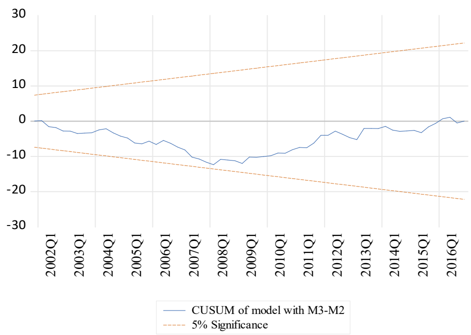
Further, here also one may question the ability of Divisia aggregate in ensuring the stability of money demand function. It is possible that Divisia aggregates may not completely internalize the substitution effect owing to changes in asset holding arising out of financial innovation. This may result in instability of money demand function and thereby the monetary model of exchange rate becomes unstable. The period of this study also includes crisis periods such as financial crisis of 2008 and Greece debt crisis of 2012. These volatile periods may also cause instability in coefficients.

Overall, these results provide evidence for the volatility in macro fundamentals as significant determinants of volatility in Rupee-Dollar exchange rate. Also, these results support the previous chapter results that long-run validity of the MMER for Rupee-Dollar rate i.e., the flexible price monetary model. This result has significant policy implication that a central bank could control exchange rate fluctuations by targeting interest rates or monetary aggregates through its monetary policy. The findings are consistent with the previous studies e.g., Balg and Metcalf (2010) and Grossmann et al. (2014) and Grydaki and Fountas (2010) and Morona (2009) that show macro fundamentals impact the exchange rate volatility. These results also support Divisia aggregates though they have produced little contradictory results that interest rate volatility is associated with lesser exchange rate volatility. However, it indicates that Divisia aggregates are one or other way relevant in capturing the dynamics of exchange rate data.

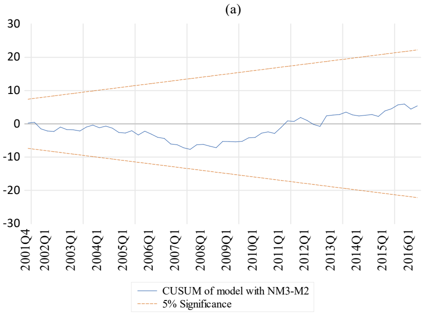
**5.5. The summing up and implications for policy**

This Chapter deals with the relationship between monetary fundamentals and exchange rate in terms of variance or volatility using “simple sum and Divisia money”. Further, it analyzes the significance of simple sum and Divisia money in the long-run relationship between quarterly Rupee-Dollar rate volatility and volatility in monetary fundamentals for the period 1996Q3 to 2016Q4. This analysis also incorporates covariance components among the fundamentals in the volatility equations. Therefore, this chapter contributes to existing literature by including Divisia aggregate and covariance among fundamentals in the exchange rate volatility analysis. To achieve this objective, OLS linear regression and ARDL cointegration methodology are applied. In the results, “it is found a long-run relationship for the Rupee-dollar exchange volatility and volatility in monetary fundamentals that includes either the simple sum or Divisia money”. Further, the results of error corrections analysis shows that more rapid adjustment to its long-run equilibrium of exchange rate volatility is brought by monetary fundamentals with simple sum aggregates compared to Divisia monetary aggregates. Therefore, it is again confirmed evidence in terms of variance that monetary fundamentals determine Rupee-Dollar exchange rate in the long run. It implies that central banks could control exchange rate fluctuations by targeting interest rate or monetary aggregates through its monetary policy. This analysis also again supports Divisia aggregates as a tool to analyze money for the Rupee-Dollar rate movements in the times of financial innovation of India. Hence, this chapter affirms that dynamics of Divisia money cannot be overlooked to capture real liquidity and demand for money function that serves as complimentary money measure to simple sum aggregates. It is better to take Divisia aggregates into consideration in framing of exchange rate and monetary policies more effectively. However, aspects like central bank intervention, capital flows, and structural breaks that arise due to policy changes and crisis are yet to include in this exchange rate volatility analysis that constitute future work.

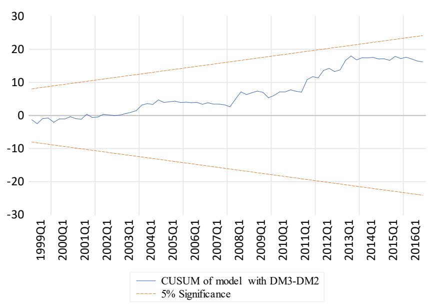
**Figure 5.1** the plots of CUSUM



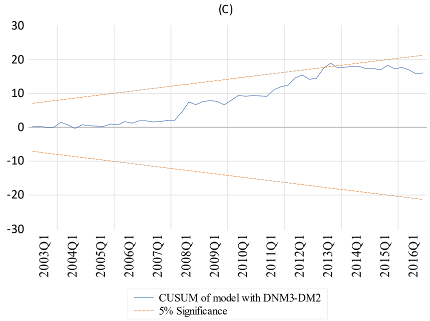

(a)




(b)

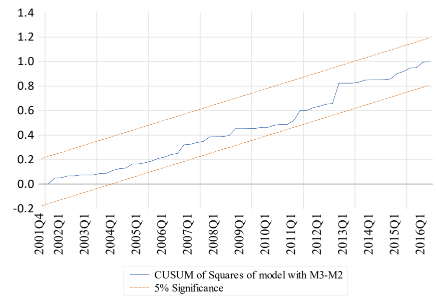



(C)

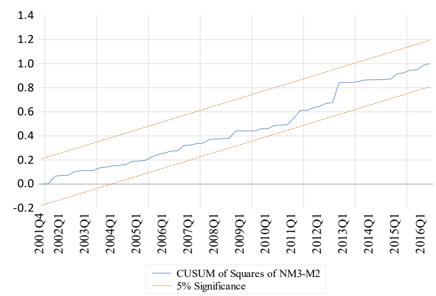



(d)

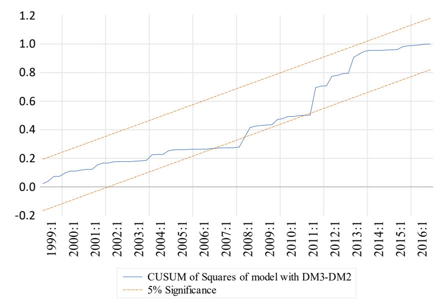
**Figure 5.2** the plots of CUSUSM of Squares



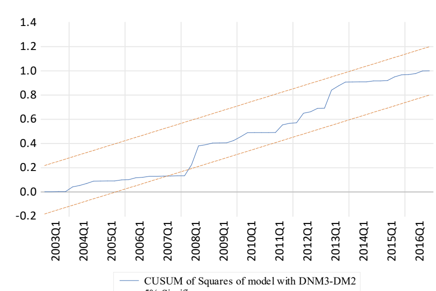

(e)




(f)




(g)




(h)

**Note:** CUSUM indicates the Cumulative Recursive Residuals.

CUSUSM of Squares indicates the Squares of Cumulative Recursive Residuals.

# Chapter 6

## Summary, conclusion, and scope for future research

This thesis set three objectives to examine "the long-run validity of the MMER, its ability to forecast and explain exchange rate volatility". Towards achieving these objectives, alternative monetary aggregates such as simple sum and Divisia money are used alternatively for money in different specifications of the monetary models for the Rupee-Dollar rate. The period of the study pertains to the post-reform era of India. These aggregates impact the demand for money in the monetary models. As a result, it is analyzed whether the exchange rate is explained better with these monetary aggregates. Chapter 1 presents the motivation, research gap, and objectives. The literature is reviewed in chapter 2. Chapters 3, 4, and 5 are devoted to the empirical modeling of the three core objectives of this study. Finally, this chapter summarizes the findings of all chapters, policy implications, and presents limitations of the study. The scope for research in future is also discussed

### 6.1. Summary

- **MMER and its validity in long run**

The first objective focuses on the usefulness of simple sum versus Divisia money in modeling long-run relationships underlying the MMER for the Rupee-Dollar exchange rate. Specifically, this objective is to examine the long relationship among Rupee-Dollar rates, monetary fundamentals such as monetary aggregates, income, and interest rate differentials between India and the US in times of financial innovation in India. Monthly data in post-reform period of India is analyzed spanning over August 1996 to February 2017. The usage of Divisia aggregates for the MMER constitutes a contribution to the literature. Therefore, Divisia aggregates are employed in a set of flexible price monetary models, and the long-run relationship is compared with simple sum aggregates.

Further, by applying the Johansen–Juselius likelihood cointegration test, a long-run cointegration for the monetary model is found, including either the simple sum or Divisia money. However, the estimated coefficients in the cointegrated equations are consistent with the flexible price version when Divisia aggregates are employed. The model with simple sum aggregates is consistent with the sticky price monetary model. The long-run relation between Rupee-Dollar rate and its fundamentals are found to be slightly better with Divisia aggregates compared to simple sum aggregates. Even this is the case with the short-run analysis where a more rapid adjustment to its long-run equilibrium of exchange rate is seen in models with Divisia aggregates compared to their simple sum counterparts. Thus, it is confirmed that the monetary fundamentals are significant determinants of Rupee-Dollar exchange rates because of the long-run relationship among them. This study found a case for Divisia aggregates in the monetary models of exchange rates relative to simple sum aggregates. Therefore, Divisia money could be more useful in holding the flexible price variant in the long run in terms of sign and significance. The findings also suggest that monetary aggregates when calculated appropriately with Divisia formulations, could render stable long run relationships in times of financial innovation and help in monetary policy formulation.

- **The forecasting ability of MMER**

The second objective is to test the forecast accuracy of “the monetary model with Divisia and simple sum monetary aggregates”. Here, various univariate and multivariate models, i.e., ARIMA (p, d, q), GARCH (p, q), VAR in first differences and levels and VEC models are employed using the same monthly data as used in the chapter 3. But the sample is split into the in-sample period August 1996 - February 2015 in which all the coefficients of model are estimated and then estimated coefficients are used in the out-of-sample to forecast monthly Rupee-Dollar exchange rate. The out-of-sample forecasting exercise involves the last 24 observations spanning from March 2015 to February 2017 and forecast errors i.e., RMSE and MAE calculated for 1 to 24 months ahead forecast horizons.

The results show that monetary models irrespective of simple sum and Divisia aggregates outperform simple random walk in out-of-sample forecasting exchange rate over short to longer horizons. Within monetary aggregates, Divisia aggregates are superior in forecasting of Rupee-Dollar exchange rate over simple sum aggregates. However, forecast results are sensitive to the econometric and time series models used. In time series models, VEC provides an improved forecast than that of VAR in first differences and levels. Hence, it indicates the significance of short and long-run dynamics in the modeling and forecasting of the Rupee-Dollar exchange rate. Further, the results suggest that ARIMA model provides a better exchange rate forecast whereas GARCH model performs poorly in the out-of-sample forecasting exercises.

The findings also imply that monetary information flows in the Divisia aggregates could enhance out-of-sample forecast of Rupee-Dollar exchange rate. Thus the evidence is in support of Divisia aggregates as appropriate measures for money demand function in the monetary model, especially during the financial innovation era.

- **Macro fundamentals and exchange rate volatility**

The third objective of the study is to examine the relationship between monetary fundamentals and exchange rate in terms of variance or volatility using simple sum and Divisia money. It analyzes “the significance of simple sum and Divisia aggregates in the long-run relationship between quarterly Rupee-Dollar exchange rate volatility” and volatility in money variables for the period 1996Q3 to 2016Q4. This analysis also incorporates covariance components among fundamentals in exchange rate volatility equations. Therefore, this study contributes to the existing literature by including Divisia aggregate and covariance among fundamentals in the exchange rate volatility analysis. To pursue this objective, OLS linear regression and ARDL cointegration models are applied to volatility equations. The results show a long-run relationship for the Rupee-dollar rate volatility and volatility in monetary fundamentals that includes either the simple sum or Divisia monetary aggregates. The long-run coefficients of monetary fundamentals are positively associated with the exchange rate with both aggregates. However, the coefficient of interest rate differentials is negatively associated with the exchange rate. This may be attributed to the larger interest rate gap between India and US and confidence in the Indian economy, which lowers Rupee-Dollar exchange rate volatility. Further, the results of error corrections analysis show that monetary fundamentals bring rapid adjustment to its long-run equilibrium of exchange rate volatility with conventional aggregates than that Divisia monetary aggregate. Such result contrasts with the results of the previous chapters of this thesis.

Overall, the results again confirm that in terms of variance also, monetary fundamentals determine the Rupee-Dollar rate in the long run. The results also reiterate the usefulness of Divisia aggregates as policy tools to analyze money for the Rupee-Dollar rate movements in the times of financial innovation of India with as much significance as the simple sum aggregates. Hence, one cannot overlook the dynamics of Divisia money in capturing the real liquidity and money demand function in the economy, impacting in turn exchange rate determination.

### 6.2. Policy implications

The policy implications are two-fold. The results confirm that the monetary fundamentals are significant determinants of Rupee-Dollar exchange rates, and in forecasting of rates. The results also explain the volatility in the post-reform period. This implies that monetary policy could be a useful tool to regulate the fluctuations of Rupee-Dollar exchange.

Divisia aggregates explain money demand stability or liquidity conditions better in the economy. Therefore, Divisia aggregates could be complimentary to simple sum monetary aggregates, and their behaviour could be monitored.

### 6.3. Limitations and scope for further research

These results are subject to structural breaks and instabilities in parameters that might arise due to financial crisis and policy changes. This kind of instabilities also arise out of unstable money demand function being the result of inappropriate measurement of aggregates with simple sum aggregates. But the result of CUSUM tests in chapters 3 and 5 also show the monetary models to be unstable even with Divisia aggregates. Therefore, Divisia aggregates may not completely internalize substitution effects owing to the financial innovation in India. Some of the shortcomings or limitations of Divisia aggregates are as follows.

1) Divisia aggregates that measure transaction services may not be accurate. Because transaction services arising from the subjective nature of monetary assets are challenging to extract. Therefore, Divisia aggregates are likely to provide misleading information flows. For example, bank accounts offer investment advice, overdraft facilities, various financial services, i.e., insurance and pensions services, and some transaction services with the use of credit card facilities irrespective of holding of monetary assets. This kind

of transaction services is difficult to count while calculating the Divisia index. Therefore, the Divisia index for money cannot provide an accurate measure of moneyness or information flows on money based on inaccurate measures of transaction services. To such extent Divisia index being incorrect due to incorrect transaction services; it is likely to not have a stable relationship with macroeconomic variables.

2) Market interest cannot represent all transaction services on which Divisia aggregate is constructed because the Divisia index uses the user cost for transaction service provided by an asset with the observed interest rate. But in practice, as the more competitive banking system and financial markets, prevailing market interest rates are less reflection of the shadow price of transaction services of the assets. The change in the degree of competition leads to changes in the interest rate that hardly gets reflected in the market interest rate. Explicit charges charged by banks on financial services that are of supply-side nature are not counted in the market interest rates. A few transaction services are delivered to the individuals for having a bank account. Such externalities are produced due to the wider acceptability of bank cheques in the banking network. Consequently, market interest rates fail to observe the full shadow prices of the prices of externalities. Further, the Divisia index is built on the assumption that double transaction service accrued with the double on components money to hold. However, banks provide transaction services without user cost to agents due to new technology innovations such as ATM and credit card services whether double the money holding in the bank account or not. This leads to further error in the Divisia index to count transaction service. Hence, this implies that the Divisia index is yet to overcome the challenges posed by financial innovation to measure money flows appropriately.

3) Divisia approach assumes that all assets are adjusted at their desired values and there is no further room for adjustment costs and measurement errors since allocation portfolio reallocation is carried based on the effective user cost. This is believed to reflect appropriate prices. But in practice, economics agents adjust their asset portfolio holdings with respect to relative interest rates between different types of deposit.
4) Benchmark asset should be the non-monetary asset that does not have any secondary market to calculate relative return for monetary assets in the Divisia index. Such kinds of non-monetary assets are seldom to find out in the developed financial market. Further, the Divisia index flaws for having the same benchmark asset in the different periods when the relative return on alternative benchmark assets changes over time.
5) Divisia aggregates reflect misleading indictor for at least short period as there is an immediate change in the weights on the components before any portfolio changes ensue. Thus, Divisia aggregates do not have equilibrium weights as long as portfolio shift are instant.

Further, the analysis of exchange rate volatility has not considered many aspects. Hence, the investigation of these aspects by including elements like structural breaks and time-varying parameters, central bank intervention, and capital flows are left for further research. Even extending these results to exchange rates of Rupee other than US Dollar also constitute potential future research work in this area.

### 6.4. Concluding remarks

Central banks of many developed countries such as “Bank of England, Federal Reserve Bank of St.Louis, National Bank of Poland, and the Bank of Israel, European Central Bank, the Bank of

Japan" monitor the Divisia aggregates from time to time to analyze the monetary conditions through publishing data. They all use insights from real monetary information flows to aid monetary policy. Most developing countries have undergone through economic reforms and liberalisation and thereby leading financial innovation. Thus, it is time for developing countries to recognize the importance of Divisia money in policymaking and publish data on Divisia aggregates. Specifically, India could benefit by monitoring and employing Divisia aggregates for monetary and exchange rate policies.

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# Modelling Rupee-Dollar exchange rate using the monetary approach: some issues and evidence

*by* Topunuru Kaladhar

# Modelling Rupee-Dollar exchange rate using the monetary approach: some issues and evidence

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Manuscript ID IJFE-20-0919 entitled *"Modelling Rupee-Dollar exchange rate using the monetary approach in the times of financial innovation: does measurement of money matter?*" which is submitted to *International Journal of Finance and Economics*, has been reviewed. This publication is the part of third chapter of thesis and coauthored with my supervisor Dr. Debashis Acharya, School of Economics, University of Hyderabad. This is under revision at present.

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