Development Research Group

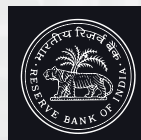# EXCHANGE RATE POLICY AND MODELLING IN INDIA

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CONTENTS

EXCHANGE RATE POLICY AND MODELLING IN INDIA

ABBREVIATIONS

VAR	Vector Autoregressive
BVAR	Bayesian vector autoregressive
ADs	Authorised Dealers
FERA	Foreign Exchange Regulations Act
LERMS	Liberalized Exchange Rate Management System
FEMA	Foreign Exchange Management Act
CCIL	Clearing Corporation of India Limited
MSS	Market Stabilisation Scheme
KYC	Know-Your-Customer
ECB	External Commercial Borrowings
FEDAI	Foreign Exchange Dealers' Association of India
CCIL	Clearing Corporation of India Ltd.
MCX-SX	Multi Commodity Exchange – Stock Exchange
RMDS	Reuters Market Data System
OTC	Over The Counter
BIS	Bank for International Settlements
IOC	Indian Oil Corporation
NDF	Non Deliverable Forward
EMEs	Emerging Market Economies
FIIs	Foreign Institutional Investors'

FDI	Foreign Direct Investment
LAF	Liquidity Adjustment Facility
OMO	Open Market Operations
MSS	Market Stabilisation Scheme
FCA	Foreign Currency Assets
PPP	Purchasing Power Parity
PBM	Portfolio Balance Model
VECM	Vector Error Correction Model
MSIH	Markov Switching Intercept Heteroscedastic
RMSE	Root Mean Square Error

Executive Summary

The exchange rate is a key financial variable that affects decisions made by foreign exchange investors, exporters, importers, bankers, businesses, financial institutions, policymakers and tourists in the developed as well as developing world. Exchange rate fluctuations affect the value of international investment portfolios, competitiveness of exports and imports, value of international reserves, currency value of debt payments, and the cost to tourists in terms of the value of their currency. Movements in exchange rates thus have important implications for the economy's business cycle, trade and capital flows and are therefore crucial for understanding financial developments and changes in economic policy.

The study covers two main topics: first, various aspects of economic policy with respect to the exchange rate, and second, modeling and forecasting the exchange rate. Accordingly, the study analyses India's exchange rate story and discusses the structure of the foreign exchange market in India in terms of participants, instruments and trading platform as also turnover in the Indian foreign exchange market and forward premia. The Indian foreign exchange market has evolved over time as a deep, liquid and efficient market as against a highly regulated market prior to the 1990s. The market participants have become sophisticated, the range of instruments available for trading has increased, the turnover has also increased, while the bid–ask spreads have declined. This study also covers the exchange rate policy of India in the background of large capital flows,

The study then attempts to develop a model for the rupee-dollar exchange rate taking into account variables from monetary and micro structure models as well as other variables including intervention by the central bank. The focus is on the exchange rate of the Indian rupee vis-à-vis the US dollar, i.e., the Re/$ rate. To model the exchange rate, the monetary model is expanded to include variables that may have been important in determining exchange rate movements in India such as forward premia, capital flows, order flows and central bank intervention.

Exchange Rates and Exchange Rate Policy in India: A Review

India's exchange rate policy has evolved over time in line with the gradual opening up of the economy as part of the broader strategy of macroeconomic reforms and liberalization since the early 1990s. In the post independence period, India's exchange rate policy has seen a shift from a *par value system* to a *basket-peg* and further to a *managed float* exchange rate system. With the breakdown of the Bretton Woods System in 1971, the rupee was linked with pound sterling. In order to overcome the weaknesses associated with a single currency peg and to ensure stability of the exchange rate, the rupee, with effect from September 1975, was pegged to a basket of currencies till the early 1990s.

The initiation of economic reforms saw, among other measures, a two step downward exchange rate adjustment by 9 per cent and 11 per cent between July 1 and 3, 1991 to counter the massive draw down in the foreign exchange reserves, to install confidence in the investors and to improve domestic competitiveness. The Liberalised Exchange Rate Management System (LERMS) was put in place in March 1992 involving the dual exchange rate system in the interim period. The dual exchange rate system was replaced by a unified exchange rate system in March 1993. The experience with a market determined exchange rate system in India since 1993 is generally described as 'satisfactory' as orderliness prevailed in the Indian market during most of the period. Episodes of volatility were effectively managed through timely monetary and administrative measures.

An important aspect of the policy response in India to the various episodes of volatility has been market intervention combined with monetary and administrative measures to meet the threats to financial stability while complementary or parallel recourse has been taken to communications through speeches and press releases. In line with the exchange rate policy, it has also been observed that the Indian rupee is moving along with the economic fundamentals in the post-reform period. Moving forward, as India progresses towards full capital account convertibility and gets more and more integrated with the rest of the world, managing periods of volatility is

bound to pose greater challenges in view of the impossible trinity of independent monetary policy, open capital account and exchange rate management. Preserving stability in the market would require more flexibility, adaptability and innovations with regard to the strategy for liquidity management as well as exchange rate management. With the likely turnover in the foreign exchange market rising in future, further development of the foreign exchange market will be crucial to manage the associated risks.

Structure of the Indian Foreign Exchange Market and Turnover

Prior to the 1990s, the Indian foreign exchange market (with a pegged exchange rate regime) was highly regulated with restrictions on transactions, participants and use of instruments. The period since the early 1990s has witnessed a wide range of regulatory and institutional reforms resulting in substantial development of the rupee exchange market as it is observed today. Market participants have become sophisticated and have acquired reasonable expertise in using various instruments and managing risks.

The foreign exchange market in India today is equipped with several derivative instruments. Various informal forms of derivatives contracts have existed since time immemorial though the formal introduction of a variety of instruments in the foreign exchange derivatives market started only in the post reform period, especially since the mid-1990s. These derivative instruments have been cautiously introduced as part of the reforms in a phased manner, both for product diversity and more importantly as a risk management tool. Recognising the relatively nascent stage of the foreign exchange market then with the lack of capabilities to handle massive speculation, the 'underlying exposure' criteria had been imposed as a prerequisite.

Trading volumes in the Indian foreign exchange market has grown significantly over the last few years. The daily average turnover has seen almost a ten-fold rise during the 10 year period from 1997-98 to 2007-08 from US $ 5 billion to US $ 48 billion. The pickup has been particularly

sharp from 2003-04 onwards since when there was a massive surge in capital inflows. It is noteworthy that the increase in foreign exchange market turnover in India between April 2004 and April 2007 was the highest amongst the 54 countries covered in the latest Triennial Central Bank Survey of Foreign Exchange and Derivatives Market Activity conducted by the Bank for International Settlements (BIS). According to the survey, daily average turnover in India jumped almost 5-fold from US $ 7 billion in April 2004 to US $ 34 billion in April 2007; global turnover over the same period rose by only 66 per cent from US $ 2.4 trillion to US $ 4.0 trillion. Reflecting these trends, the share of India in global foreign exchange market turnover trebled from 0.3 per cent in April 2004 to 0.9 per cent in April 2007. With the increasing integration of the Indian economy with the rest of the world, the efficiency in the foreign exchange market has improved as evident from low bid-ask spreads. It is found that the spread is almost flat and very low. In India, the normal spot market quote has a spread of 0.25 paisa to 1 paise while swap quotes are available at 1 to 2 paise spread. Thus, the foreign exchange market has evolved over time as a deep, liquid and efficient market as against a highly regulated market prior to the 1990s.

Capital Flows and Exchange Rates: The Indian Experience

In the recent period, external sector developments in India have been marked by strong capital flows, which had led to an appreciating tendency in the exchange rate of the Indian rupee up to January 2008. The movement of the Indian rupee is largely influenced by the capital flow movements rather than traditional determinants like trade flows. Though capital flows are generally seen to be beneficial to an economy, a large surge in flows over a short span of time in excess of the domestic absorptive capacity can, however, be a source of stress to the economy giving rise to upward pressures on the exchange rate, overheating of the economy, and possible asset price bubbles.

In India, the liquidity impact of large capital inflows was traditionally managed mainly through the repo and reverse repo auctions under the

day-to-day Liquidity Adjustment Facility (LAF). The LAF operations were supplemented by outright open market operations (OMO), i.e. outright sales of the government securities, to absorb liquidity on an enduring basis. In addition to LAF and OMO, excess liquidity from the financial system was also absorbed through the building up of surplus balances of the Government with the Reserve Bank, particularly by raising the notified amount of 91-day Treasury Bill auctions, and forex swaps. In view of the large capital flows during the past few years, relaxations were effected in regard to outflows, both under the current and capital accounts. In addition, changes in policies are made from time to time to modulate the debt-creating capital flows depending on the financing needs of the corporate sector and vulnerability of the domestic economy to external shocks.

In the face of large capital flows coupled with declining stock of government securities, the Reserve Bank of India introduced a new instrument of sterilisation, viz., the Market Stabilisation Scheme (MSS) to sustain market operations. Since its introduction in April 2004, the MSS has served as a very useful instrument for medium term monetary and liquidity management. The cost of sterilisation in India is shared by the Central Government (the cost of MSS), Reserve Bank (sterilization under LAF) and the banking system (in case of increase in the reserve requirements).

With the surge in capital flows to EMEs, issues relating to management of those flows have assumed importance as they have bearings on the exchange rates. Large capital inflows create important challenges for policymakers because of their potential to generate overheating, loss of competitiveness, and increased vulnerability to crisis. Reflecting these concerns, policies in EMEs have responded to capital inflows in a variety of ways. While some countries have allowed the exchange rate to appreciate, in many cases monetary authorities have intervened heavily in forex markets to resist currency appreciation. EMEs have sought to neutralize the monetary impact of intervention through sterilization. Cross-country experiences reveal that in the recent period most of the EMEs have adopted a more flexible exchange rate regime.

In view of the importance of capital flows, foreign exchange intervention and turnover in determination of exchange rates, these variables are included in the modeling exercise undertaken to analyze the behaviour of the exchange rate.

Modelling and Forecasting the Re/$ Exchange Rate: Economic Theory and Review of Literature

In the international finance literature, various theoretical models are available to analyze exchange rate determination and behaviour. Most of the studies on exchange rate models prior to the 1970s were based on the fixed price assumption[1]. With the advent of the floating exchange rate regime amongst major industrialized countries in the early 1970s, an important advance was made with the development of the monetary approach to exchange rate determination. The dominant model was the flexible-price monetary model that has been analyzed in many early studies like Frenkel (1976), Mussa (1976, 1979), Frenkel and Johnson (1978), and more recently by Vitek (2005), Nwafor (2006), Molodtsova and Papell, (2007). Following this, the sticky price or overshooting model by Dornbusch (1976, 1980) evolved, which has been tested, amongst others, by Alquist and Chinn (2008) and Zita and Gupta (2007). The portfolio balance model also developed alongside[2], which allowed for imperfect substitutability between domestic and foreign assets, and considered wealth effects of current account imbalances.

With liberalization and development of foreign exchange and assets markets, variables such as capital flows, volatility in capital flows and forward premium have also became important in determining exchange rates. Furthermore, with the growing development of foreign exchange markets and a rise in the trading volume in these markets, the micro level dynamics in foreign exchange markets increasingly became important in

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[1] See e.g. Marshall (1923), Lerner (1936), Nurkse (1944), Harberger (1950), Mundell (1961, 1962, 1963) and Fleming (1962).

[2] See e.g. Dornbusch and Fischer (1980), Isard (1980), Branson (1983, 1984).

determining exchange rates. Agents in the foreign exchange market have access to private information about fundamentals or liquidity, which is reflected in the buying/selling transactions they undertake, that are termed as order flows (Medeiros, 2005; Bjonnes and Rime, 2003). Microstructure theory evolved in order to capture the micro level dynamics in the foreign exchange market (Evans and Lyons, 2001, 2005, 2007). Another variable that is important in determining exchange rates is central bank intervention in the foreign exchange market.

Non-linear models have also been considered in the literature. Sarno (2003), Altaville and Grauwe (2006) are some of the recent studies that have used non-linear models of the exchange rate.

Overall, forecasting the exchange rates has remained a challenge for both academicians as well as market participants. In fact, Meese and Rogoff's seminal study (1983) on the forecasting performance of the monetary models demonstrated that these failed to beat the random walk model. This has triggered a plethora of studies that test the superiority of theoretical and empirical models of exchange rate determination *vis-a-vis* a random walk.

In sum, several exchange rate models available in the literature have been tested during the last two and a half decades. No particular model seems to work best at all times/horizons. Monetary models based on the idea of fundamentals' driven exchange rate behaviour work best in the long-run, but lose their predictability in the short-run to naïve random walk forecasts. The volatility of exchange rates also substantially exceeds that of the volatility of macroeconomic fundamentals, thus providing further evidence of weakening fundamental-exchange rate link. A combination of the different monetary models, however, at times gives better results than the random walk. Order flows also play an important role in influencing the exchange rate. Keeping in view all the above results of the literature, this study attempts to develop a model for the rupee-dollar exchange rate taking into account all the different monetary models along with the microstructure models incorporating order flow, as well as capital flows, forward premium and central bank intervention.

Modelling and Forecasting the Exchange Rate: Econometric Methodology, Estimation, Evaluation and Findings

This study attempts to gauge the forecasting ability of economic models with respect to exchange rates with the difference that this is done in the context of a developing country that follows a managed floating (as opposed to flexible) exchange rate regime. Starting from the naïve model, this study examines the forecasting performance of the monetary model and various extensions of it in the vector autoregressive (VAR) and Bayesian vector autoregressive (BVAR) framework. Extensions of the monetary model considered in this study include the forward premium, capital inflows, volatility of capital flows, order flows and central bank intervention. The study therefore examines, first, whether the monetary model can beat a random walk. Second, it investigates if the forecasting performance of the monetary model can be improved by extending it. Third, the study evaluates the forecasting performance of a VAR model vs a BVAR model. Lastly, it considers if information on intervention by the central bank can improve forecast accuracy. The main findings are as follows:

(i)   The monetary model generally outperforms the naïve model. This negates the findings of the seminal study by Meese and Rogoff (1983) that finds that models which are based on economic fundamentals cannot outperform a naive random walk model.

(ii) The result that it is possible to beat the naïve model may be due to the fact that the intervention by the central bank may help to curb volatility arising due to demand-supply mismatch and stabilize the exchange rate. The exchange rate policy of the RBI is guided by the need to reduce excess volatility. The Reserve Bank has been prepared to make sales and purchases of foreign currency in order to even out lumpy demand and supply in the relatively thin foreign exchange market and to smoothen jerky movements.

(iii) Forecast accuracy can be improved by extending the monetary model to include forward premium, volatility of capital inflows and order flow.

(iv) Information on intervention by the central bank helps to improve forecasts at the longer end.

(v) Bayesian vector autoregressive models generally outperform their corresponding VAR variants.

(vi) Turning points are difficult to predict as illustrated using Model 4 with predictions made in February 2008.

Thus, availability of information on certain key variables at regular intervals that affect the exchange rate can lead to a more informed view about the behavior of the future exchange rates by the market participants, which may allow them to plan their foreign exchange exposure better by hedging them appropriately. Such key variables could include past data on exchange rates, forward premia, capital flows, turnover, and intervention by central banks etc. As regards availability of data on key variables relating to the Indian foreign exchange market, most of the data are available in public domain and can easily be accessed by market participants, academicians and professional researchers. Using these variables skillfully will help them to gain sound insight into future exchange rate movements.

In this context, it is important to recognize that the Indian approach in recent years has been guided by the broad principles of careful monitoring and management of exchange rates with flexibility, without a fixed target or a pre-announced target or a band, coupled with the ability to intervene if and when necessary, while allowing the underlying demand and supply conditions to determine the exchange rate movements over a period in an orderly way. Subject to this predominant objective, the exchange rate policy is guided by the need to reduce excess volatility, prevent the emergence of establishing speculative activities, help maintain adequate level of reserves, and develop an orderly foreign exchange market.

EXCHANGE RATE POLICY AND MODELLING IN INDIA

Pami Dua, Rajiv Ranjan*

SECTION I

Introduction

The exchange rate is a key financial variable that affects decisions made by foreign exchange investors, exporters, importers, bankers, businesses, financial institutions, policymakers and tourists in the developed as well as developing world. Exchange rate fluctuations affect the value of international investment portfolios, competitiveness of exports and imports, value of international reserves, currency value of debt payments, and the cost to tourists in terms of the value of their currency. Movements in exchange rates thus have important implications for the economy's business cycle, trade and capital flows and are therefore crucial for understanding financial developments and changes in economic policy. Timely forecasts of exchange rates can therefore provide valuable information to decision makers and participants in the spheres of international finance, trade and policy making. Nevertheless, the empirical literature is skeptical about the possibility of accurately predicting exchange rates.

In the international finance literature, various theoretical models are available to analyze exchange rate behaviour. While exchange rate models existed prior to 1970s (Nurkse, 1944; Mundell, 1961, 1962, 1963), most of them were based on the fixed price assumption. With the advent of the floating exchange rate regime amongst major industrialized countries in the early 1970s, a major advance was made with the development of the monetary approach to the exchange rate determination. The dominant model was the flexible price monetary model that gave way to the sticky price and portfolio balance model. While considerable amount of empirical work was devoted to testing these monetary models, most of them focused on in-sample tests that do not really give the true predictive accuracy of the models. Following this, the sticky price or overshooting model by Dornbusch (1976, 1980)

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evolved, which has been tested, amongst others, by Alquist and Chinn (2008) and Zita and Gupta (2007). The portfolio balance model also developed alongside, which allowed for imperfect substitutability between domestic and foreign assets, and considered wealth effects of current account imbalances.

With liberalization and development of foreign exchange and assets markets, variables such as capital flows, volatility in capital flows and forward premium have also became important in determining exchange rates. Furthermore, with the growing development of foreign exchange markets and a rise in the trading volume in these markets, the micro level dynamics in foreign exchange markets have increasingly became important in determining exchange rates. Agents in the foreign exchange market have access to private information about fundamentals or liquidity, which is reflected in the buying/selling transactions they undertake, that are termed as order flows (Medeiros, 2005; Bjonnes and Rime 2003). Thus microstructure theory evolved in order to capture the micro level dynamics in the foreign exchange market (Evans and Lyons, 2001, 2005, 2007). Another variable that is important in determining exchange rates is central bank intervention in the foreign exchange market.

Non-linear models have also been considered in the literature. Sarno (2003), Altaville and Grauwe (2006) are some of the recent studies that have used non-linear models of the exchange rate.

This study attempts to develop a model for the rupee-dollar exchange rate taking into account the different monetary models along with the micro structure models incorporating order flow as well as other variables including intervention by the central bank. The focus is on the exchange rate of the Indian rupee vis-à-vis the US dollar, i.e., the Re/$ rate.

India has been operating on a managed floating exchange rate regime from March 1993, marking the start of an era of a market determined exchange rate regime of the rupee with provision for timely intervention

by the central bank[1]. India's exchange rate policy has evolved overtime in line with the global situation and as a consequence to domestic developments. 1991-92 represents a major break in policy when India harped on reform measures following the balance of payments crisis and shifted to a market determined exchange rate system. As has been the experience with the exchange rate regimes the world over, the Reserve Bank as the central bank of the country has been actively participating in the market dynamics with a view to signaling its stance and maintaining orderly conditions in the foreign exchange market. The broad principles that have guided India's exchange rate management have been periodically articulated in the various Monetary Policy Statements. These include careful monitoring and management of exchange rates with flexibility, no fixed target or a pre-announced target or a band and ability to intervene, if and when necessary. Based on the preparedness of the foreign exchange market and India's position on the external front (in terms of reserves, debt, current account deficit etc), reform measures have been progressively undertaken to have a liberalized exchange and payments system for current and capital account transactions and further to develop the foreign exchange market.

This study covers two main topics: first, various aspects of economic policy with respect to the exchange rate, second, modelling and forecasting the exchang rate. Accordingly, this study analyses India's exchange rate story, with particular focus on the policy responses during difficult times and the reforms undertaken to develop the rupee exchange market during relatively stable times. This study also discusses the structure of the foreign exchange market in India in terms of participants, instruments and trading platform as also turnover in the Indian foreign exchange

[1] The exchange rate regime up to 1990 was an adjustable nominal peg to a basket of currencies of major trading partners with a band. In the early 1990s, India was faced with a severe balance of payment crisis due to the significant rise in oil prices, the suspension of remittances from the Gulf region and several other exogenous developments. Amongst the several measures taken to tide over the crisis was a devaluation of the rupee in July 1991 to maintain the competitiveness of Indian exports. This initiated the move towards greater exchange rate flexibility. After a transitional 11-month period of dual exchange rates, a market determined exchange rate was established in March 1993. The current exchange rate policy relies on the underlying demand and supply factors to determine the exchange rate with continuous monitoring and management by the central bank.

market and forward premia. The Indian foreign exchange market has evolved over time as a deep, liquid and efficient market as against a highly regulated market prior to the 1990s. The market participants have become sophisticated, the range of instruments available for trading has increased, the turnover has also increased, while the bid–ask spreads have declined. This study also covers the exchange rate policy of India in the background of large capital flows, in terms of their magnitude, composition and management. In the recent period, up to 2007-08, external sector developments in India have been marked by strong capital inflows. Capital flows to India, which were earlier mainly confined to small official concessional finance, gained momentum from the 1990s after the initiation of economic reforms.

After studying the analytics of foreign exchange market and the factors affecting the exchange rate in the first part of the study (Sections II, III and IV), this study then in the second part attempts to gauge the forecasting ability of economic models with respect to exchange rates in the context of a developing country that follows a managed floating (as opposed to flexible) exchange rate regime. Starting from the naïve model, this study examines the forecasting performance of the monetary model and various extensions of it in the vector autoregressive (VAR) and Bayesian vector autoregressive (BVAR) framework. Extensions of the monetary model considered in this study include the forward premium, capital inflows, volatility of capital flows, order flows and central bank intervention. The study therefore examines, first, whether the monetary model can beat a random walk. Second, it investigates if the forecasting performance of the monetary model can be improved by extending it. Third, the study evaluates the forecasting performance of a VAR model versus a BVAR model. Lastly, it considers if information on intervention by the central bank can improve forecast accuracy.

This study concentrates on the post March 1993 period and provides insights into forecasting exchange rates for developing countries where the central bank intervenes periodically in the foreign exchange market. The alternative forecasting models are estimated using monthly data from

Exchange Rate Policy and Modelling in India

July 1996[2] to December 2006 while out-of-sample forecasting performance is evaluated from January 2007 to June 2008. This study negates the finding of the seminal Study by Meese and Rogoff (1983) that models which are based on economic fundamentals cannot outperform a naive random walk model.

Against this backdrop, Section II of this study presents a review of exchange rates and exchange rate policy in India during different phases. In Section III, the structure of the foreign exchange market in India, turnover and forward premia are discussed in detail. This is followed by a discussion on capital flows and the foreign exchange market in Section IV. The economic theory and review of literature are covered in Section V, while the econometric methodology is discussed in Section VI. The estimation and evaluation of forecasting models is done in Section VII. The last Section VIII presents some concluding observations.

SECTION II

Exchange Rates and Exchange Rate Policy in India: A Review

India's exchange rate policy has evolved over time in line with the gradual opening up of the economy as part of the broader strategy of macroeconomic reforms and liberalization since the early 1990s. This change was also warranted by the consensus response of all major countries to excessive exchange rate fluctuations that accompanied the abolishment of fixed exchange rate system. The major changes in the exchange rate policy started with the implementation of the recommendations of the High Level Committee on Balance of Payments (Chairman: Dr. C. Rangarajan, 1993) to make the exchange rate market-determined. The Expert Group on Foreign Exchange Markets in India (popularly known as Sodhani Committee, 1995) made several recommendations with respect to participants, trading, risk management

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[2]   The starting period is based on availability of data for all series.

as well as selective market intervention by the Reserve Bank to promote greater market development in an orderly fashion. Consequently, the period starting from January 1996 saw wide-ranging reforms in the Indian foreign exchange market. In essence, the exchange rate developments changed in side-by-side with the reform in the external sector of India.

With the external sector reform, India stands considerably integrated with the rest of the world today in terms of increasing openness of the economy. As a result of calibrated and gradual capital account openness, the financial markets, particularly forex market, in India have also become increasingly integrated with the global network since 2003-04. This is reflected in the extent and magnitude of capital that has flown to India in recent years. Exchange rates exhibited considerable volatility and increased capital mobility has posed several challenges before the monetary authorities in managing exchange rates.

Against this backdrop, the following section analyses in retrospect India's exchange rate story, with particular focus on the policy responses during difficult times and the reforms undertaken to develop the rupee exchange market during relatively stable times.

1. Chronology of Reform Measures

In the post independence period, India's exchange rate policy has seen a shift from a *par value system* to a *basket-peg* and further to a *managed float* exchange rate system. During the period 1947 till 1971, India followed the par value system of the exchange rate whereby the rupee's external par value was fixed at 4.15 grains of fine gold. The RBI maintained the par value of the rupee within the permitted margin of ±1% using pound sterling as the intervention currency. The devaluation of the rupee in September 1949 and June 1966 in terms of gold resulted in the reduction of the par value of rupee in terms of gold to 2.88 and 1.83 grains of fine gold, respectively. Since 1966, the exchange rate of the rupee remained constant till 1971 (Chart 2.1).

Chart 2.1: History of rupee dollar exchange rate

Per cent of GDP

Par value

Basket peg

Market determined
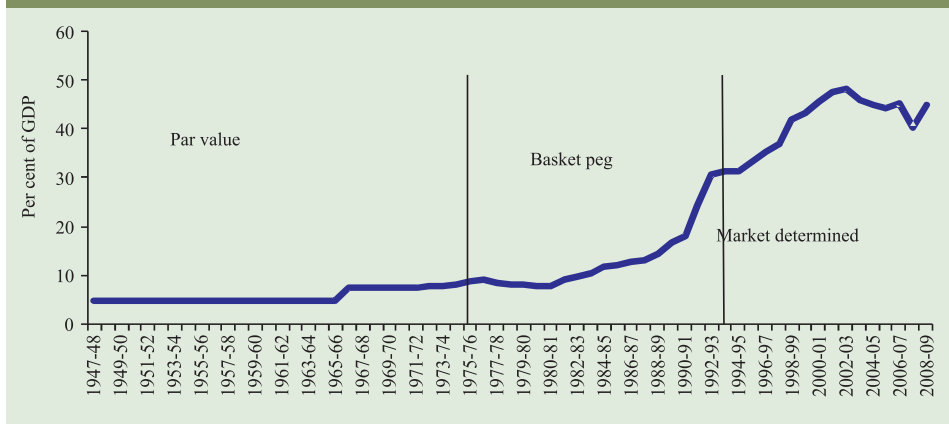
With the breakdown of the Bretton Woods System, in December 1971, the rupee was linked with pound sterling. Sterling being fixed in terms of US dollar under the Smithsonian Agreement of 1971, the rupee also remained stable against dollar. In order to overcome the weaknesses associated with a single currency peg and to ensure stability of the exchange rate, the rupee, with effect from September 1975, was pegged to a basket of currencies (Table 2.1). The currencies included in the basket as well as their relative weights were kept confidential by the Reserve Bank to discourage speculation.

By the late 'eighties and the early 'nineties, it was recognised that both macroeconomic policy and structural factors had contributed to balance of payment difficulties. The current account deficit widened to 3.0 per cent of GDP in 1990-91 and the foreign currency assets depleted to less than a billion dollar by July 1991. It was against this backdrop that India embarked on stabilisation and structural reforms to generate impulses for growth.

Table 2.1: Chronology of the Indian Exchange Rate	
Year	**The Foreign Exchange Market and Exchange Rate**
1947-1971	Par Value system of exchange rate. Rupee's external par value was fixed in terms of gold with the pound sterling as the intervention currency.
1971	Breakdown of the Bretton-Woods system and floatation of major currencies. Rupee was linked to the pound sterling in December 1971.
1975	To ensure stability of the Rupee, and avoid the weaknesses associated with a single currency peg, the Rupee was pegged to a basket of currencies. Currency selection and weight assignment was left to the discretion of the RBI and not publicly announced.
1978	RBI allowed the domestic banks to undertake intra-day trading in foreign exchange.
1978-1992	Banks began to start quoting two-way prices against the Rupee as well as in other currencies. As trading volumes increased, the 'Guidelines for Internal Control over Foreign Exchange Business' were framed in 1981. The foreign exchange market was still highly regulated with several restrictions on external transactions, entry barriers and transactions costs. Foreign exchange transactions were controlled through the Foreign Exchange Regulations Act (FERA). These restrictions resulted in an extremely efficient unofficial parallel (*hawala*) market for foreign exchange.
1990-1991	Balance of Payments crisis
July 1991	To stabilize the foreign exchange market, a two step downward exchange rate adjustment was done (9% and 11%). This was a decisive end to the pegged exchange rate regime.
March 1992	To ease the transition to a market determined exchange rate system, the Liberalized Exchange Rate Management System (LERMS) was put in place, which used a dual exchange rate system. This was mostly a transitional system.
March 1993	The dual rates converged, and the market determined exchange rate regime was introduced. All foreign exchange receipts could now be converted at market determined exchange rates.

Source: Reserve Bank of India

The Report of the High Level Committee on Balance of Payments (Chairman Dr. C. Rangarajan) laid the framework for a credible macroeconomic, structural and stabilisation programme encompassing trade, industry, foreign investment, exchange rate and the foreign

exchange reserves. With regard to the exchange rate policy, the committee recommended that consideration be given to (i) a realistic exchange rate, (ii) avoiding use of exchange mechanisms for subsidization, (iii) maintaining adequate level reserves to take care of short-term fluctuations, (iv) continuing the process of liberalization on current account, and (v) reinforcing effective control over capital transactions. The key to the maintenance of a realistic and a stable exchange rate is containing inflation through macro-economic policies and ensuring net capital receipts of the scale not beyond the expectation. The Committee further recommended that a decision be taken to unify the exchange rate, as an important step towards full convertibility.

The initiation of economic reforms saw, among other measures, a two step downward exchange rate adjustment by 9 per cent and 11 per cent between July 1 and 3, 1991 to counter the massive draw down in the foreign exchange reserves, to install confidence in the investors and to improve domestic competitiveness. The two-step adjustment of July 1991 effectively brought to a close the period of pegged exchange rate. Following the recommendations of Rangarajan Committee to move towards the market-determined exchange rate, the Liberalised Exchange Rate Management System (LERMS) was put in place in March 1992 involving dual exchange rate system in the interim period. The dual exchange rate system was replaced by unified exchange rate system in March 1993.

2. Foreign Exchange Intervention

In the post-Asian crisis period, particularly after 2002-03, capital flows into India surged creating space for speculation on Indian rupee. The Reserve Bank intervened actively in the forex market to reduce the volatility in the market. During this period, the Reserve Bank made direct interventions in the market through purchases and sales of the US Dollars in the forex market and sterilised its impact on monetary base. The Reserve Bank has been intervening to curb volatility arising due to demand-supply mismatch in the domestic foreign exchange market (Table 2.2).

	Table 2.2: Reserve Bank's Intervention in the Foreign Exchange Market			
				(US$ billion)
	Purchase	**Sale**	**Net**	**Outstanding Net Forward Sales/ Purchase (end-March)**
1995-96	3.6	3.9	-0.3	-
1996-97	11.2	3.4	7.8	-
1997-98	15.1	11.2	3.8	-1.8
1998-99	28.7	26.9	1.8	-0.8
1999-00	24.1	20.8	3.2	-0.7
2000-01	28.2	25.8	2.4	-1.3
2001-02	22.8	15.8	7.1	-0.4
2002-03	30.6	14.9	15.7	2.4
2003-04	55.4	24.9	30.5	1.4
2004-05	31.4	10.6	20.8	0
2005-06	15.2	7.1	8.1	0
2006-07	26.8	0.0	26.8	0
2007-08	79.7	1.5	78.2	14.7
2008-09	26.6	61.5	-34.9	2.0

Source : Reserve Bank of India.

Sales in the foreign exchange market are generally guided by excess demand conditions that may arise due to several factors. Similarly, the Reserve Bank purchases dollars from the market when there is an excess supply pressure in market due to capital inflows. Demand-supply mismatch proxied by the difference between the purchase and sale transactions in the merchant segment of the spot market reveals a strong co-movement between demand-supply gap and intervention by the Reserve Bank (Chart 2.2)[3]. Thus, the Reserve Bank has been prepared to make sales and purchases of foreign currency in order to even out lumpy demand and supply in the relatively thin foreign exchange market

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[3]   A positive correlation of 0.7 is also found in case of demand-supply mismatch and net RBI purchases.

Chart 2.2: The relationship between demand-supply mismatch and RBI intervention
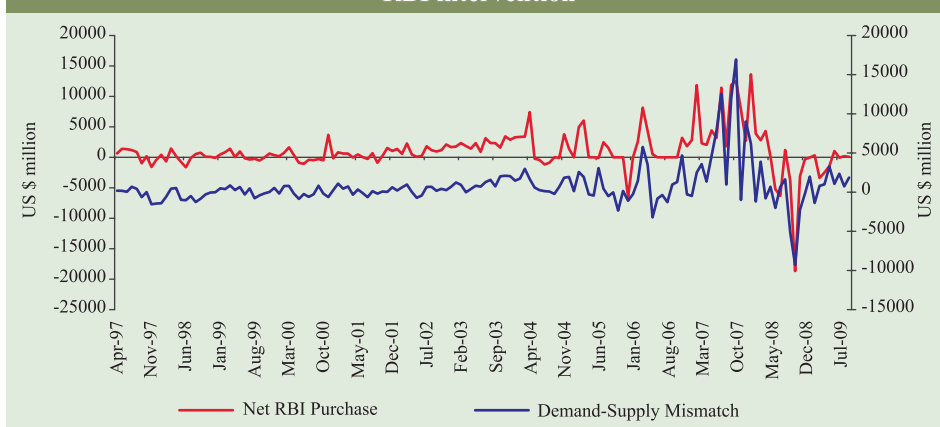
and to smoothen jerky movements. However, such intervention is generally not governed by any predetermined target or band around the exchange rate (Jalan, 1999).

The volatility of Indian rupee remained low against the US dollar than against other major currencies as the Reserve Bank intervened mostly through purchases/sales of the US dollar. Empirical evidence in the Indian case has generally suggested that in the present day managed float regime of India, intervention has served as a potent instrument in containing the magnitude of exchange rate volatility of the rupee and the intervention operations do not influence as much the level of rupee (Pattanaik and Sahoo, 2001; Kohli, 2000; RBI, RCF 2002-03, 2005-06).

The intervention of the Reserve Bank in order to neutralise the impact of excess foreign exchange inflows enhanced the RBI's Foreign Currency Assets (FCA) continuously. In order to offset the effect of increase in FCA on monetary base, the Reserve Bank had mopped up the excess liquidity from the system through open market

operation (Chart 2.3). It is, however, pertinent to note that Reserve Bank's intervention in the foreign exchange market has been relatively small in terms of volume (less than 1 per cent during last few years), except during 2008-09. The Reserve Bank's gross market intervention as a per cent of turnover in the foreign exchange market was the highest in 2003-04 though in absolute terms the highest intervention was US$ 84 billion in 2008-09 (Table 2.3). During October 2008 alone, when the contagion of the global financial crisis started affecting India, the RBI sold US$ 20.6 billion in the foreign exchange market. This was the highest intervention till date during any particular month.

Chart 2.3: Sterilization Operation of the RBI
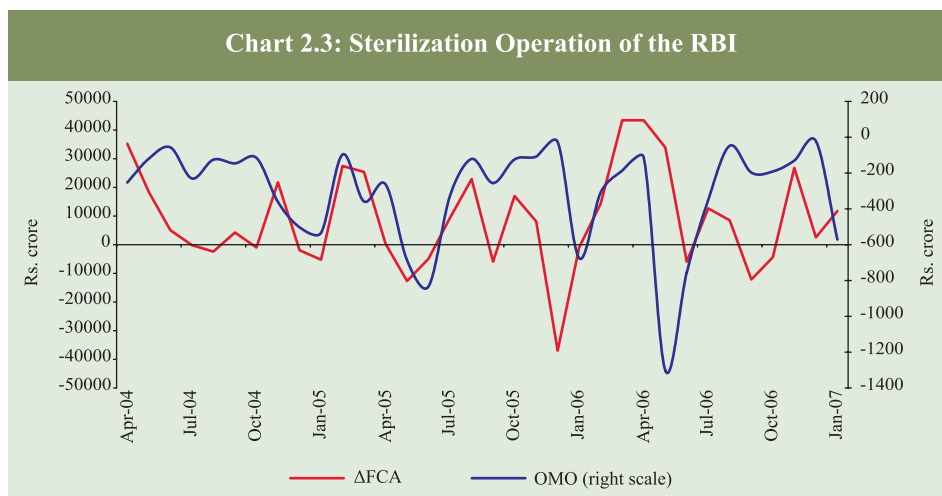
3. Trends in Exchange Rate

A look at the entire period since 1993 when we moved towards market determined exchange rates reveals that the Indian Rupee has generally depreciated against the dollar during the last 15 years except during the period 2003 to 2005 and during 2007-08 when the rupee had appreciated

Table 2.3 : Extent of RBI Intervention in Foreign exchange Market			
	RBI Intervention in Foreign exchange market ($ billion)	**Foreign exchange Market Turnover ($ billion)**	**Column 2 over 3 (in per cent)**
1	2	3	4
2002-03	45.6	1,560	2.9
2003-04	80.4	2,118	3.8
2004-05	42.0	2,892	1.5
2005-06	15.8	4,413	0.4
2006-07	26.8	6,571	0.4
2007-08	81.2	12,249	0.7
2008-09P	83.9	12,092	0.7

P: Provisional
Note: RBI Intervention includes both purchases and sales of US dollar by the RBI
Source: Reserve Bank of India.

on account of dollar's global weakness and large capital inflows (Table 2.4). For the period as a whole, 1993-94 to 2007-08, the Indian Rupee

Table2.4: Movements of Indian Rupee 1993-94 to 2008-09					
Year	**Range (Rs per US $)**	**Average Exchange Rate (Rs per US $)**	**Daily average Appreciation/ Depreciation**	**Coefficient of Variation (%)**	**Standard Deviation**
1	2	3	4	5	6
1993-94	31.21-31.49	31.37	0.03	0.1	0.05
1994-95	31.37-31.97	31.40	-0.11	0.3	0.12
1995-96	31.37-37.95	33.46	-6.17	5.8	0.56
1996-97	34.14-35.96	35.52	-5.77	1.3	0.21
1997-98	35.70-40.36	37.18	-4.47	4.2	0.37
1998-99	39.48-43.42	42.13	-11.75	2.1	0.24
1999-00	42.44-43.64	43.34	-2.79	0.7	0.10
2000-01	43.61-46.89	45.71	-5.19	2.3	0.15
2001-02	46.56-48.85	47.69	-4.15	1.4	0.13
2002-03	47.51-49.06	48.40	-1.48	0.9	0.07
2003-04	43.45-47.46	45.92	5.40	1.6	0.19
2004-05	43.36-46.46	44.95	2.17	2.3	0.31
2005-06	43.30-46.33	44.28	1.51	1.8	0.22
2006-07	43.14-46.97	45.28	-2.22	2.0	0.27
2007-08	39.26-43.15	40.24	12.53	2.1	0.38
2008-09	39.89-52.09	45.92	-12.36	7.8	0.73

Source: Reserve Bank of India.

has depreciated against the dollar. The rupee has also depreciated against other major international currencies. Another important feature has been the reduction in the volatility of the Indian exchange rate during last few years. Among all currencies worldwide, which are not on a nominal peg, and certainly among all emerging market economies, the volatility of the rupee-dollar rate has remained low. Moreover, the rupee in real terms generally witnessed stability over the years despite volatility in capital flows and trade flows (Table 2.5).

Table 2.5: Trend in External value of the Indian Rupee				
Year	36 country REER (Trade Based): Base 1993-94=100			
	REER	% Variation	NEER	% Variation
1993-94	100.00	-	100.00	-
1994-95	104.32	4.3	98.91	-1.1
1995-96	98.19	-5.9	91.54	-7.5
1996-97	96.83	-1.4	89.27	-2.5
1997-98	100.77	4.1	92.04	3.1
1998-99	93.04	-7.7	89.05	-3.2
1999-00	95.99	3.2	91.02	2.2
2000-01	100.09	4.3	92.12	1.2
2001-02	100.86	0.8	91.58	-0.6
2002-03	98.18	-2.7	89.12	-2.7
2003-04	99.56	1.4	87.14	-2.2
2004-05	100.09	0.5	87.31	0.2
2005-06	102.35	2.3	89.85	2.9
2006-07	98.48	-3.8	85.89	-4.4
2007-08	104.81	6.4	93.91	9.3
2008-09	94.31	-10.0	84.66	-9.8

Source : Reserve Bank of India.

The various episodes of volatility of exchange rate of the rupee have been managed in a flexible and pragmatic manner. In line with the exchange rate policy, it has also been observed that the Indian rupee is moving along with the economic fundamentals in the post-reform period. Thus, as can be observed maintaining orderly market conditions have been the central theme of RBI's exchange rate policy. Despite several unexpected external and domestic developments, India's exchange rate

Exchange Rate Policy and Modelling in India

performance is considered to be satisfactory. The Reserve Bank has generally reacted promptly and swiftly to exchange market pressures through a combination of monetary, regulatory measures along with direct and indirect interventions and has preferred to withdraw from the market as soon as orderly conditions are restored.

Moving forward, as India progresses towards full capital account convertibility and gets more and more integrated with the rest of the world, managing periods of volatility is bound to pose greater challenges in view of the impossible trinity of independent monetary policy, open capital account and exchange rate management. Preserving stability in the market would require more flexibility, adaptability and innovations with regard to the strategy for liquidity management as well as exchange rate management. Also, with the likely turnover in the foreign exchange market rising in future, further development of the foreign exchange market will be crucial to manage the associated risks.

SECTION III

Structure of the Indian Foreign Exchange Market and Turnover

Prior to the 1990s, the Indian foreign exchange market (with a pegged exchange rate regime) was highly regulated with restrictions on transactions, participants and use of instruments. The period since the early 1990s has witnessed a wide range of regulatory and institutional reforms resulting in substantial development of the rupee exchange market as it is observed today. Market participants have become sophisticated and have acquired reasonable expertise in using various instruments and managing risks. The range of instruments available for trading has also increased. Against this background, this Section discusses the structure of the foreign exchange market in India. The first sub-section of the Section gives an overview of the structure of the foreign exchange market in terms of participants, instruments and trading platform followed by discussions on turnover and forward premia in subsequent sections.

1. Current Rupee Market Structure

While analysing the exchange rate behavior, it is also important to have a look at the market micro structure where the Indian rupee is traded. As in case of any other market, trading in Indian foreign exchange market involves some participants, a trading platform and a range of instruments for trading. Against this backdrop, the current market set up is given below.

Market Segments and Players

The Indian foreign exchange market is a decentralised multiple dealership market comprising two segments – the spot and the derivatives market. In a spot transaction, currencies are traded at the prevailing rates and the settlement or value date is two business days ahead. The two-day period gives adequate time for the parties to send instructions to debit and credit the appropriate bank accounts at home and abroad. The derivatives market encompasses forwards, swaps, and options. As in case of other Emerging Market Economies (EMEs), the spot market remains an important segment of the Indian foreign exchange market. With the Indian economy getting exposed to risks arising out of changes in exchange rates, the derivative segment of the foreign exchange market has also strengthened and the activity in this segment is gradually rising.

Players in the Indian market include (a) Authorised Dealers (ADs), mostly banks who are authorised to deal in foreign exchange[4], (b) foreign exchange brokers who act as intermediaries between counterparties, matching buying and selling orders and (c) customers – individuals, corporates, who need foreign exchange for trade and investment purposes. Though customers are a major player in the foreign exchange market, for all practical purposes they depend upon ADs and brokers. In the

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[4] ADs have been divided into different categories: (1) All scheduled commercial banks, which include Public sector banks, private sector banks and foreign banks operating in India, belong to category I of ADs, (2) All upgraded full fledged money changers (FFMCs) and select Regional rural banks and cooperative banks belong to category II of ADs and (3) Select financial institutions such as EXIM bank belong to Category III of ADs.

spot foreign exchange market, foreign exchange transactions were earlier dominated by brokers, but the situation has changed with evolving market conditions as now the transactions are dominated by ADs. The brokers continue to dominate the derivatives market. The Reserve Bank like other central banks is a market participant who uses foreign exchange to manage reserves and intervenes to ensure orderly market conditions.

The customer segment of the spot market in India essentially reflects the transactions reported in the balance of payments – both current and capital account. During the decade of the 1980s and 1990s, current account transactions such as exports, imports, invisible receipts and payments were the major sources of supply and demand in the foreign exchange market. Over the last five years, however, the daily supply and demand in the foreign exchange market is being increasingly determined by transactions in the capital account such as foreign direct investment (FDI) to India and by India, inflows and outflows of portfolio investment, external commercial borrowings (ECB) and its amortisations, non-resident deposit inflows and redemptions. It needs to be observed that in India, with the government having no foreign currency account, the external aid received by the Government comes directly to the reserves and the RBI releases the required rupee funds. Hence, this particular source of supply of foreign exchange *e.g.* external aid does not go into the market and to that extent does not reflect itself in the true determination of the value of the rupee.

The foreign exchange market in India today is equipped with several derivative instruments. Various informal forms of derivatives contracts have existed since time immemorial though the formal introduction of a variety of instruments in the foreign exchange derivatives market started only in the post reform period, especially since the mid-1990s. These derivative instruments have been cautiously introduced as part of the reforms in a phased manner, both for product diversity and more importantly as a risk management tool. Recognising the relatively nascent stage of the foreign exchange market then with the lack of capabilities to handle massive speculation, the 'underlying exposure' criteria had been imposed as a prerequisite.

2. Foreign Exchange Market Turnover

The depth and size of foreign exchange market is gauged generally through the turnover in the market. Foreign exchange turnover considers all the transactions related to foreign currency, i.e. purchases, sales, booking and cancelation of foreign currency or related products. Forex turnover or trading volume, which is also an indicator of liquidity in the market, helps in price discovery. In the literature, it is held that the foreign exchange market turnover may convey important private information about market clearing prices, thus, it could act as a key variable while making informed judgment about the future exchange rates. Trading volumes in the Indian foreign exchange market has grown significantly over the last few years. The daily average turnover has seen almost a ten-fold rise during the 10 year period from 1997-98 to 2007-08 from US $ 5 billion to US $ 48 billion (Table 3.1). The pickup has been particularly sharp from 2003-04 onwards since when there was a massive surge in capital inflows.

Table 3.1: Total Turnover in the Foreign Exchange Market						
	Turnover in US $ billion			Share of spot turnover in per cent		
Year	Merchant	Inter-bank	Total	Merchant	Inter-bank	Total
1	2	3	4	5	6	7
1997-98	210	1,096	1,305	57.5	50.4	51.6
1998-99	246	1,057	1,303	51.1	48.6	49.1
1999-00	244	898	1,142	60.6	49.2	51.6
2000-01	269	1,118	1,387	62.9	43.8	47.5
2001-02	257	1,165	1,422	61.8	38.1	42.4
2002-03	325	1,236	1,560	57.0	42.0	45.1
2003-04	491	1,628	2,118	52.5	48.2	49.2
2004-05	705	2,188	2,892	48.2	50.5	50.0
2005-06	1,220	3,192	4,413	45.0	52.6	50.5
2006-07	1,798	4,773	6,571	46.1	54.1	51.9
2007-08	3,545	8,704	12,249	45.9	51.2	49.7
2008-09	3,231	8,861	12,092	37.7	48.1	45.3

Source: Reserve Bank of India.

It is noteworthy that the increase in foreign exchange market turnover in India between April 2004 and April 2007 was the highest amongst the 54 countries covered in the latest Triennial Central Bank Survey of Foreign Exchange and Derivatives Market Activity conducted by the Bank for International Settlements (BIS). According to the survey, daily average turnover in India jumped almost 5-fold from US $ 7 billion in April 2004 to US $ 34 billion in April 2007; global turnover over the same period rose by only 66 per cent from US $ 2.4 trillion to US $ 4.0 trillion. Reflecting these trends, the share of India in global foreign exchange market turnover trebled from 0.3 per cent in April 2004 to 0.9 per cent in April 2007.

Looking at some of the comparable indicators, the turnover in the foreign exchange market has been an average of 7.6 times higher than the size of India's balance of payments during last five years (Table 3.2). With the deepening of foreign exchange market and increased turnover, income of commercial banks through treasury operations has increased considerably.

Table3.2: Foreign Exchange market Turnover and BoP Size					
Year	Foreign Exchange Market-Annual Turnover ($ billion)	BoP size ($ billion)	Foreign Currency Assets* ($ billion)	Col 2 over Col 3	Col 2 over Col 4
1	2	3	4	5	6
2000-01	1,387	258	39.6	5.4	35.0
2001-02	1,422	237	51.0	6.0	27.9
2002-03	1,560	267	71.9	5.8	21.7
2003-04	2,118	361	107.3	5.9	19.7
2004-05	2,892	481	135.6	6.0	21.3
2005-06	4,413	663	145.1	6.7	30.4
2006-07	6,571	918	191.9	7.2	34.2
2007-08	12,249	1,405	299.2	8.7	40.9
2008-09	12,092	1,301	241.4	9.3	50.1

*   As at end-March
Source: Reserve Bank of India.

A look at the segments in the Indian foreign exchange market reveals that the spot market remains the most important foreign exchange market segment accounting for about 50 per cent of the total turnover (Table 3.3). However, its share has seen a marginal decline in the recent past mainly due to a pick up in turnover in derivative segment. The merchant segment of the spot market is generally dominated by the Government of India, select public sector units, such as Indian Oil Corporation (IOC), and the FIIs. As the foreign exchange demand on account of public sector units and FIIs tends to be lumpy and uneven, resultant demand-supply mismatches entail occasional pressures on the foreign exchange market, warranting market interventions by the Reserve Bank to even out lumpy demand and supply. However, as noted earlier, such intervention is not governed by a predetermined target or band around the exchange rate. Further, the inter-bank to merchant turnover ratio has almost halved from 5.2 during 1997-98 to 2.8 during 2008-09 reflecting the growing participation in the merchant segment of the foreign exchange market associated with growing trade activity, better corporate performance and increased liberalisation. Mumbai alone accounts for almost 80 per cent of the foreign exchange turnover.

Table 3.3: Indicators of Indian Foreign Exchange Market Activity			
	1997-98	2007-08	2008-09
1	2	3	4
Total annual turnover	1,305	12,249	12,092
Average daily Turnover	5	48	48
Average Daily Merchant Turnover	1	14	13
Average Daily Inter-bank Turnover	4	34	35
Inter-bank to Merchant ratio	5.2	2.5	2.7
Spot/Total Turnover (%)	51.6	49.7	45.3
Forward/Total Turnover (%)	12.0	19.3	21.1
Swap/Total Turnover (%)	36.4	31.1	33.6

Exchange Rate Policy and Modelling in India

Behaviour of Forward Premia

Next to the spot exchange market, the transactions on forwards and swaps are large in Indian context. Onshore deliverable forward contracts are generally available for maturities ranging from one month to ten years; however, the most common and liquid contracts have maturities of one year or less, and these have a bid/offer spread of Rs.0.01. The forward exchange rate[5] is an important indicator of the future behavior of exchange rates as it is determined in the foreign exchange market based on expectations on the future exchange rates, which is expected to get influenced by a set of variables. Given its very nature, the forward premia is sensitive to any news having financial bearing. Thus, the information content of forward premia is important in any forecasting exercise.

A swap transaction in the foreign exchange market is a combination of a spot and a forward in the opposite direction. Foreign exchange swaps account for the largest share of the total derivatives turnover in India, followed by forwards and options. In the Indian context, the forward price of the rupee is not essentially determined by the interest rate differentials, but it is also significantly influenced by: (a) supply and demand of forward US dollars; (b) interest differentials and expectations of future interest rates; and (c) expectations of future US dollar-rupee exchange rate (Chart 3.1).

Empirical studies in the Indian context reveal that forward premia on US dollar is driven to a large extent by the interest rate differential in the interbank market of the two economies combined with FII flows, current account balance as well as changes in exchange rates of US dollar vis-à-vis Indian rupee (Sharma and Mitra, 2006). Further empirical analysis for the period January 1995-December 2006 have shown that

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[5] Mathematically, forward rate equation can be expressed as:

$$F_t = \frac{(1+i^*_t)S_t}{(1+i_t)}$$ where F is forward rate at time t; i is domestic interest rate; i* stands for interest

rates on foreign currency; and S is the spot rate, i.e. foreign currencies per unit of domestic currency.

Chart 3.1:Movement of Forward Premia & USD

Legend:
Forward Premia (1-month)   Forward Premia (3-month)
Forward Premia (6-month)   Rs./USD (right scale)
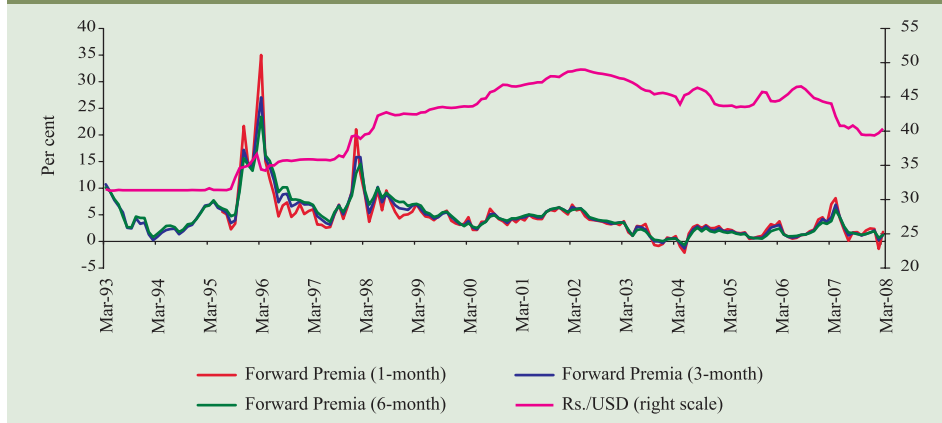
the ability of forward rates in correctly predicting the future spot rates has improved overtime and there is co-integration relationship between the forward rate and the future spot rate (RCF, 2005-06).

With the opening up of the capital account, the forward premia is getting aligned with the interest rate differential reflecting market efficiency (Chart 3.2). While free movement in capital account is only a necessary condition for full development of forward and other foreign exchange derivatives market, the sufficient condition is provided by a deep and liquid money market with a well-defined yield curve in place.

Market Efficiency

With the exchange rate primarily getting determined in the market, the issue of foreign exchange[6] market efficiency has assumed importance for India in recent years. The bid-ask spread of Rupee/US$ market has almost converged with that of other major currencies in the international

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[6] A market is said to be efficient when the price reflect all available information in the market and therefore, the possibilities of making arbitrage profits are nil.

Chart 3.2: Movement of Forward Premia and Interest Rate Differential
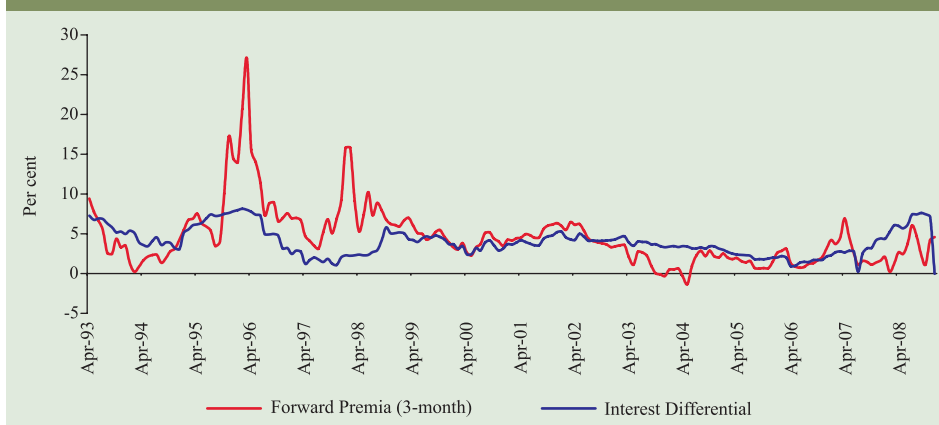
market. On some occasions, in fact, the bid-ask spread of Rupee/US$ market was lower than that of some major currencies.

Besides maintaining orderly conditions, markets are perceived as efficient when market prices reflect all available information, so that it is not possible for any trader to earn excess profits in a systematic manner. The efficiency/liquidity of the foreign exchange market is often gauged in terms of bid-ask spreads. The bid-ask spread refers to the transaction costs and operating costs involved with the transaction of the currency. These costs include phone bills, cable charges, book-keeping expenses, trader salaries, etc. in the spot segment, it may also include the risks involved with holding the foreign exchange. These costs/bid-ask spread may reduce with the increase in the volume of transaction of the currency.

In the Indian context, it is found that the spread is almost flat and very low. In India, the normal spot market quote has a spread of 0.25 paisa to 1 paise while swap quotes are available at 1 to 2 paise spread. A closer look at the bid-ask spread in the rupee-US dollar spot market reveals that during the initial phase of market development (i.e., till the mid-

1990s), the spread was high and volatile due to thin market with unidirectional behavior of market participants (Chart 3.3). In the later period, with relatively deep and liquid markets, bid-ask spread has sharply declined and has remained low and stable, reflecting efficiency gains.
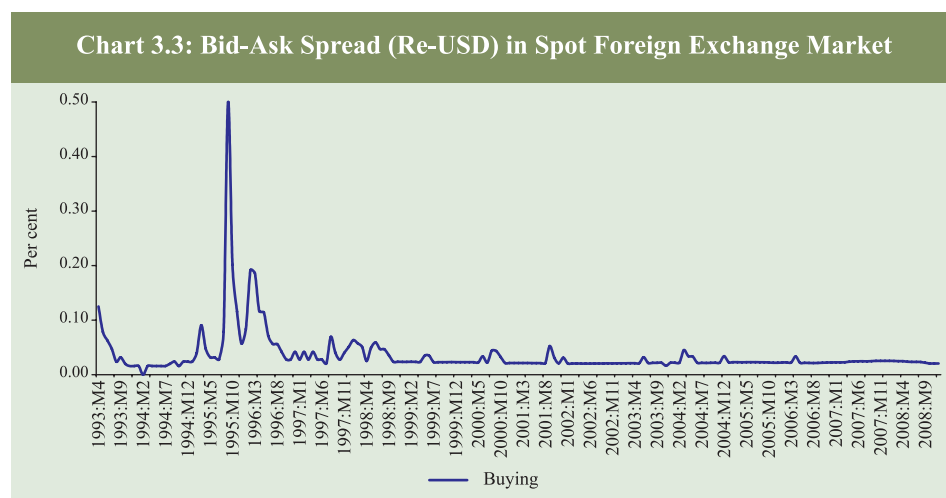
Chart 3.3: Bid-Ask Spread (Re-USD) in Spot Foreign Exchange Market

Thus, the foreign exchange market has evolved over time as a deep, liquid and efficient market as against highly regulated market prior to the 1990s. The market participants have become sophisticated, the range of instruments available for trading has increased, the turnover has also increased, while the bid-ask spreads have declined. The next Section discusses the dynamics of capital flows, which are also key variables in the modelling exercise.

SECTION IV

Capital Flows and Exchange Rates: The Indian Experience

The capital inflows and outflows have implications for the conduct of domestic monetary policy and exchange rate management. The

emerging market economies including India had seen a very sharp rise in capital flows in the past few years. The surge in the capital flows till 2007-08 had coincided mostly with a faster pace of financial liberalization, particularly a move towards regulation free open economies. Moreover, high interest rates prevailing in the emerging market economies had led to a wider interest rate differential in favour of the domestic markets, which stimulated a further surge of capital flows. In emerging markets, capital flows are often relatively more volatile and sentiment driven, not necessarily being related to the fundamentals in these markets. Such volatility imposes substantial risks on the market agents, which they may not be able to sustain or manage (Committee on the Global Financial System, BIS, 2009). In the literature, several instruments have been prescribed for sterilization purposes. Such tools include open market operations, tightening the access of banks at the discount window, adjusting reserve requirements or the placement of government deposits, using a foreign exchange swap facility, easing restrictions on capital outflows, pre-payment of external debt and promoting investment through absorption of capital flows for growth purposes.

1. Capital Flows: Indian Context

In the recent period, external sector developments in India have been marked by strong capital flows, which had led to an appreciating tendency in the exchange rate of the Indian rupee up to January 2008. The movement of the Indian rupee is largely influenced by the capital flow movements rather than traditional determinants like trade flows (Chart 4.1). Capital flows to India, which were earlier mainly confined to small official concessional finance, gained momentum from the 1990s after the initiation of economic reforms. Apart from an increase in size, capital flows to India have undergone a compositional shift from predominantly official and private debt flows to non-debt creating flows in the post reform period. Private debt flows have begun to increase again in the more recent period. Though capital flows are generally seen to be beneficial to an economy, a large surge in flows over a short span of time in excess of the

domestic absorptive capacity can, however, be a source of stress to the economy giving rise to upward pressures on the exchange rate, overheating of the economy, and possible asset price bubbles.

Chart 4.1: Trade, Capital Flows and Exchange Rate Movements
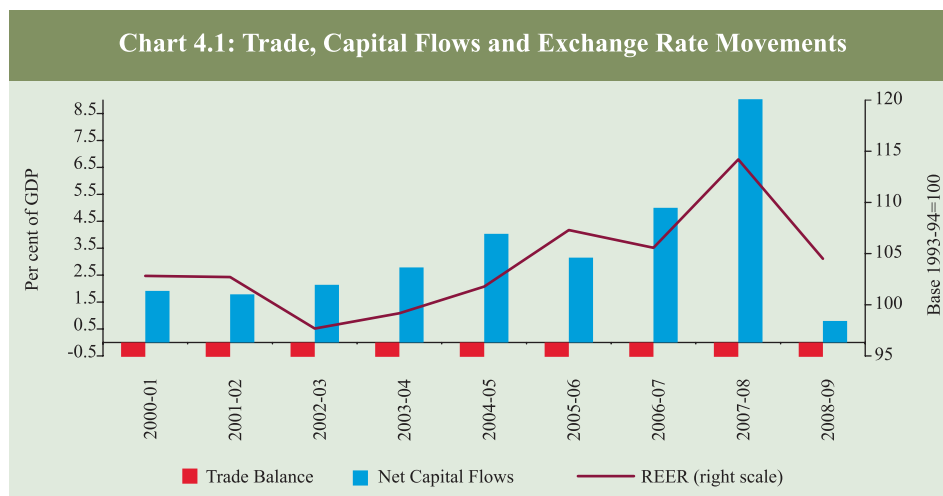
The far reaching economic reforms in India in the 1990s, witnessed a sharp increase in capital inflows as a result of capital account liberalisation in India and a gradual decrease in home bias in asset allocation in advanced economies. During 1990-91, it was clear that the country was heading for a balance of payment crisis due to deficit financed fiscal expansion of the 1980s and the trigger of oil price spike caused by the Gulf War. The balance of payments crisis of 1991 led to the initiation of reform process. The broad approach to reform in the external sector was based on the recommendations made in the Report of the High Level Committee on Balance of Payments (Chairman: Shri. C. Rangarajan), 1991. The objectives of reform in the external sector were conditioned by the need to correct the deficiencies that led to payment imbalances in 1991. Recognizing that an inappropriate exchange rate regime, unsustainable current account deficit and a rise in short term debt in relation to the official reserves were amongst the key contributing factors

to the crisis, a series of reform measures were put in place. The measures included a swift transition to a market determined exchange rate regime, dismantling of trade restrictions, moving towards current account convertibility and gradual opening up of the capital account. While liberalizing the private capital inflows, the Committee recommended, inter alia, a compositional shift in capital flows away from debt to non-debt creating flows; strict regulation of external commercial borrowings, especially short term debt; discouraging volatile element of flows from non-resident Indians; and gradual liberalization of outflows.

Among the components, since the 1990s, the broad approach towards permitting foreign direct investment has been through a dual route, i.e., automatic and approval, with the ambit of automatic route progressively enlarged to almost all the sectors, coupled with higher sectoral caps stipulated for such investments. Portfolio investments are restricted to institutional investors. The approach to external commercial borrowings has been one of prudence, with self imposed ceilings on approvals and a careful monitoring of the cost of raising funds as well as their end use. In respect of NRI deposits, some modulation of inflows is exercised through specification of interest rate ceilings and maturity requirements. In respect of capital outflows, the approach has been to facilitate direct overseas investment through joint ventures and wholly owned subsidiaries and provision of financial support to exports, especially project exports from India. Ceilings on such outflows have been substantially liberalized over time. The limits on remittances by domestic individuals have also been eased. With progressive opening up of its capital account since the early 1990s, the state of capital account in India today can be considered as the most liberalized it has ever been in its history since the late 1950s. All these developments have ramifications on exchange rate management (Mohan 2008b).

2. Management of Capital Flows and Exchange Rates

The recent episode of capital flows, which has occurred in the backdrop of current account surplus in most of the emerging Asian

economies, highlights the importance of absorption of capital flows. The absorption of capital flows is limited by the extant magnitude of the current account deficit, which has traditionally been low in India, and seldom above 2 per cent of GDP. In India, with a view to neutralising the impact of excess forex flows on account of a large capital account surplus, the central bank has intervened in the foreign exchange market at regular intervals. But unsterilised forex market intervention can result in inflation, loss of competitiveness and attenuation of monetary control. The loss of monetary control could be steep if such flows are large. Therefore, it is essential that the monetary authorities take measures to offset the impact of such foreign exchange market intervention, partly or wholly, so as to retain the intent of monetary policy through such intervention.

In India, the liquidity impact of large capital inflows was traditionally managed mainly through the repo and reverse repo auctions under the day-to-day Liquidity Adjustment Facility (LAF). The LAF operations were supplemented by outright open market operations (OMO), i.e. outright sales of the government securities, to absorb liquidity on an enduring basis. In addition to LAF and OMO, excess liquidity from the financial system was also absorbed through the building up of surplus balances of the Government with the Reserve Bank, particularly by raising the notified amount of 91-day Treasury Bill auctions, forex swaps and pre-payment of external loans,

The market-based operations led to a progressive reduction in the quantum of securities with the Reserve Bank. This apart, as per those operations, the usage of the entire stock of securities for outright open market sales was constrained by the allocation of a part of the securities for day-to-day LAF operations as well as for investments of surplus balances of the Central Government, besides investments by the State Governments in respect of earmarked funds (CSF/GRF) while some of the government securities were also in non-marketable lots. In the face of large capital flows coupled with declining stock of government

securities, the Reserve Bank of India introduced a new instrument of sterilisation, viz., the Market Stabilisation Scheme (MSS) to sustain market operations. Since its introduction in April 2004, the MSS has served as a very useful instrument for medium term monetary and liquidity management.

In the choice of instruments for sterilisation, it is important to recognise the benefits from and the costs of sterilisation in general and the relative costs/benefits in the usage of a particular instrument. The various instruments have differential impact on the balance sheets of the central bank, government and the financial sector. The cost of sterilisation in India is shared by the Central Government (the cost of MSS), Reserve Bank (sterilization under LAF) and the banking system (in case of increase in the reserve requirements). Since surpluses of the Reserve Bank are transferred to the Central Government, on a combined balance sheet basis, the relative burdens of cost between the Government and Reserve Bank are not of great relevance. However, the direct cost borne by the Government is transparently shown in its budget accounts. Owing to the difference between international and Indian interest rates, there is a positive cost of sterilisation but the cost has to be traded-off with the benefits associated with market stability, export competitiveness and possible crisis avoidance in the external sector. Sterilized interventions and interest rate policy are generally consistent with overall monetary policy stance that is primarily framed on the basis of the domestic macro-economic outlook.

With surge in capital flows to EMEs, issues relating to management of those flows have assumed importance as they have bearings on the exchange rates. Large capital inflows create important challenges for policymakers because of their potential to generate overheating, loss of competitiveness, and increased vulnerability to crisis. Reflecting these concerns, policies in EMEs have responded to capital inflows in a variety of ways. While some countries have allowed exchange rate to appreciate, in many cases monetary authorities have intervened heavily in forex

markets to resist currency appreciation. EMEs have sought to neutralize the monetary impact of intervention through sterilization. Cross-country experiences reveal that in the recent period most of the EMEs have adopted a more flexible exchange rate regime. In view of the importance of capital flows and foreign exchange intervention in determination of exchange rates, these variables are included in the modelling exercise undertaken in this study to analyze the behaviour of the exchange rate.

SECTION V

Modelling and Forecasting the Exchange Rate: Economic Theory and Review of Literature

In the international finance literature, various theoretical models are available to analyze exchange rate determination and behaviour. Most of the studies on exchange rate models prior to the 1970s were based on the fixed price assumption[7]. With the advent of the floating exchange rate regime amongst major industrialized countries in the early 1970s, an important advance was made with the development of the monetary approach to exchange rate determination. The dominant model was the flexible-price monetary model that has been analyzed in many early studies like Frenkel (1976), Mussa (1976, 1979), Frenkel and Johnson (1978), and more recently by Vitek (2005), Nwafor (2006), Molodtsova and Papell, (2007). Following this, the sticky price or overshooting model by Dornbusch (1976, 1980) evolved, which has been tested, amongst others, by Alquist and Chinn (2008) and Zita and Gupta (2007). The portfolio balance model also developed alongside[8], which allowed for imperfect substitutability between domestic and foreign assets and considered wealth effects of current account imbalances.

With liberalization and development of foreign exchange and assets markets, variables such as capital flows, volatility in capital flows and

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[7] See e.g. Marshall (1923), Lerner (1936), Nurkse (1944), Harberger (1950), Mundell (1961, 1962, 1963) and Fleming (1962).
[8] See e.g. Dornbusch and Fischer (1980), Isard (1980), Branson (1983, 1984).

forward premium have also became important in determining exchange rates. Furthermore, with the growing development of foreign exchange markets and a rise in the trading volume in these markets, the micro level dynamics in foreign exchange markets increasingly became important in determining exchange rates. Agents in the foreign exchange market have access to private information about fundamentals or liquidity, which is reflected in the buying/selling transactions they undertake, that are termed as order flows (Medeiros, 2005; Bjonnes and Rime, 2003). Microstructure theory evolved in order to capture the micro level dynamics in the foreign exchange market (Evans and Lyons, 2001, 2005, 2007). Another variable that is important in determining exchange rates is central bank intervention in the foreign exchange market.

Non-linear models have also been considered in the literature. Sarno (2003), Altaville and Grauwe (2006) are some of the recent studies that have used non-linear models of the exchange rate.

Overall, forecasting the exchange rates has remained a challenge for both academicians as well as market participants. In fact, Meese and Rogoff's seminal study (1983) on the forecasting performance of the monetary models demonstrated that these failed to beat the random walk model. This has triggered a plethora of studies that test the superiority of theoretical and empirical models of exchange rate determination vis-à-vis a random walk.

Against this backdrop, various models of exchange rate determination are examined to derive the relevant macroeconomic fundamentals affecting exchange rates. The empirical literature on exchange rate determination is analyzed next.

1. Exchange Rate Models: Theoretical Considerations

(i) Theory: Purchasing Power Parity, Monetary and Portfolio Balance Models

The earliest and simplest model of exchange rate determination, known as the **Purchasing Power Parity (PPP) theory**, represented the

application of "the law of one price". This states that arbitrage forces will lead to the equalization of goods prices internationally once the prices are measured in the same currency. PPP theory provided a point of reference for the long-run exchange rate in many of the modern exchange rate theories. It was observed initially that there were deviations from the PPP in short-run, but in the long-run, PPP holds in equilibrium. However, many of the recent studies like Jacobson, Lyhagen, Larsson and Nessen (2002) find deviations from PPP even in the long-run. The reasons for the failure of the PPP have been attributed to heterogeneity in the baskets of goods considered for construction of price indices in various countries, the presence of transportation cost, the imperfect competition in the goods market, and the increase in the volume of global capital flows during the last few decades which led to sharp deviation from PPP.

The **Harrod Balassa Samuelson Model**, rationalized the long run deviations from PPP. According to this model, productivity differentials are important in explaining exchange rates. They relax PPP assumption and allow real exchange rates to depend on relative price of non-tradables which are a function of productivity differentials. Chinn (1999) and Clostermann and Schnatz (2000) find that a model with productivity differentials, better explains and forecasts exchange rate behaviour.

The failure of PPP models gave way to **Monetary Models** which took into account the possibility of capital/bond market arbitrage apart from goods market arbitrage assumed in the PPP theory. In the monetary models, it is the money supply in relation to money demand in both home and foreign country, which determine the exchange rate. The prominent monetary models include the flexible and sticky-price monetary models of exchange rates as well as the real interest differential model and Hooper-Morton's extension of the sticky-price model. In this class of asset market models, domestic and foreign bonds are assumed to be perfect substitutes.

The **Flexible-Price Monetary Model** (Frenkel, 1976) assumes that prices are perfectly flexible. Consequently, changes in the nominal interest

rate reflect changes in the expected inflation rate. A relative increase in the domestic interest rate compared to the foreign interest rate implies that the domestic currency is expected to depreciate through the effect of inflation which causes the demand for the domestic currency to fall relative to the foreign currency. In addition to flexible prices, the model also assumes uncovered interest parity, continuous purchasing power parity and the existence of stable money demand functions for the domestic and foreign economies.

The model further implies that an increase in the domestic money supply relative to the foreign money supply would lead to a rise in domestic prices and depreciation of the domestic currency to maintain PPP. Further, an increase in domestic output would lead to an appreciation of the domestic currency since an increase in real income creates an excess demand for domestic money supply. This, in turn, causes a reduction in aggregate demand as agents try to increase their real money balances leading to a fall in prices until money market equilibrium is restored.

In the **Sticky-Price Monetary Model** (due originally to Dornbusch, 1976), changes in the nominal interest rate reflect changes in the tightness of monetary policy. When the domestic interest rate rises relative to the foreign rate, it is because there has been a contraction in the domestic money supply relative to the domestic money demand without a matching fall in prices. The higher interest rate at home attracts a capital inflow, which causes the domestic currency to appreciate. This model retains the assumption of stability of the money demand function and uncovered interest parity but replaces instantaneous purchasing power parity with a long-run version.

Since the PPP holds only in the long-run, an increase in the money supply does not depreciate the exchange rate proportionately in the short-run. In the short-run, because of sticky prices, a monetary expansion leads to a fall in interest rates resulting in a capital outflow. This causes the exchange rate to depreciate instantaneously and overshoot its

equilibrium level to give rise to an anticipation of appreciation in order to satisfy the uncovered interest parity condition. The above analysis assumes full employment so that real output is fixed. If instead, output responds to aggregate demand, the exchange rate and interest rate changes will be dampened.

Frankel (1979) argued that a drawback of the Dornbusch (1976) formulation of the sticky-price monetary model was that it did not allow a role for differences in secular rates of inflation. He develops a model that emphasizes the role of expectation and rapid adjustment in capital markets. The innovation is that it combines the assumption of sticky prices with that of flexible prices with the assumption that there are secular rates of inflation. This yields the *real interest differential model*.

Hooper and Morton (1982) extend the sticky price formulation by incorporating changes in the long-run real exchange rate. The change in the long-run exchange rate is assumed to be correlated with unanticipated shocks to the trade balance. They therefore introduce the trade balance in the exchange rate determination equation. A domestic (foreign) trade balance surplus (deficit) indicates an appreciation (depreciation) of the exchange rate.

The four models discussed above can be derived from the following equation specified in logs with starred variables denoting foreign counterparts:

$$e_t = \gamma + \delta\,(m_t\text{-}m_t^*) + \phi\,(y_t\text{-}y_t^*) + \alpha(i_t\text{-}i_t^*) + \beta(\pi_t\text{-}\pi_t^*) + \eta(tb_t\text{-}tb_t^*) + \mu_t$$

where e = price of foreign currency in domestic currency

    m = money supply

    y   = real output

    i   = nominal interest rate

    IT = inflation

    tb = trade balance

Exchange Rate Policy and Modelling in India

The alternative testable hypotheses are as follows:

Flexible-price model:	$\delta>0$, $\alpha>0$, $\phi<0$, $\beta=\eta=0$
Sticky price model:	$\delta>0$, $\alpha<0$, $\phi<0$, $\beta=\eta=0$
Real interest differential model:	$\delta>0$, $\alpha<0$, $\phi<0$, $\beta>0$, $\eta=0$
Hooper-Morton model:	$\delta>0$, $\alpha<0$, $\phi<0$, $\beta>0$, $\eta<0$

These models can be further extended to incorporate portfolio choice between domestic and foreign assets. The **portfolio balance model** assumes imperfect substitutability between domestic and foreign assets. It is a dynamic model of exchange rate determination that allows for the interaction between the exchange rate, current account and the level of wealth. For instance, an increase in the money supply is expected to lead to a rise in domestic prices. The change in prices, in turn, can affect net exports and thus imply changes in the current account of the balance of payments. This, in turn, affects the level of wealth (via changes in the capital account) and consequently, asset market and exchange rate behaviour. Under freely floating exchange rates, a current account deficit (surplus) is compensated by accommodating transactions in the capital account i.e. capital account surplus (deficit). This has implications for the demand and supply of currency in the foreign exchange market, which can lead to appreciation (depreciation) of the exchange rate. Thus the coefficient of the current account differential in the exchange rate model is hypothesized to have a positive sign. The portfolio approach thus introduces current account in the exchange rate equation. The theoretical model can be expressed as a hybrid model as follows:

$$e_t = \gamma + \delta(m_t\text{-}m_t{}^*) + \phi(y_t\text{-}y_t{}^*) + \alpha(i_t\text{-}i_t{}^*) + \beta(\pi_t\text{-}\pi_t{}^*) + \eta(tb_t\text{-}tb_t{}^*) + \theta(ca_t\text{-}ca_t{}^*) + \mu_t$$

where ca denotes current account balance and $\theta > 0$

(ii) *Theory: Capital flows, forward premium*

With an increase in liberalization and opening up of capital accounts the world over, capital flows have become important in determining exchange rate behaviour. The relation between capital flows and exchange

rates is hypothesized to be negative (with the exchange rate defined as the price of foreign currency in domestic currency). This is because capital inflow implies purchase of domestic assets by foreigners and capital outflow as purchase of foreign assets by residents. Since the exchange rate is determined by the supply and demand for foreign and domestic assets, the purchase of foreign assets drives up the price of foreign currency. Likewise, the purchase of domestic assets drives up the price of domestic currency. Thus, an increase in capital inflows leads to appreciation of the domestic currency when there is no government intervention in the foreign exchange market or if there is persistent sterilized intervention. In the case of unsterilized government intervention, the potential of capital inflows to influence exchange rates decreases to a great extent.

Dua and Sen (2009) develop a model which examines the relationship between the real exchange rate, level of capital flows, volatility of the flows, fiscal and monetary policy indicators and the current account surplus, and find that an increase in capital inflows and their volatility lead to an appreciation of the exchange rate. The theoretical sign on volatility can, however, be positive or negative.

The forward premium measured by the difference between the forward and spot exchange rate can provide useful information about future exchange rates. According to covered interest parity, the interest differential between two countries equals the premium on forward contracts. Thus, if domestic interest rates rise, the forward premium on the foreign currency will rise and the foreign currency is expected to appreciate. The exchange rate defined as the price of foreign currency in domestic currency and the forward premium are therefore expected to be positively related.

(iii) *Theory: Microstructure Framework*

The microstructure theory of exchange rates provides an alternative view to the determination of exchange rates. Unlike macroeconomic models that are based on public information, micro-based models suggest

that some agents may have access to private information about fundamentals or liquidity that can be exploited in the short-run. In microeconomic models of asset prices, transactions play a causal role in price determination (Evans and Lyons, 2001, 2007). The causal role arises because transactions convey information that is not common knowledge. These models assume that information is dispersed and heterogeneous agents have different information sets. The trading process in foreign exchange markets is not transparent and features bid-ask spreads that reflect the costs to market makers / dealers of processing orders and managing inventories. Thus, a distinctive feature of the microstructure models is the central role played by transactions volume or order flows in determining nominal exchange rate changes (Medeiros, 2005; Bjonnes and Rime 2003).

Order flow is the cumulative flow of transactions, signed positively or negatively depending on whether the initiator of the transaction is buying or selling. Order flow takes positive values if the agent purchases foreign currency from the dealer and takes negative values if it sells at the dealer's bid. Conventionally, order flow is taken as purchase minus sales of foreign currency. Hence an increase in order flow (i.e. an increase in the volume of positively signed transactions) will generate forces in the foreign exchange market such that there is pressure on the domestic exchange rate to depreciate. Hence the order flow and the exchange rate are positively related. The explanatory power or information content of order flow depends on the factors that cause it. Order flow is most informative when it is caused due to dispersion of private information amongst agents with respect to macroeconomic fundamentals (Evans and Lyons, 2005). Order flow is less informative when it is caused due to management of inventories by the foreign exchange dealers in response to liquidity shocks.

If the dealers of foreign exchange are heterogeneous and have different information sets, then there is information asymmetry in the foreign exchange market. In this case, order flow will capture the reaction of the market (obtained from aggregating the different reactions

of the dealers having different information sets) to changes in macroeconomic fundamentals and news related to changes in economic conditions. As macroeconomic fundamentals change, future expectations of the dealers of foreign exchange also change and so they adjust their portfolio of foreign currency accordingly, leading to a change in exchange rates. Another aspect of micro structure theory that has drawn attention is the liquidity effect of order flow. Studies in the literature have empirically tested whether the relationship between order flow and exchange rates is due to liquidity effects that are temporary in nature such as the herding behaviour of foreign exchange dealers (Breedon and Vitale 2004).

(iv) *Theory: Intervention*

Intervention by the central bank in the foreign exchange market also plays an important role in influencing exchange rates in countries that have managed floating regime. With the growing importance of capital flows in determining exchange rate movements in most emerging market economies, intervention in foreign exchange markets by central banks has become necessary from time to time to contain volatility in foreign exchange markets.

The motive of central bank intervention may be to align the current movement of exchange rates with the long-run equilibrium value of exchange rates; to maintain export competitiveness; to reduce volatility and to protect the currency from speculative attacks. Many studies in the literature including Edison (1993), Dominguez and Frankel (1993), Almenkinders (1995) and more recently Sarno and Taylor (2001) and Neely (2005) survey the literature on modelling the reaction function of the central bank and assessing the effectiveness of intervention.

Intervention is of two types - sterilised and non-sterilised. Intervention is sterilised if the sale or purchase of foreign currency is accompanied by expansionary or contractionary open market operations, so that domestic money supply is insulated from the effects of foreign exchange sale/purchase. Intervention is unsterilised if the sale or purchase of foreign

currency is not accompanied by offsetting open market operations. The impact of sterilised and unsterilised intervention on exchange rates can be quite different.

In case of non-sterilised intervention, say, purchase of foreign exchange (to prevent appreciation) not accompanied by contractionary open market operations, money supply increases, which reduces the rate of interest and increases demand. This leads to capital outflow on one hand and an increase in import demand on the other. All this leads to an increase in the demand for foreign currency and hence the exchange rate depreciates. Thus non-sterilised intervention and exchange rates are positively related.

While non-sterilised intervention directly influences the exchange rate through the monetary channel, sterilised intervention also influences exchange rate through different channels - by changing the portfolio balance, through the signaling channel where sterilised purchase of foreign currency will lead to a depreciation of the exchange rate if the foreign currency purchase is assumed to signal a more expansionary domestic monetary policy and more recently, the noise-trading channel, according to which, a central bank can use sterilised interventions to induce noise traders to buy or sell currency. Hence the overall effect of sterilised intervention on exchange rates is ambiguous.

Kletzer and Kohli (2001) develop a theoretical model and discuss the role of financial repression in exchange rate management in the Indian context. They find that policy instruments of financial repression can be used as tools for exchange rate intervention under managed float.

Recognizing the importance of both monetary models as well as micro structure theory in determining the exchange rates, the study uses a combination of both the models. Exchange rate is determined by monetary variables as well as order flows. Theory has been further expanded to include forward premia, capital inflows, volatility of capital flows and central bank intervention as determining the exchange rate behaviour. The theoretical model so generated can be expressed as follows:

$$e_t = \gamma + \delta(m_t - m_t^*) + \phi(y_t - y_t^*) + \alpha(i_t - i_t^*) + \beta(\pi_t - \pi_t^*) + \eta(tb_t - tb_t^*) + \theta(ca_t - ca_t^*)$$
$$+ \nu cap_t + \rho vol_t + \omega fdpm_t + \psi of_t + \xi int_t + \mu_t$$

where cap_t = capital inflow

vol_t = volatility of capital flows

$fdpm_t$ = 3-month forward premia

of_t = order flow

int_t = central bank intervention

The additional signs are as follows: $\theta > 0$; $\nu < 0$; $\rho >$ or < 0; $\omega > 0$; $\psi >$ or < 0; and $\xi >$ or < 0. The expected signs can be summarized as follows:

Expected Signs of Independent Variables Dependent Variable: e_t	
(price of foreign currency in terms of domestic currency)	
Variables	Expected Sign
$i_t - i_t^*$	+/-
$y_t - y_t^*$	-
$m_t - m_t^*$	+
$\pi_t - \pi_t^*$	+
$tb - tb^*$	-
$ca - ca^*$	+
$fdpm_t$	+
$capflow_t$	-
vol_t	+/-
of_t	+/-
int_t	+/-

2. Exchange Rate Models: Empirical Results

The previous section discusses sequentially the theoretical models that potentially determine exchange rate behaviour. The empirical

performance of these theoretical models in forecasting and explaining exchange rate behaviour is crucial in determining the superiority of one theory over the other. A caveat, of course, is that if a theory can explain the behaviour of the exchange rate better than others, it does not necessarily imply that it can also forecast exchange rates with relatively greater accuracy, and vice versa.

Some of the empirical findings for the various theoretical frameworks are given below. An extensive survey of literature is also available in Dornbusch (1990), Frankel and Rose (1994), Taylor (1995), Cuthbertson (1996), Sarno and Taylor (2002), Gandolfo (2006) and Schmidt (2006). The main conclusions drawn from the survey of literature are summarized as under.

(i)   Empirics: Purchasing Power Parity, Monetary and Portfolio Balance Models

Frenkel (1976) suggests that PPP holds in the long-run but not in short-run because of price stickiness in goods market. However, stationarity of the variables is not tested and the fact that exchange rate and prices are endogenous is not taken into account.

Recent studies that overcome these shortcomings like Johnson (1990), Kong (2000), Lothian and Mc Carthy (2001), Kleijn and Dijk (2001) and Bahrumshah, Sen and Ping (2003), Diaz (2003), also find that PPP is a long-run phenomenon. Reitz (2002) studied the performance of PPP during periods of central bank intervention and found that PPP is not strengthened during intervention. On the other hand, many other studies like Jacobson, Lyhagen, Larsson and Nessen (2002), Cheung, Chinn and Pascual (2004) find that PPP is not a common phenomenon even in the long-run. Hence the evidence in favour of the PPP theory is mixed. In another strand of work on modelling the exchange rate, Apte et al. characterize the equilibrium exchange rate in a general equilibrium economy and show that standard regressions or cointegration tests of PPP suffer from missing variable biases and ignore variations in risk aversion across countries and overtime.

Early studies which modelled exchange rates using the flexible price monetary model such as Frenkel (1976), Bilson (1978), Hodrick (1978), Putnam and Woodbury (1980), and Dornbusch (1984) support the performance of the flexible price monetary model in modelling and forecasting exchange rates. Subsequent studies by Frankel (1979), Driskill and Sheffrin (1981) and Taylor (1995), however, fail to support the performance of the flexible price monetary model and real interest differential model in terms of explaining the exchange rate behaviour.

Empirical studies on the sticky price version of the monetary model show mixed results and suggest weak performance in explaining exchange rate movements. On one hand, studies like Driskill (1981) show that the sticky price monetary model explains exchange rates well, while studies such as Backus (1984) show that the sticky price monetary model fails to explain the exchange rate behaviour.

Buiter and Miller (1981) proposed an extended version of the sticky price monetary model, which included trend inflation, which was put to test by Barr (1989) and Smith and Wickens (1986, 1990). These studies support the extended version of the model, in terms of forecasting exchange rates.

The empirical literature suggests that there is no consensus among economists on the appropriate monetary model that explains exchange rates well. It is also observed that the in-sample predictive performance of monetary models was good in the years following the breakdown of the Bretton Woods system (see e.g. Frankel 1976, 1979; Bilson 1978), but their performance collapsed in the 1980s.

Meese and Rogoff (1983) recognized the limitations of testing the in-sample predictive accuracy (that simply tell us that the model fits the data reasonably well), and examined the out-of-sample predictive performance of the monetary models vis-à-vis the simple random-walk model. They observed that the forecasts using models based on economic fundamentals were in all cases worse than a random walk model. In response to this study, some of the studies tried to improve the forecasting

performance of the monetary models using advanced techniques. Some other studies gave up the monetary model and tried to improve the forecasting performance of exchange rates using pure technical time series techniques. There were also studies that tried to explain the movement of the exchange rate through a suitable economy-wide macroeconometric model capable of capturing all complex associations between exchange rate and other variables. For example, using an economy-wide macro econometric model for Italy, Gandolfo and Padaon (1990) and Gandolfo (2006) have shown that an economy-wide model beats the random walk (which in turn outperformed the traditional structural models) in out-of-sample forecasts of the exchange rate. There were also many studies, which investigated the reasons for the failure of monetary models.

Meese (1990) attributed the failure of monetary models to weaknesses in their underlying relationships such as the PPP condition, the instability found in money demand functions and expectations that agents' forecasts do not obey the axioms of rational expectations. Meese and Rose (1991) observed that the non-linearity in money demand functions is not responsible for failure of monetary models in explaining and forecasting exchange rates. This is because the statistical performance of the monetary model could not be improved using a non-linear money demand function.

Flood and Rose (1995) compare the volatility in the exchange rate and in economic fundamentals for periods of fixed and floating rates. While exchange rates exhibit substantial volatility in the floating rate periods, a corresponding increase in volatility was not observed in the economic fundamentals. This led Flood and Rose to speculate that it is unlikely that any exchange rate model based only on economic fundamentals will prove adequate. This view is also supported by Baxter and Stockman (1989) who further explain that there are speculative forces in the foreign exchange market that are important in determining exchange rates, which are not reflected in the behaviour of macroeconomic variables.

Studies by MacDonald and Taylor (1991, 1993, 1994), Choudhary and Lawler (1997), Diamandis, Georgoutsos and Kouretas (1998), Mark and Sul (2001) attributed monetary models to be long-run equilibrium phenomena. Empirical literature (e.g. Chinn and Meese, 1995; Taylor, 1995; Neely and Sarno, 2002; Sarno and Taylor, 2002) suggests that over short horizons of one to three years, monetary fundamentals generally do not predict changes in the spot rate. However, over longer horizons of four to five years, fundamentals do provide predictive power for some currencies (Kim and Mo, 1994; Mark, 1995; Chinn and Meese, 1995). These studies examine the predictive power of structural exchange rate models using parametric and non-parametric techniques and find that the random walk model outperforms monetary models in forecasting exchange rates in the short-run. But in the long-run, the monetary model outperforms the random walk model.

Some of the recent empirical studies on the monetary model performance have also exhibited mixed results. Studies have shown that inclusion of exchange rate expectations and the degree of openness in the Dornbusch sticky price monetary model improves forecast ability of the monetary model (Zita and Gupta, 2007). While models involving Taylor-rule interest rate reaction functions forecast well when there is exchange rate targeting, the random walk, however, remains unbeaten in terms of forecasting ability (Molodtsova and Papell, 2007). Alquist and Chinn (2008), however, report that structural models do not perform as poorly as suggested by earlier studies.

Recognizing the fact that monetary models do work in the long-run, studies have also attempted to obtain a combined forecast of all the monetary models and compared them with the benchmark obtained by the random walk model and the historical average return. Empirical results so obtained suggest the superiority of combined forecasts over benchmarks and generally yield better results than a single model (Lam et. al, 2008).

For the portfolio balance model (PBM) of exchange rate determination, not much empirical literature is available because of data limitations,

which restricts the empirical application of the portfolio balance model. The earlier studies that estimated the log-linear version of the reduced form portfolio balance model such as Branson, Halttunen and Masson (1977), Bisignano and Hoover (1982) and Dooley and Isard (1982) find dismal performance of the portfolio balance model in explaining exchange rate behaviour. Studies by Frankel (1982a, b) and Rogoff (1984) did not find any support in favour of the model. On the other hand, some empirical support for the portfolio balance model is provided by Backus (1984), Lewis (1988) and Dominguez and Frankel (1993).

(ii) Empirics: Capital Flows, Forward Premium, Central Bank Intervention

Dua and Sen (2009) find that an increase in both net capital inflows and their volatility lead to an appreciation of the exchange rate, and that they jointly explain a large part of the variations in exchange rate in the Indian economy. Kohli (2001) analyses the effect of capital flows in the Indian context and finds that the inflow of foreign capital results in a real appreciation of the exchange rate.

Calvo, Leiderman and Reinhart (1993) and Edwards (1999a), analyze the impact of capital flows on the exchange rate for Latin American and Asian countries and find that an increase in capital flows cause the exchange rate to appreciate. However, the degree of appreciation or the strength of the relation between capital flows and the exchange rate may vary across countries and time.

Clarida and Taylor (1997) examine the ability of the forward exchange rate in forecasting exchange rates and argued that failure of the forward exchange rate in predicting future spot rates does not imply that forward exchange rates don't contain valuable information for forecasting exchange rates. Using the linear Vector Error Correction Model (VECM), they extract information from the term structure of forward premia and produce out-of-sample forecasts that outperform the forecasts from the random walk model. Clarida, Sarno, Taylor and Valente (2003) use the Markov Switching Intercept Heteroskedastic VECM model for the term structure

of forward premia and find that this model outperforms the linear VECM and the random walk model in terms of its forecasting performance. More recently, Della Corte, Sarno and Tsiakas, (2007) examine the predictive ability of exchange rate models based on lagged values of the forward premium and other macroeconomic variables, as compared to the random walk model. The study finds that the predictive ability of forward exchange rate premia has substantial economic value in predicting exchange rates compared to a random walk model.

With respect to the effect of intervention, Dominguez and Frankel (1993) examine its impact on exchange rates using primary survey data along with secondary intervention data. They find that intervention has a significant effect on exchange rates. Neely (2000) surveyed central bankers who conduct intervention, and reports that intervention is effective in changing exchange rates. Fatum and King (2005) analyse the effects of Canadian intervention and find that intervention does systematically affect exchange rates and is associated with reduced volatility in exchange rates.

Other recent studies that use high frequency data (see e.g. Payne and Vitale, 2003; Dominguez 2003a,b) form a consensus that intervention has significant effects on exchange rates, especially in the very short-run. Reitz (2002) concludes that the predictive power of forecasting methods increases in the case of intervention in the foreign exchange market by the central bank, relative to cases when the central bank does not intervene.

(iii) Empirics: Microstructure Theory

The micro structure theory of exchange rates gained popularity since the late 1990s when it was empirically tested that information in order flows drives exchange rates (Evans and Lyons, 1999; Luo, 2001; Medeiros, 2005). In a landmark study by Evans and Lyons (2001), three sources of exchange rate variation were identified, i.e. direct effect of changes in macro fundamentals, indirect effects of changes in macro fundamentals via order flow and order flow not related to macro news. The use of a

pseudo GARCH model with high frequency hourly data reveals that the news of intervention increases the effect of order flow on the exchange rate (Scalia, 2006). Recognizing that news effects are not common knowledge and are not impounded in exchange rates directly, Evans and Lyons (2007) have tried to quantify the effect of news on exchange rates. They observe that two-thirds of the effect of macro news on exchange rates is transmitted via order flow.

Bjonnes and Rime (2003) find that private information plays an important role in the foreign exchange market and has a permanent effect on exchange rates. Order flows carrying this private information are hence important in determining exchange rates. Marsh and Rourke (2005) find that order flows from profit seeking financial institutions are positively correlated with exchange rate and flows from non-financial corporates are negatively correlated. They also find that the impact of order flow on exchange rate increases, as probability of flow from the informed source increases. These views are also supported by Menkhoff and Schmeling (2006) who find that order flows coming from centres of political and financial decision making influence exchange rates permanently.

Mizuno, Takayasu and Takayasu (2004) find that traders in the foreign exchange market use past information on exchange rates to carry out transactions. This feedback of information from traders is responsible for autocorrelation in exchange rate changes and volatility.

The survey of literature based on microstructure theory by Sager and Taylor (2006) critically examines the role of order flows in forecasting exchange rates. They indicate that inter-dealer order flows can explain exchange rates contemporaneously, but cannot help to improve out-of-sample exchange rate forecasts. This is because order flow data comes with publication lags. These results cast doubt on the practical value of order flow data for traders in the foreign exchange market.

Another aspect of asset market approach that has been empirically tested is whether there are systematic and meaningful effects of macroeconomic news on exchange rates. Love and Paynes (2002) find

that the order flow is more informative around macroeconomic data releases. Additionally, recent studies like Galati and Ho (2003) and Andersen et. al (2003) report evidence of an asymmetric response of exchange rates to news. Markets respond differently to positive or negative news from the same category. This evidence once again contradicts the proposition of the asset market theory to exchange rate determination (Schmidt, 2006). These results indicate that the response of traders in the foreign exchange market to macroeconomic announcements or data releases influence exchange rates, via order flows.

(iv) Empirics: Time Series and Non-Linear Models

The general failure of structural models in explaining movements in the spot exchange rate has led researchers to consider time series and non-linear models. Vector Autoregression Models, Vector Error Correction Models and Bayesian Vector Sutoregression formulations of the monetary models of exchange rate determination for developed countries are known to have produced forecasts which beat the random walk (see. e.g. MacDonald and Taylor (1993, 1994) and Chaudhry and Lawler (1997) for VAR; Chen and Leung (2003) for BVAR and BVECM; Zita and Gupta (2007) for VAR, VECM, BVAR and BVECM). Goldberg and Frydman (2001) maintain that the existing macroeconomic exchange rate models are able to explain monthly or quarterly movements of exchange rates for some sub-periods reasonably well while for others their explanatory power completely disappears. This finding led them to suggest that empirical exchange rate models with fixed coefficients are unlikely to perform well either in-sample or out-of-sample. Analyzing the relationship between exchange rates and fundamentals in a non-linear framework, De Grauwe and Vansteenkiste (2001) also find significant switches in the coefficients.

Sarno (2003) observes that a non-linear framework produces both better point forecasts and measure of uncertainty surrounding the forecasts. They further observe that the Markov Switching Intercept Heteroscedastic (MSIH) VECM gives more accurate results than the

random walk. Moreover, MSIH outperforms the linear VECM. Studies such as Cheung, Cinn and Pascual (2004) have reported that model specifications/currency combinations that produce accurate forecasts at certain horizons may not do so at other horizons. Similarly, some models or specifications may forecast certain exchange rates well, but not others. In other words there is no unique model or specification that may forecast well for all currencies and at all time horizons. It has also been empirically tested that while linear models outperform at short forecast horizons, non-linear models dominate at longer horizons (Altaville and Grauwe, 2006).

Many studies like Diebold, Gardeazabal and Yilmaz (1994), Hock and Tan (1996), and Trapletti, Geyer and Leisch (2002) analyse the dynamics of the foreign exchange market and see whether there is co-movement between different exchange rates. They report that observing the trading strategy in the foreign exchange market for a particular currency may provide additional information about the movement of another currency and thus produce better out-of-sample forecasts. However, their forecast performance results are not encouraging.

The common conclusion of these studies is that time series methods can produce accurate forecasts only in the very short-run but not in the medium or long-run. On the other hand, studies that use fractional integration or fractional cointegration methods (e.g. Baillie and Bollerslev, 1994; Belkacem, Meddeb and Boubaker, 2005; Chortareas, Nankewis and Jiang, 2007) support the view that different exchange rates may be tied to each other through a long memory process, and that it is possible to predict one exchange rate, given the observations of the other.

The literature on modelling or forecasting exchange rate volatility uses ARCH, GARCH, FIGARCH, E-GARCH models (e.g. Martens, 2001; Wang, Fawson, Barett and Mc Donald, 2001; Bauwens and Sucarat, 2006; Chortareas, Nankervis and Jiang, 2007). There is a consensus that using higher frequency data improves the forecast performance of exchange rate volatility over that of lower frequency data.

3. Summing up: Theory and Empirics

In sum, several exchange rate models available in the literature have been tested during the last two and a half decades. No particular model seems to work best at all times/horizons. Monetary models based on the idea of fundamental driven exchange rate behaviour work best in the long-run, but lose their predictability in the short-run to naïve random walk forecasts. The volatility of exchange rates also substantially exceeds that of the volatility of macro economic fundamentals, thus providing further evidence of weakening fundamental-exchange rate link. A combination of the different monetary models, however, at times gives better results than the random walk. Order flows also play an important role in influencing the exchange rate. Keeping in view all the above results of the literature, this study attempts to develop a model for the rupee-dollar exchange rate taking into account all the different monetary models along with the microstructure models incorporating order flow, as well as capital flows, forward premium and central bank intervention.

SECTION VI

Modelling and Forecasting the Exchange Rate: Econometric Methodology

This study employs Vector Autoregressive (VAR) and Bayesian Vector Autoregressive (BVAR) models to estimate the monetary model of the exchange rate (Re/$) and its augmented variants. Tests for nonstationarity are first conducted followed by tests for cointegration and Granger causality. Finally, the VAR and BVAR models are estimated and tested for out-of-sample forecast accuracy. This section briefly describes the tests for nonstationarity, VAR and BVAR modelling, cointegration and Granger causality and tests for out-of-sample forecast accuracy.

1. Tests for Nonstationarity

The classical regression model requires that the dependent and independent variables in a regression be stationary in order to avoid the

problem of what Granger and Newbold (1974) called 'spurious regression' characterized by a high R^2, significant t-statistics but results that are without economic meaning. A stationary series exhibits mean reversion, has a finite, time invariant variance and a finite covariance between two values that depends only on their distance apart in time, not on their absolute location in time. If the characteristics of the stochastic process that generated a time series change overtime, i.e. if the series is nonstationary, it becomes difficult to represent it over past and future intervals of time by a simple algebraic model. Thus the first econometric exercise is to test if all the series are nonstationary or have a unit root.

A battery of unit root tests now exists to discern whether a time series exhibits I(1) (unit root) or I(0) (stationary) behaviour. In this study, we employ the augmented Dickey-Fuller (ADF) test (1979, 1981) and its more powerful variant, the Dickey-Fuller Generalized Least Squares (DF-GLS) test proposed by Elliot, Rothenberg and Stock (1996). These two tests share the same null hypothesis of a unit root. An alternative test is that proposed by Kwiatkowski et al. (1992) which has a null hypothesis of stationarity. If two of these three tests indicate nonstationarity for any series, we conclude that the series has a unit root. The KPSS test is also often used in conjunction with these tests to investigate the possibility that a series is fractionally integrated (that is, neither I(1) nor I(0)) although this is not explored in this study.

To test if a sequence y_t contains a unit root using the ADF procedure, three different regression equations are considered.

$$\Delta y_t = \alpha + \gamma y_{t-1} + \theta t + \sum_{i=2}^{P} \beta_t \, \Delta y_{t-i+1} + \varepsilon_t \qquad (1)$$

$$\Delta y_t = \alpha + \gamma y_{t-1} + \sum_{i=2}^{P} \beta_t \, \Delta y_{t-i+1} + \varepsilon_t \qquad (2)$$

$$\Delta y_t = \gamma y_{t-1} + \sum_{i=2}^{P} \beta_t \, \Delta y_{t-i+1} + \varepsilon_t \qquad (3)$$

The most general form of the D-F test (equation 1) allows for both a drift term and a deterministic trend; the second excludes the deterministic trend; and the third does not contain an intercept or a trend term. In all three equations, the parameter of interest is . If $\gamma=0$, the y_t sequence has a unit root. The null is therefore $\gamma=0$ against the alternative $\gamma\neq0$. The estimated t-statistic is compared with the appropriate critical value in the Dickey-Fuller tables to determine if the null hypothesis is valid. The critical values are denoted by τ_τ, τ_μ and τ for equations (1), (2) and (3) respectively. The D-F test presumes the existence of white noise errors in the regression, hence lags of the dependent variable are added to the regressions to whiten the errors.

Following Doldado, Jenkinson and Sosvilla-Rivero (1990), a sequential procedure is used to test for the presence of a unit root when the form of the data-generating process is unknown. This involves testing the most general model (equation 1) first and following various tests, moving to the most parsimonious model (equation 3). Such a procedure is necessary since including the intercept and trend term reduces the degrees of freedom and the power of the test implying that we may conclude that a unit root is present when, in fact, this is not true. Further, additional regressors increase the absolute value of the critical value making it harder to reject the null hypothesis. On the other hand, inappropriately omitting the deterministic terms can cause the power of the test to go to zero (Campbell and Perron, 1991).

Compared to the ADF test, the DF-GLS test has substantially improved power when an unknown mean or trend is present (Elliot et al., 1996). The DF-GLS procedure relies on demeaning and/or detrending a series prior to the implementation of the auxiliary ADF regression as follows:

$$y^d_t = y_t - \varphi'z_t \qquad\qquad (4)$$

For detrending, $z_t=(1,t)'$ and φ_0 and φ_1 are estimated by regressing $[y_1,(1-\bar{\rho}L)y_2,.....(1-\bar{\rho}L)y_T]$ on $[z_1,(1-\bar{\rho}L)z_2,....(1-\bar{\rho}L)z_T]$ where $\bar{\rho}=1+(\bar{c}/T)$

with $\bar{c}$ = -13.5, and L is the lag operator. For demeaning, z_t=(1)′ and the same regression is run with $\bar{c}$= -7.0. (see Elliott et al., 1996 for details). The augmented Dickey-Fuller regression is then computed using the y^d_t series:

$$\Delta y^d_t = \alpha + \gamma y^d_{t-1} + \theta t + \sum_{i=2}^{P} \beta_t \Delta y^d_{t-i+1} + \varepsilon_t \qquad (5)$$

Critical values for the GLS detrended test are taken from Elliott et al. (1996). Critical values for the GLS demeaned test are the same as those applicable to the no-constant, no-trend ADF test.

In contrast to the ADF and DF-GLS tests, the KPSS (Kwiatkowski et al., 1992) semi-parametric procedure tests the null hypothesis of level (with test statistic-η_μ) or trend stationarity (with test statistic η_τ) against the unit root alternative. The KPSS test starts with the following model:

$$y_t = \beta t + r_t + \varepsilon_t \qquad (6)$$

where ε_t is a stationary process, r_t is a random walk given by $r_t = r_{t-1}+\mu_t$ and $\mu_t \sim N(0,\sigma^2_\mu)$. The initial value of r_t, r_0, is assumed fixed and therefore serves as the intercept. The null hypothesis of stationarity is $\sigma^2_\mu = 0$ (or r_t is a constant). Under the null hypothesis, $\beta=0$ implies y_t is level stationary and $\beta\neq0$ means that it is trend-stationary (viz., stationary around a level r_0). The test statistic is as follows:

$$\eta_\mu(\eta_\tau) = T^{-2} \sum_{t=1}^{T} S^2_t / s^2(l)$$

This is derived from the residuals from the regression of yt on a constant (a constant and trend), et, t=1,2,...,T. The partial sum process of the residuals is defined as:

$$S_t = \sum_{i=1}^{t} e_i \qquad \text{for } t = (1,...T)$$

The long run variance of the partial error process is defined by KPSS as

$$\sigma^2 = \lim_{T \to \infty} T^{-1} E(S_T^2).$$

A consistent estimator of σ^2, $s^2(l)$, can be constructed from the residuals e_t as

$$s^2(l) = T^{-1} \sum_{t=1}^{T} e_t^2 + 2T^{-1} \sum_{s=1}^{l} w(s,l) \sum_{t=s+1}^{T} e_t e_{t-s}$$

where $w(s,l)$ is an optional lag window that corresponds to the selection of a spectral window. KPSS employ the Bartlett window, $w(s,l) = 1-s/(l+1)$ as in Newey and West (1987), which ensures the non-negativity of $s^2(l)$. The lag truncation parameter l corrects for residual serial correlation. If the residual series are independently and identically distributed, a choice of $l = 0$ is appropriate.

2. VAR and BVAR Modelling

In this study, we employ multivariate forecasting models in the Vector Autoregressive (VAR) and Bayesian VAR framework. A Vector Autoregressive (VAR) model does not require specification of the projected values of the exogenous variables as in a simultaneous equations model. It uses regularities in the historical data on the forecasted variables. Economic theory only selects the economic variables to include in the model. An unrestricted VAR model (Sims 1980) is written as follows:

$$y_t = C + A(L)y_t + \varepsilon_t,$$

where y: (nx1) vector of variables being forecast; A(L): (nxn) polynomial matrix in the back-shift operator L with lag length p, i.e. $A(L) = A_1 L + A_2 L^2 + \ldots\ldots\ldots + A_p L^p$; C: (nx1) vector of constant terms; and ε: (nx1) vector of white noise error terms.

The model uses the same lag length for all variables. A serious drawback of the VAR model, however, is that overparameterisation produces multicollinearity and loss of degrees of freedom that can lead to inefficient estimates and large out-of-sample forecasting errors. A possible solution is to exclude insignificant variables and/or lags based on statistical tests.

An alternative approach to overcome over-parameterisation uses a Bayesian VAR model as described in Litterman (1981, 1982), Doan, Litterman and Sims (1984), Todd (1984), Litterman (1986), and Spencer (1993). Instead of eliminating longer lags and/or less important variables, the Bayesian technique imposes restrictions on these coefficients on the assumption that these are more likely to be near zero than the coefficients on shorter lags and/or more important variables. If, however, strong effects do occur from longer lags and/or less important variables, the data can override this assumption. Thus, the Bayesian model imposes prior beliefs on the relationships between different variables as well as between own lags of a particular variable. If these beliefs (restrictions) are appropriate, the forecasting ability of the model should improve. The Bayesian approach to forecasting therefore provides a scientific way of imposing prior or judgmental beliefs on a statistical model. Several prior beliefs can be imposed so that the set of beliefs that produces the best forecasts is selected for making forecasts. The selection of the Bayesian prior, of course, depends on the expertise of the forecaster.

The restrictions on the coefficients specify normal prior distributions with means zero and small standard deviations for all coefficients with decreasing standard deviations on increasing lags, except for the coefficient on the first own lag of a variable that is given a mean of unity. This so-called "Minnesota prior" was developed at the Federal Reserve Bank of Minneapolis and the University of Minnesota.

The standard deviation of the prior distribution for lag m of variable j in equation i for all i, j, and m -- $S(i, j, m)$ can be expressed as function of a small number of hyperparameters: w, d, and a weighting matrix

f(i,j). This allows the forecaster to specify individual prior variances for a large number of coefficients based on only a few hyperparameters. The standard deviation is specified as follows:

$$S(i, j, m) = \{w_x g(m)_x f(i, j)\} s_i / s_j;$$

$$f(i, j) = 1, \quad \text{if } i = j;$$

$$= k \quad \text{otherwise } (0 < k < 1); \text{ and}$$

$$g(m) = m^{-d}, d > 0.$$

The term s_i equals the standard error of a univariate autoregression for variable *i*. The ratio s_i/s_j scales the variables to account for differences in units of measurement and allows the specification of the prior without consideration of the magnitudes of the variables. The parameter w measures the standard deviation on the first own lag and describes the overall tightness of the prior. The tightness on lag m relative to lag 1 equals the function $g(m)$, assumed to have a harmonic shape with decay factor *d*. The tightness of variable j relative to variable i in equation i equals the function *f(i, j)*. Examples of selection of hyperparameters are given in Dua and Ray (1995), Dua and Smyth (1995), Dua and Miller (1996) and Dua, Miller and Smyth (1999); Dua, Raje and Sahoo (2003, 2008).

The BVAR method uses Theil's (1971) mixed estimation technique that supplements data with prior information on the distributions of the coefficients. With each restriction, the number of observations and degrees of freedom artificially increase by one. Thus, the loss of degrees of freedom due to overparameterisation does not affect the BVAR model as severely.

Another advantage of the BVAR model is that empirical evidence on comparative out-of-sample forecasting performance generally shows that the BVAR model outperforms the unrestricted VAR model. A few examples are Holden and Broomhead (1990), Artis and Zhang (1990), Dua and Ray (1995), Dua and Miller (1996), Dua, Miller and Smyth (1999), Dua and Miller (2006), Dua, Raje and Sahoo (2003, 2008).

The above description of the BVAR models assumes that the variables are stationary. If the variables are nonstationary, they can continue to be specified in levels in a BVAR model because as pointed out by Sims et. al (1990, p.136) '......the Bayesian approach is entirely based on the likelihood function, which has the same Gaussian shape regardless of the presence of nonstationarity, [hence] Bayesian inference need take no special account of nonstationarity'. Furthermore, Dua and Ray (1995) show that the Minnesota prior is appropriate even when the variables are cointegrated.

In the case of a VAR, Sims (1980) and others, e.g. Doan (1992), recommend estimating the VAR in levels even if the variables contain a unit root. The argument against differencing is that it discards information relating to comovements between the variables such as cointegrating relationships. The standard practice in the presence of a cointegrating relationship between the variables in a VAR is to estimate the VAR in levels or to estimate its error correction representation, the vector error correction model, VECM. If the variables are nonstationary but not cointegrated, the VAR can be estimated in first differences.

3. Cointegration and Granger Causality

The possibility of a cointegrating relationship between the variables is tested using the Johansen and Juselius (1990, 92) methodology. Since the Johansen procedure is well known in the time series literature, a detailed explanation is not presented here.

If the presence of cointegration is established, the concept of Granger causality can also be tested in the VECM framework. For example, if two variables are cointegrated, i.e. they have a common stochastic trend, causality in the Granger (temporal) sense must exist in at least one direction (Granger, 1986; 1988). Since Granger causality is also a test of whether one variable can improve the forecasting performance of another, it is important to test for it to evaluate the predictive ability of a model.

Granger-causality with respect to a particular variable can be tested by a joint test of statistical significance of the lagged error correction term and the lags of that explanatory variable.

4. Evaluation of Forecasting Models

Evaluation of the forecasting models is based on RMSE, Theil's U (Theil, 1966), and the Diebold-Mariano (1995) test. The models are initially estimated using monthly data over the period July 1996 to December 2006 and tested for out-of-sample forecast accuracy from January 2007 to June 2008. Recursive forecasts are generated from one-through twelve-months-ahead and out-of-sample forecast accuracy of monetary model and its augmented variants is assessed. The overall average of the U statistic and the RMSE for up to twelve-months-ahead is also calculated to gauge the accuracy of a model.

The forecast accuracy of the VAR technique vs the BVAR method is also evaluated.

To test for accuracy, the Theil coefficient is used that implicitly incorporates the naïve forecasts as the benchmark. If A_{t+n} denotes the actual value of a variable in period (t+n), and $_tF_{t+n}$ the forecast made in period t for (t+n), then for T observations, the Theil U-statistic is defined as follows:

$$U = [\Sigma(A_{t+n} - {_t}F_{t+n})^2/\Sigma(A_{t+n} - A_t)^2]^{0.5}.$$

The U-statistic measures the ratio of the Root Mean Square Error (RMSE) of the model forecasts to the RMSE of naive, no-change forecasts (forecasts such that $_tF_{t+n} = A_t$). The RMSE is given by the following formula:

$$RMSE = [\Sigma(A_{t+n} - {_t}F_{t+n})^2/T]^{0.5}.$$

A comparison with the naïve model is, therefore, implicit in the U-statistic. A U-statistic of 1 indicates that the model forecasts match the performance of naïve, no-change forecasts. A U-statistic >1 shows that the naïve

forecasts outperform the model forecasts. If U is <1, the forecasts from the model outperform the naïve forecasts. The U-statistic is, therefore, a relative measure of accuracy and is unit-free.

Since the U-statistic is a relative measure, it is affected by the accuracy of the naïve forecasts. Extremely inaccurate naïve forecasts can yield U<1, falsely implying that the model forecasts are accurate. This problem is especially applicable to series with trend. The RMSE, therefore, provides a check on the U-statistic and is also reported.

The Diebold-Mariano test compares the forecast performance of alternative models, i.e., it tests the null hypothesis of no difference of the accuracy of two competing forecasts. Let $\hat{Y}_{1t}$ and $\hat{Y}_{2t}$, where $t = 1,2...n$, be a pair of h-step ahead forecasts of Y_t and e_{1t} and e_{2t} be the associated forecast errors. If g(e) be a function (e.g., mean square error) of the forecasts errors, then the null hypothesis of equality of expected forecast performance is: $E[g(e_{1t}) - g(e_{2t})] = 0$. Define $d_t = g(e_{1t}) - g(e_{2t})$; $t = 1,2,...n$. For optimal h-step ahead forecasts, the sequence of forecasts errors follows a moving average process of order h-1. Therefore, it is assumed that for h-step ahead forecasts, all autocorrelations of order h or higher of the sequence d_t are zero. Then the variance of

$$\overline{d} \ (= n^{-1} \sum_{t=1}^{n} d_t) \quad \text{is, asymptotically,}$$

$$V(\overline{d}) \overset{a}{\approx} n^{-1} \left[\gamma_o + 2 \sum_{k=1}^{h-1} \gamma_k \right],$$

where γ_k is the kth autocovariance of d_t. This autocovariance can be estimated by

$$\hat{y}_k = n^{-1} \sum_{t=k+1}^{n} (d_t - \overline{d})(d_{t-k} - \overline{d}).$$

The Diebold-Mariano test statistic is given by

$$S_1 = \left[\hat{V}(\bar{d}) \right]^{-1/2} \bar{d}$$

where $\hat{V}(\bar{d})$ is the estimated variance of $\bar{d}$. Under the null hypothesis, Diebold-Mariano test statistic has an asymptotic standard normal distribution.

Harvey et. al (1997) note that the Diebold-Mariano test could be seriously over-sized as the prediction horizon, h, increases. They therefore provide a modified Diebold-Mariano test statistic

$$S_1^* = \left[\frac{n + 1 - 2h + n^{-1}h(h-1)}{n} \right]^{-1/2} S_1$$

Harvey et. al also recommend a further modification of comparing the statistics with critical values from the Student's t distribution with (n-1) degrees of freedom, rather than from the standard normal distribution.

5. Summary of Steps in Econometric Estimation

In sum, the study proceeds as follows. First, the series are tested for the presence of a unit root using the augmented Dickey-Fuller, DF-GLS and KPSS tests.

Second, multivariate models (Models 2 through 4) described in the previous section on theoretical models are estimated using the VAR and BVAR techniques. Since Model 2 is the monetary model, Models 3 and 4 examine if the forecast performance of the monetary model can be improved by including additional variables. To estimate VAR models, if all the variables are nonstationary and integrated of the same order, the Johansen test is conducted for the presence of cointegration. If a cointegrating relationship exists, the VAR model can be estimated in levels.

Tests for Granger causality are also conducted in the VECM framework to evaluate the forecasting ability of the model. Lastly, Bayesian vector autoregressive models are estimated that impose prior beliefs on the relationships between different variables as well as between own lags of a particular variable. If these beliefs (restrictions) are appropriate, the forecasting ability of the model should improve. Thus, the performance of the VAR models against the corresponding BVAR versions is also assessed.

SECTION VII

Estimation and Evaluation of Alternative Forecasting Models

The models discussed in the earlier Sections have been estimated and evaluated in this Section. The alternative models are estimated from July 1996 through December 2006. The out-of-sample forecasting performance of the alternative models is evaluated over January 2007 to June 2008 and also over the sub-period January 2007 to January 2008 to take into account the turning point in January 2008. Figure 1 shows the movements in the Re/$ rate in the period under study: July 1996

Figure 1: Exchange Rate – Re/$
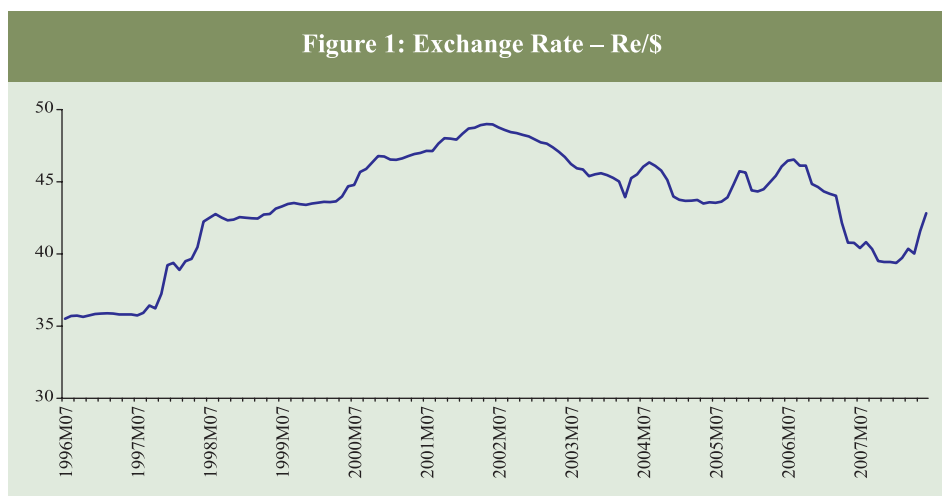
through June 2008. Table 7.1 reports the summary statistics of the exchange rate over the full period and the sub-periods. These statistics, along with the plot indicate turning points in May 2002 (maximum of Rs. 49/$), January 2007 (maximum of Rs. 44.33/$), and January 2008 (minimum of Rs. 39.37).

Table 7.1: Summary Statistics for Exchange Rate				
Time Period	Mean	Maximum	Minimum	Standard Deviation
Jul 1996 - Jun 2008	43.52	49.00 (May 2002)	35.51 (Jul 1996)	3.73
Jul 1996 - Dec 2006	43.86	49.00 (May 2002)	35.51 (Jul 1996)	3.82
Jan 2007 – Jun 2008	41.12	44.33 (Jan 2007)	39.37 (Jan 2008)	1.69
Jan 2007 - Jan 2008	41.20	44.33 (Jan 2007)	39.37 (Jan 2008)	1.86
Feb 2008 - Jun 2008	40.90	42.82 (Jun 2008)	39.73 (Feb 2008)	1.28

The various models estimated in the VAR and BVAR framework are described in Section 5 and are summarized below:

1. Theoretical Models

Model 1: Naïve forecast

$$_t e_{t+n} = e_t$$

Model 2: Monetary Model

$$e_t = f[(i_t - i_t^*), (y_t - y_t^*), (m_t - m_t^*)]$$

Model 3[9]: Model 2 + other variables (inflation differential + trade balance differential + forward premium + capital inflows + volatility of capital inflows + order flow)

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[9] Current account differential is not included due to its correlation with trade balance differential.

$e_t = f((i_t\text{-}i_t^*), (y_t\text{-}y_t^*), (m_t\text{-}m_t^*), (\pi_t\text{-}\pi_t^*), (tb\text{-}tb^*), fdpm_t, cap_t, vol_t, of_t)$

Model 4: Model 3 + central bank intervention

$e_t = f((i_t\text{-}i_t^*), (y_t\text{-}y_t^*), (m_t\text{-}m_t^*), (\pi_t\text{-}\pi_t^*), (tb\text{-}tb^*), fdpm_t, cap_t, vol_t, of_t, int_t)$

Expected Signs of Variables Dependent Variable: e_t	
Variables	Expected Sign
$i_t\text{-}i_t^*$	+/-
$y_t\text{-}y_t^*$	-
$m_t\text{-}m_t^*$	+
$\pi_t\text{-}\pi_t^*$	+
$tb\text{-}tb^*$	-
$fdpm_t$	+
cap_t	
vol_t	+/-
of_t	+/-
int_t	+

The notation is as follows:

e_t	:	Log of exchange rate of India (Rs./\$)
$i_t\text{-}i_t^*$	:	Difference between Indian (domestic) and US (foreign) Treasury bill rate
$y_t\text{-}y_t^*$	:	Difference between log of Indian and US index of industrial production
$m_t\text{-}m_t^*$	:	Difference between log of Indian and US money supply
$\pi_t\text{-}\pi_t^*$	:	Difference between inflation rate of India and US
$tb\text{-}tb^*$	:	Difference between trade balance of India and US
$fdpm_t$	:	3-month forward premia
vol_t	:	Volatility of capital inflows
of_t	:	Order Flow
int_t	:	Government intervention in open market

Data definitions and sources are given in Annexure 1. Unit root tests are conducted on the above variables. Tests for the existence of a

cointegrating relationship as well for Granger causality are also undertaken for the multivariate models given above. The models are then estimated in the VAR and BVAR framework.

2. Tests for Nonstationarity

The first step in the estimation of the alternative models is to test for nonstationarity. Three alternative tests are used, i.e., the augmented Dickey-Fuller (ADF) test, the Dickey-Fuller Generalized Least Squares test and the KPSS test. If at least two of the three tests show the existence of a unit root, the series is considered as nonstationary. The tests for nonstationarity are reported monthly data from June 1996 to December 2006.

Table 7.2 reports the three tests with constant and trend. The inference at the 5% significance level is given in Table 7.3. This shows that apart from order flow and intervention, all other variables are nonstationary. Testing for differences of each variable confirms that all the variables are integrated of order one.

Table 7.2: ADF, DF-GLS and KPSS Tests (Constant and trend) July 1996 to December 2006			
VARIABLE	**ADF**	**DF-GLS**	**KPSS** (l=8)
1	2	3	4
e_t	-1.1192	-0.4147	0.346
$i_t\text{-}i_t^*$	-2.5144	-2.2992	0.227
$y_t\text{-}y_t^*$	-3.0568	-0.5383	0.317
$m_t\text{-}m_t^*$	-0.77086	-0.2207	0.354
$\pi_t\text{-}\pi_t^*$	-2.6037	-2.9580	0.116
tb-tb*	-2.5620	-3.1571	0.108
$fdpm_t$	-2.6281	-3.3942	0.054
vol_t	-3.1237	-0.7189	0.239
Δof_t	-2.5657	-8.0816	0.107
int_t	-24.184	-8.6548	0.122
Critical Value			
10%	-3.13	-3.55	0.119
5%	-3.41	-3.01	0.146
1%	-3.96	-2.72	0.216

Table 7.3: Unit Root Test Summary July 1996 to December 2006				
Variables	**ADF**	**DF-GLS**	**KPSS**	**Inference**
1	2	3	4	5
e_t	I(1)	I(1)	I(1)	I(1)
$i_t\text{-}i_t^*$	I(1)	I(1)	I(1)	I(1)
$y_t\text{-}y_t^*$	I(1)	I(1)	I(1)	I(1)
$m_t\text{-}m_t^*$	I(1)	I(1)	I(1)	I(1)
$\pi_t\text{-}\pi_t^*$	I(1)	I(1)	I(0)	I(1)
tb-tb*	I(1)	I(1)	I(0)	I(1)
$fdpm_t$	I(1)	I(1)[a]	I(0)	I(1)
vol_t	I(1)	I(1)	I(1)	I(1)
Δof_t	I(1)	I(0)	I(0)	I(0)
int_t	I(0)	I(0)	I(0)[b]	I(0)

a. Null hypothesis of unit root not rejected at 1%
b. Null hypothesis of no unit root not rejected at 1% but rejected at 5%.
This does not affect overall inference

3. Tests for Cointegration and Granger Causality

Various specifications of the theoretical Model 3 were estimated using the cointegration approach. The final model was selected based on diagnostic checking and signs of the coefficients. The empirical models selected are given below and their cointegration equations are reported in Table 7.4.

Empirical Models (based on overall fit)

Model 1: *Naïve forecast*

$$_t e_{t+n} = e_t$$

Model 2: *Monetary Model*

$$e_t = f((i_t\text{-}i_t^*), (y_t\text{-}y_t^*), (m_t\text{-}m_t^*))$$

Model 3': *Model 2 + other variables (forward premium + volatility of capital inflows + order flow)*

$$e_t = f((i_t\text{-}i_t^*), (y_t\text{-}y_t^*), (m_t\text{-}m_t^*), fdpm_t, vol_t, \Delta of_t)$$

Model 4′: *Model 3 + central bank intervention*

$e_t = f((i_t-i_t^*), (y_t-y_t^*), (m_t-m_t^*), fdpm_t, vol_t, \Delta of_t, \Delta int_t)$

Table 7.4: Cointegrating Equations (Dependent Variable: e_t) July 1996 to December 2006			
Variable	**Model 2**	**Model 3**	**Model 4**
1	2	3	4
$i_t-i_t^*$	-0.097	-0.126	-0.185
$y_t-y_t^*$	-1.061	-3.277	-4.228
$m_t-m_t^*$	2.283	5.585	6.401
$fdpm_t$	-	0.070	0.0833
vol_t	-	-2.102	-1.999

Models 1 and 2 above are the same as the theoretical versions. Model 3 has fewer independent variables compared to its theoretical counterpart. This directly feeds into Model 4 . Since the order flow and intervention variables are stationary, their sign and significance is determined in the framework of an error correction model. The empirical signs of all the variables conform to economic theory and are given below:

Empirical Signs of Variables: Model 4′ Dependent Variable: e_t	
Variables	Expected Sign
$i_t-i_t^*$	-
$y_t-y_t^*$	-
$m_t-m_t^*$	+
$fdpm_t$	+
vol_t	-
Δof_t	+
Δint_t	+

The Granger causality tests for Models 2-4 are reported in Tables 7.5-7.7. Apart from the intervention variable, all other variables Granger cause the exchange rate[10]. This result thus justifies the inclusion of all

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[10] The null hypothesis of no causality is tested up to 15% level of significance.

Exchange Rate Policy and Modelling in India

the variables that Granger cause the exchange rate since these variables can potentially improve the predictive performance of the model.

Models 2 through 4 are estimated both in the VAR and BVAR frameworks and their predictive ability is evaluated over two out-of-sample periods taking into account the turning point in January 2008: January 2007 through January 2008 and January 2007 through June 2008.

Table 7.5: Granger Causality Tests
(July 1996 to December 2006)

MODEL 2: $e_t = f((i_t - i_t^*), (y_t - y_t^*), (m_t - m_t^*)$

Null Hypothesis	Number of Lags	χ^2 [p-value]	Conclusion
1	2	3	4
e_t is not Granger caused by i_t-i_t^*	2	4.2082[.122]	Reject H_0
e_t is not Granger caused by y_t-y_t^*	2	6.6321[.036]	Reject H_0
e_t is not Granger caused by m_t-m_t^*	2	5.2722[.072]	Reject H_0

Table 7.6: Granger Causality Tests
(July 1996 to December 2006)

MODEL 3: $e_t = f((i_t - i_t^*), (y_t - y_t^*), (m_t - m_t^*), fdpm_t, vol_t, \Delta of_t)$

Null Hypothesis	Number of Lags	χ^2 [p-value]	Conclusion
1	2	3	4
e_t is not Granger caused by i_t-i_t^*	2	4.8623[.088]	Reject H_0
e_t is not Granger caused by y_t-y_t^*	2	5.9908[.050]	Reject H_0
e_t is not Granger caused by m_t-m_t^*	2	6.1741[.046]	Reject H_0
e_t is not Granger caused by $fdpm_t$	2	4.8883[.087]	Reject H_0
e_t is not Granger caused by vol_t	2	5.7506[.056]	Reject H_0
e_t is not Granger caused by Δof_t	2	2.5585[.012]*	Reject H_0

* t-statistic is from the error correction model where Δof_t has a positive sign.

Table 7.7: Granger Causality Tests			
(July 1996 to December 2006)			
MODEL 4: $e_t = f((i_t-i_t^*), (y_t-y_t^*), (m_t-m_t^*), fdpm_t, vol_t, \Delta of_t, \Delta int)$			
Null Hypothesis	Number of Lags	χ^2 [p-value]	Conclusion
1	2	3	4
e_t is not Granger caused by $i_t-i_t^*$	2	5.2473[.073]	Reject H_0
e_t is not Granger caused by $y_t-y_t^*$	2	6.4220[.040]	Reject H_0
e_t is not Granger caused by $m_t-m_t^*$	2	6.5762[.037]	Reject H_0
e_t is not Granger caused by $fdpm_t$	2	5.2624[.072]	Reject H_0
e_t is not Granger caused by vol_t	2	6.1058[.047]	Reject H_0
e_t is not Granger caused by Δof_t	2	2.4236[.017]**	Reject H_0
e_t is not Granger Caused by Δint_t	2	0.48722[.627]**	Do not reject H_0

** t-statistic from the error correction model where Δint_t has a positive sign.

4. Empirical Results: Out-of-sample Forecasts - January 2007 to January 2008

(i) VAR Models: January 2007 to January 2008

The forecast accuracy results for the VAR models are reported in Table 7.8. Table 7.9 gives the Diebold-Mariano test across various VAR models. The main results are summarized below:

a. Model 2 performs consistently better than Model 1. This implies that the monetary model outperforms the random walk model.

b. Model 3′ performs better than Model 2 for longer term forecasts. Thus, forecast accuracy can be improved by extending the monetary model to include forward premium, volatility of capital inflows and order flow.

c. Model 4′ performs better than Model 3 for longer term forecasts. Information on intervention by the central bank thus helps to improve forecasts at the longer end.

Table 7.8: VAR Models
Out-of-sample Forecast Accuracy: January 2007 to January 2008

Months ahead	No of Obs	RMSE								Theil U2					
		Model 1 3-mth avg		Model 2 3-mth avg		Model 3' 3-mth avg		Model 4 3-mth avg		Model 2 3-mth avg		Model 3' 3-mth avg		Model 4' 3-mth avg	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	13	0.722		0.508		0.447		0.446		0.704		0.619		0.618	
2	12	1.275		0.945		0.877		0.877		0.741		0.688		0.688	
3	**11**	**1.756**	**1.251**	**1.344**	**0.932**	**1.325**	**0.883**	**1.318**	**0.880**	**0.765**	**0.737**	**0.754**	**0.687**	**0.751**	**0.685**
4	10	2.252		1.694		1.719		1.712		0.752		0.763		0.760	
5	9	2.617		1.919		1.940		1.931		0.733		0.741		0.738	
6	**8**	**2.888**	**2.586**	**2.017**	**1.876**	**1.931**	**1.863**	**1.909**	**1.851**	**0.698**	**0.728**	**0.669**	**0.724**	**0.661**	**0.720**
7	7	3.302		2.189		1.900		1.870		0.663		0.576		0.566	
8	6	3.709		2.444		2.069		2.001		0.659		0.558		0.539	
9	**5**	**4.307**	**3.773**	**2.910**	**2.514**	**2.566**	**2.178**	**2.472**	**2.114**	**0.676**	**0.666**	**0.596**	**0.576**	**0.574**	**0.560**
10	4	4.852		3.407		3.242		3.132		0.702		0.668		0.645	
11	3	4.962		3.765		3.784		3.654		0.759		0.763		0.736	
12	**2**	**5.079**	**4.964**	**3.657**	**3.609**	**3.803**	**3.610**	**3.746**	**3.511**	**0.720**	**0.727**	**0.749**	**0.727**	**0.738**	**0.706**
Average		**3.143**		**2.233**		**2.134**		**2.089**		**0.714**		**0.679**		**0.668**	

Note: 1. Accuracy measures are calculated using antilog of forecast and actual values although the models are estimated using logs
2. For Model 1 (naïve forecast), Theil U2, by definition, equals one.
3. Optimal number of lags for all VAR models is 2.

Table 7.9: DM Test for VAR Models
Out-of-sample Forecast Accuracy: January 2007 to January 2008

Month Ahead	Model 1 vs Model 2	Model 2 vs Model 3'	Model 3' vs Model 4'
1	2	3	4
1	2 is better than 1[b]	3 is better than 2[c]	4 is better than 3[c]
2	2 is better than 1[b]	Indifferent	Indifferent
3	**2 is better than 1[b]**	**Indifferent**	**Indifferent**
4	2 is better than 1[a]	Indifferent	Indifferent
5	2 is better than 1[a]	Indifferent	Indifferent
6	**2 is better than 1[a]**	**Indifferent**	**Indifferent**
7	2 is better than 1[a]	3 is better than 2[c]	Indifferent
8	2 is better than 1[a]	3 is better than 2[a]	4 is better than 3[d]
9	**2 is better than 1[a]**	**3 is better than 2[a]**	**4 is better than 3[c]**
10	2 is better than 1[a]	3 is better than 2[e]	4 is better than 3[c]
11	2 is better than 1[a]	Indifferent	4 is better than 3[a]
12	**2 is better than 1[a]**	**2 is better than 3[a]**	**4 is better than 3[d]**

Note: 1. "Better" implies "yields more accurate forecasts".
2. *a* : significant at 1%; *b* : significant at 5%; *c* : significant at 10%; *d* : significant at 15%; *e* : significant at 20%

(ii) BVAR Models: January 2007 to January 2008

The forecast accuracy statistics for the BVAR models are reported in Table 7.10. The comparison of out-of-sample forecast accuracy across BVAR models is reported in Table 7.11. Overall, the results are generally similar to those obtained for VAR models.

a. Model 2 (monetary model) performs consistently better than Model 1 (random walk).

b. Model 3′ performs consistently better than Model 2. In the case of VAR models, the superiority of Model 3′ was established in the longer term forecasts whereas in the BVAR case, this is true of all forecast horizons.

c. Model 4′ performs better than Model 3′ for longer term forecasts implying that information on central bank intervention produces more accurate forecasts at the longer end.

Table 7.10: BVAR Models
Out-of-sample Forecast Accuracy: January 2007 to January 2008

Months ahead	No of Obs	RMSE								Theil U2					
		Model 1 3-mth avg		Model 2 3-mth avg		Model 3' 3-mth avg		Model 4 3-mth avg		Model 2 3-mth avg		Model 3' 3-mth avg		Model 4' 3-mth avg	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	13	0.722		0.508		0.447		0.446		0.704		0.619		0.618	
2	12	1.275		0.945		0.877		0.877		0.741		0.688		0.688	
3	11	1.756	1.251	1.344	0.932	1.325	0.883	1.318	0.880	0.765	0.737	0.754	0.687	0.751	0.685
4	10	2.252		1.694		1.719		1.712		0.752		0.763		0.760	
5	9	2.617		1.919		1.940		1.931		0.733		0.741		0.738	
6	8	2.888	2.586	2.017	1.876	1.931	1.863	1.909	1.851	0.698	0.728	0.669	0.724	0.661	0.720
7	7	3.302		2.189		1.900		1.870		0.663		0.576		0.566	
8	6	3.709		2.444		2.069		2.001		0.659		0.558		0.539	
9	5	4.307	3.773	2.910	2.514	2.566	2.178	2.472	2.114	0.676	0.666	0.596	0.576	0.574	0.560
10	4	4.852		3.407		3.242		3.132		0.702		0.668		0.645	
11	3	4.962		3.765		3.784		3.654		0.759		0.763		0.736	
12	2	5.079	4.964	3.657	3.609	3.803	3.610	3.746	3.511	0.720	0.727	0.749	0.727	0.738	0.706
Average		3.143		2.233		2.134		2.089		0.714		0.679		0.668	

Note: 1. Accuracy measures are calculated using antilog of forecast and actual values although the models are estimated using logs
2. For Model 1 (naïve forecast), Theil U2, by definition, equals one.
3. Optimal hyperparameters for all BVAR models are as follows: w=.2, d=1, k=.7
4. Optimal number of lags is 3 for Model 2 and 2 for Models 3 and 4

Table 7.11: DM Test for BVAR Models Out-of-sample Forecast Accuracy: January 2007 to January 2008			
Month Ahead	**Model 1 vs Model 2**	**Model 2 vs Model 3'**	**Model 3' vs Model 4'**
1	2	3	4
1	2 is better than 1^b	3 is better than 2^a	4 is better than 3^b
2	2 is better than 1^b	3 is better than 2^b	Indifferent
3	**2 is better than 1^b**	**3 is better than 2^a**	**Indifferent**
4	2 is better than 1^a	3 is better than 2^b	Indifferent
5	2 is better than 1^a	3 is better than 2^b	Indifferent
6	**2 is better than 1^a**	**3 is better than 2^a**	**Indifferent**
7	2 is better than 1^a	3 is better than 2^b	4 is better than 3^e
8	2 is better than 1^a	3 is better than 2^a	4 is better than 3^c
9	**2 is better than 1^a**	**3 is better than 2^a**	**4 is better than 3^c**
10	2 is better than 1^a	3 is better than 2^a	4 is better than 3^e
11	2 is better than 1^a	3 is better than 2^a	4 is better than 3^b
12	**2 is better than 1^a**	**3 is better than 2^a**	4 is better than 3^e

Note: 1. "Better" implies "yields more accurate forecasts".

2. a : significant at 1% ; b : significant at 5%; c : significant at 10%; d : significant at 15%; e : significant at 20%

(iii) VAR vs BVAR Models: January 2007 to January 2008

The Diebold Mariano test results for the comparison of VAR and BVAR models for Models 3 and 4 are reported in Table 7.12.

a. BVAR Model 3′ performs almost consistently better than the corresponding VAR model.

b. BVAR Model 4′ performs almost consistently better than the corresponding VAR model.

The above results show that BVAR models yield more accurate forecasts than the VAR models.

Table 7.12: DM Test for VAR vs BVAR Models Out-of-sample Period: January 2007 to January 2008			
Model 3'		**Model 4'**	
Month Ahead	**VAR vs BVAR**	**Month Ahead**	**VAR vs BVAR**
1	2	1	2
1	**VAR better than BVAR[b]**	**1**	**VAR better than BVAR[b]**
2	Indifferent	2	Indifferent
3	**BVAR better than VAR[c]**	**3**	**BVAR better than VAR[c]**
4	BVAR better than VAR[b]	4	BVAR better than VAR[b]
5	BVAR better than VAR[a]	5	BVAR better than VAR[a]
6	**BVAR better than VAR[a]**	**6**	**BVAR better than VAR[a]**
7	BVAR better than VAR[a]	7	BVAR better than VAR[a]
8	BVAR better than VAR[a]	8	BVAR better than VAR[b]
9	**BVAR better than VAR[a]**	**9**	**BVAR better than VAR[b]**
10	BVAR better than VAR[a]	10	BVAR better than VAR[a]
11	BVAR better than VAR[a]	11	BVAR better than VAR[a]
12	**BVAR better than VAR[a]**	**12**	**BVAR better than VAR[a]**

Note: 1. "Better" implies "yields more accurate forecasts".

2. *a* : significant at 1% ; *b* : significant at 5%; *c* : significant at 10%; *d* : significant at 15%; *e* : significant at 20%

(iv) Conclusions: January 2007 to January 2008

a. The monetary model outperforms the naïve forecast model.

b. Information on the forward premium, volatility of capital inflows and order flows improve the accuracy of forecasts. It is thus possible to beat the monetary model.

c. Including data on central bank intervention (Model 4′) helps to improve forecast accuracy further.

d. BVAR models yield more accurate forecasts than their VAR counterparts.

5. Empirical Results: Out-of-sample Forecasts - January 2007 to June 2008

(i) VAR vs BVAR Models: January 2007 to June 2008

The out-of-sample forecast accuracy statistics for the VAR model are reported in Table 7.13 and the Diebold-Mariana test inferences for comparison across the VAR models are given in Table 7.14. The corresponding tables for the BVAR models are 7.15 and 7.16.

This period includes a turning point in January 2008. Possibly due to this, the empirical results are not as sharp as those obtained in the shorter period. At certain forecast horizons, the monetary model is not able to beat the random walk although the extended model (Model 3′) is almost consistently better than the monetary model for the VAR model. The results are similar for BVAR models although the result that Model 3 produces better forecasts than Model 2 comes out more clearly in the BVAR case. Furthermore, a comparison of the VAR and BVAR Models 3′ and 4′ shows that BVAR models have a distinct advantage in producing more accurate longer term forecasts.

Figures 2A through 2D illustrate the 3, 6, 9 and 12-month-ahead out-of-sample forecasts made using both the VAR and BVAR versions of Model 3′. Likewise, Figures 3A through 3D report the same on the basis of Model 4′. It is clear from these figures that the VAR and BVAR forecasts move in tandem. Further, the differences between the direction of forecasts made using Model 3′ vs Model 4′ are not obvious from the graphs. The two sets of graphs look similar. Therefore the benefit of including intervention data is not apparent by examining the graphs although the superiority of Model 4′ vs Model 3′ (at least at the longer end) emerges more clearly in the Diebold-Mariano test.

We also examine the direction of forecasts made around a turning point. This is illustrated by using Model 4 to forecast in February 2008 up to June 2008. The forecasts are shown in Figure 4 and highlight the problem common to forecasting models - that forecasters tend to miss the turning point. The forecasts exhibit a downward trend while the series has moved upwards.

Table 7.13: VAR Models
Out-of-sample Forecast Accuracy: January 2007 to June 2008

Months ahead	No of Obs	RMSE								Theil U2					
		Model 1 3-mth avg		Model 2 3-mth avg		Model 3' 3-mth avg		Model 4 3-mth avg		Model 2 3-mth avg		Model 3' 3-mth avg		Model 4' 3-mth avg	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	18	0.795		0.617		0.520		0.519		0.777		0.654		0.652	
2	17	1.328		1.168		1.013		1.016		0.879		0.763		0.765	
3	**16**	**1.673**	**1.266**	**1.569**	**1.118**	**1.434**	**0.989**	**1.433**	**0.989**	**0.938**	**0.864**	**0.857**	**0.758**	**0.856**	**0.758**
4	15	2.104		1.933		1.761		1.756		0.919		0.837		0.835	
5	14	2.384		2.223		1.985		1.973		0.932		0.833		0.828	
6	**13**	**2.545**	**2.345**	**2.363**	**2.173**	**2.051**	**1.932**	**2.021**	**1.917**	**0.928**	**0.926**	**0.806**	**0.825**	**0.794**	**0.819**
7	12	2.782		2.497		2.080		2.046		0.898		0.748		0.736	
8	11	2.966		2.568		2.122		2.101		0.866		0.716		0.708	
9	**10**	**3.177**	**2.975**	**2.587**	**2.551**	**2.155**	**2.119**	**2.122**	**2.089**	**0.814**	**0.859**	**0.678**	**0.714**	**0.668**	**0.704**
10	9	3.435		2.534		2.365		2.304		0.738		0.689		0.671	
11	8	3.581		2.449		2.440		2.377		0.684		0.681		0.664	
12	**7**	**3.666**	**3.561**	**2.573**	**2.519**	**2.541**	**2.449**	**2.469**	**2.383**	**0.702**	**0.708**	**0.693**	**0.688**	**0.673**	**0.669**
Average		2.536		2.090		1.872		1.845		0.840		0.746		0.737	

Note: 1. Accuracy measures are calculated using antilog of forecast and actual values although the models are estimated using logs.
2. For Model 1 (naïve forecast), Theil U2, by definition, equals one.
3. Optimal number of lags for all VAR models is 2

Table 7.14: DM Test for VAR Models
Out-of-sample Forecast Accuracy: January 2007 to June 2008

Month Ahead	Model 1 vs Model 2	Model 2 vs Model 3'	Model 3' vs Model 4'
1	2	3	4
1	2 is better than 1[b]	3 is better than 2[a]	4 is better than 3[b]
2	2 is better than 1[c]	3 is better than 2[b]	3 is better than 4[e]
3	**Indifferent**	**3 is better than 2[b]**	**Indifferent**
4	2 is better than 1[e]	3 is better than 2[b]	Indifferent
5	Indifferent	3 is better than 2[b]	Indifferent
6	**Indifferent**	**3 is better than 2[b]**	**4 is better than 3[d]**
7	Indifferent	3 is better than 2[a]	4 is better than 3[e]
8	2 is better than 1[e]	3 is better than 2[b]	Indifferent
9	**2 is better than 1[c]**	**3 is better than 2[c]**	**Indifferent**
10	2 is better than 1[b]	Indifferent	4 is better than 3[d]
11	2 is better than 1[a]	Indifferent	4 is better than 3[d]
12	**2 is better than 1[a]**	**Indifferent**	**4 is better than 3[c]**

Note: 1. "Better" implies "yields more accurate forecasts".
2. *a* : significant at 1% ; *b* : significant at 5%; *c* : significant at 10%; *d* : significant at 15%; *e* : significant at 20%

Table 7.15: BVAR Models
Out-of-sample Forecast Accuracy: January 2007 to June 2008

Months ahead	No of Obs	RMSE								Theil U2					
		Model 1 3-mth avg		Model 2 3-mth avg		Model 3' 3-mth avg		Model 4 3-mth avg		Model 2 3-mth avg		Model 3' 3-mth avg		Model 4' 3-mth avg	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	18	0.795		0.646		0.550		0.548		0.813		0.692		0.689	
2	17	1.328		1.218		1.039		1.039		0.917		0.783		0.782	
3	**16**	**1.673**	**1.266**	**1.642**	**1.169**	**1.435**	**1.008**	**1.430**	**1.005**	**0.982**	**0.904**	**0.858**	**0.777**	**0.854**	**0.775**
4	15	2.104		2.032		1.750		1.742		0.966		0.832		0.828	
5	14	2.384		2.347		1.952		1.941		0.985		0.819		0.814	
6	**13**	**2.545**	**2.345**	**2.518**	**2.299**	**1.984**	**1.895**	**1.957**	**1.880**	**0.989**	**0.980**	**0.779**	**0.810**	**0.769**	**0.804**
7	12	2.782		2.659		1.979		1.951		0.956		0.711		0.701	
8	11	2.966		2.698		1.945		1.924		0.910		0.656		0.649	
9	**10**	**3.177**	**2.975**	**2.683**	**2.680**	**1.905**	**1.943**	**1.856**	**1.910**	**0.845**	**0.903**	**0.600**	**0.656**	**0.584**	**0.645**
10	9	3.435		2.613		2.081		1.990		0.761		0.606		0.579	
11	8	3.581		2.566		2.110		2.020		0.717		0.589		0.564	
12	**7**	**3.666**	**3.561**	**2.771**	**2.650**	**2.226**	**2.139**	**2.129**	**2.046**	**0.756**	**0.744**	**0.607**	**0.601**	**0.581**	**0.575**
Average		2.536		2.199		1.746		1.710		0.883		0.711		0.700	

Note: 1. Accuracy measures are calculated using antilog of forecast and actual values although the models are estimated using logs
2. For Model 1 (naïve forecast), Theil U2, by definition, equals one.
3. Optimal hyperparameters for all BVAR models are as follows: w=.2, d=1, k=.7
4. Optimal number of lags is 3 for Model 2 and 2 for Models 3 and 4

Table 7.16: DM Test for BVAR Models
Out-of-sample Forecast Accuracy: January 2007 to June 2008

Month Ahead	Model 1 vs Model 2	Model 2 vs Model 3'	Model 3' vs Model 4'
1	2	3	4
1	2 is better than 1[b]	3 is better than 2[a]	4 is better than 3[a]
2	2 is better than 1[e]	3 is better than 2[b]	Indifferent
3	**Indifferent**	**3 is better than 2[a]**	**Indifferent**
4	Indifferent	3 is better than 2[a]	Indifferent
5	Indifferent	3 is better than 2[a]	4 is better than 3[e]
6	**Indifferent**	**3 is better than 2[a]**	**4 is better than 3[c]**
7	Indifferent	3 is better than 2[a]	4 is better than 3[d]
8	Indifferent	3 is better than 2[a]	Indifferent
9	**2 is better than 1[e]**	**3 is better than 2[a]**	**4 is better than 3[c]**
10	2 is better than 1[b]	3 is better than 2[a]	4 is better than 3[b]
11	2 is better than 1[a]	3 is better than 2[a]	4 is better than 3[a]
12	**2 is better than 1[b]**	**3 is better than 2[a]**	**4 is better than 3[a]**

Note: 1. "Better" implies "yields more accurate forecasts".
2. *a* : significant at 1% ; *b* : significant at 5%; *c* : significant at 10%; *d* : significant at 15%; *e* : significant at 20%

Table 7.17: DM Test for VAR vs BVAR Models Out-of-sample Period: January 2007 to June 2008			
Model 3'		**Model 4'**	
Month Ahead	VAR vs BVAR	Month Ahead	VAR vs BVAR
1	2	1	2
1	**VAR better than BVAR[a]**	**1**	**VAR better than BVAR[a]**
2	Indifferent	2	VAR better than BVAR[e]
3	**Indifferent**	**3**	**Indifferent**
4	Indifferent	4	Indifferent
5	Indifferent	5	Indifferent
6	**Indifferent**	**6**	**Indifferent**
7	Indifferent	7	Indifferent
8	BVAR better than VAR[d]	8	BVAR better than VAR[d]
9	**BVAR better than VAR[c]**	**9**	**BVAR better than VAR[c]**
10	BVAR better than VAR[e]	10	BVAR better than VAR[e]
11	BVAR better than VAR[b]	11	BVAR better than VAR[e]
12	**BVAR better than VAR[c]**	**12**	**BVAR better than VAR[d]**

Note: 1. "Better" implies "yields more accurate forecasts".

2. *a* : significant at 1% ; *b* : significant at 5%; *c* : significant at 10%; *d* : significant at 15%; *e* : significant at 20%

(ii) Conclusions: January 2007 to June 2008

a. The monetary model does not always beat the naïve forecast.

b. Information on the forward premium, volatility of capital inflows and order flows improve the accuracy of forecasts. It is thus possible to beat the monetary model.

c. Including data on central bank intervention (Model 4′) helps to improve forecast accuracy further especially at the longer end.

d. BVAR models yield more accurate forecasts than their VAR counterparts especially at longer forecast horizons.

Model 3′

Figure 2.A: 3-Month Ahead Forecast
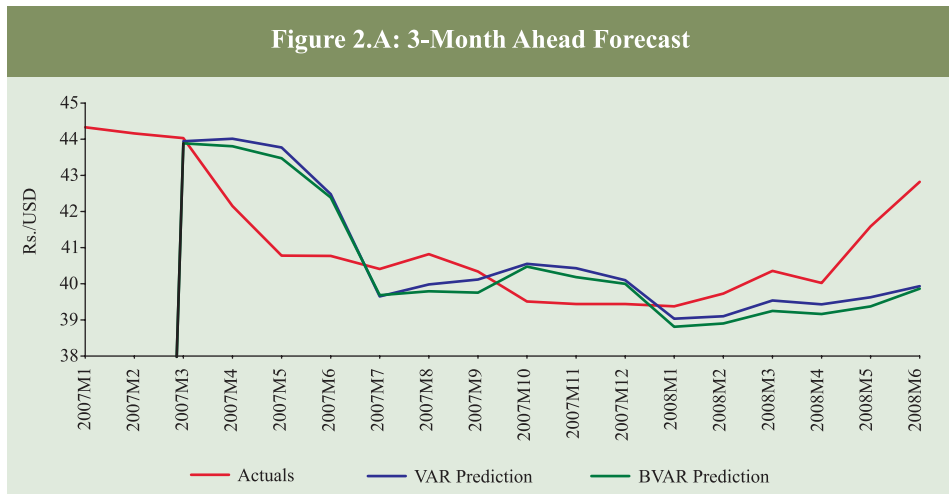
Figure 2.B: 6-Month Ahead Forecast
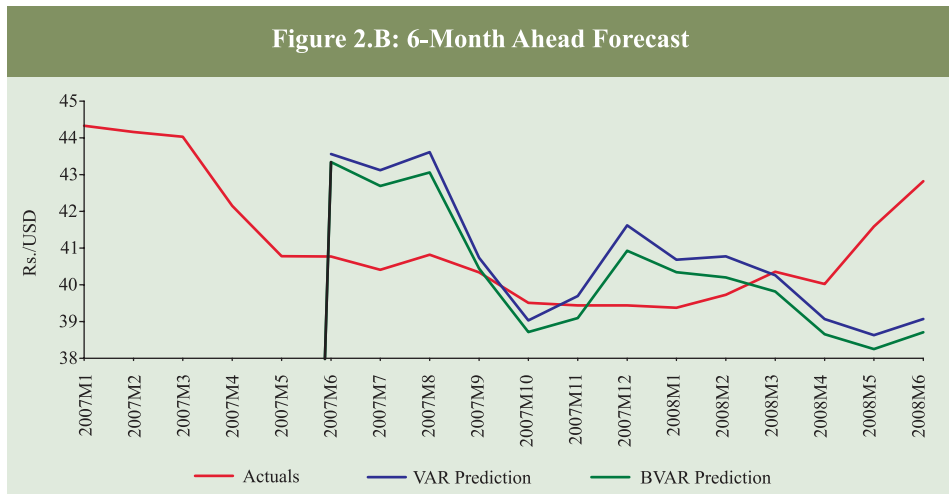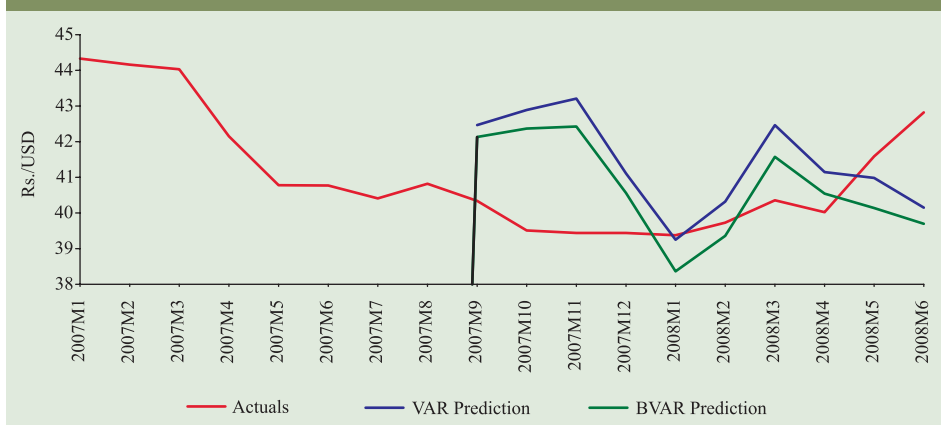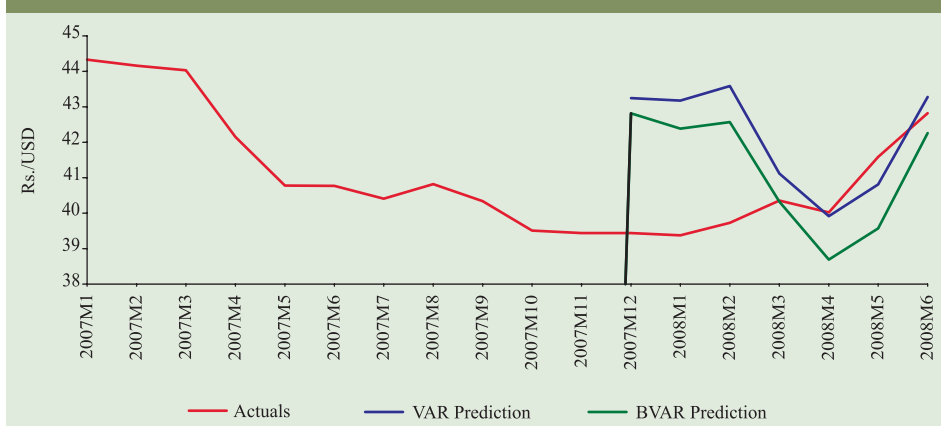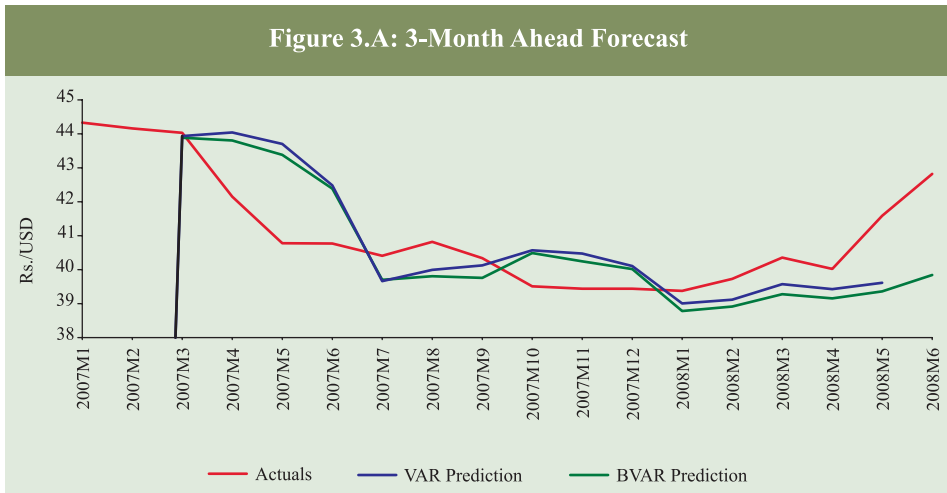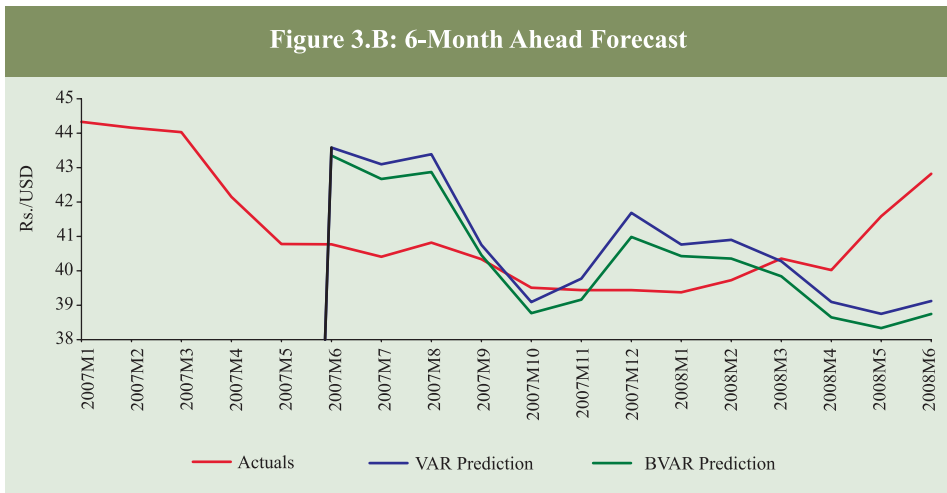
Figure 2.C: 9-Month Ahead Forecast

Rs./USD

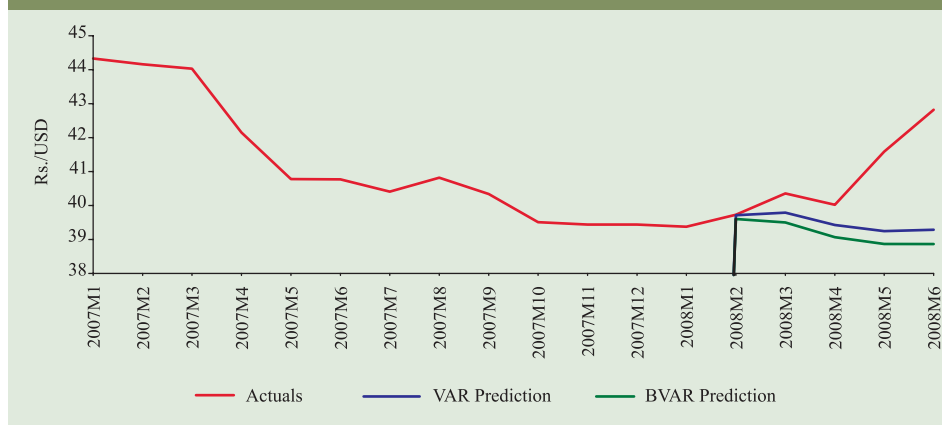Actuals   VAR Prediction   BVAR Prediction

Figure 2.D: 12-Month Ahead Forecast

Rs./USD

Actuals   VAR Prediction   BVAR Prediction

Exchange Rate Policy and Modelling in India

Model 4 '

Figure 3.A: 3-Month Ahead Forecast

Figure 3.B: 6-Month Ahead Forecast

Figure 3.C: 9-Month Ahead Forecast

Rs./USD

Actuals — VAR Prediction — BVAR Prediction
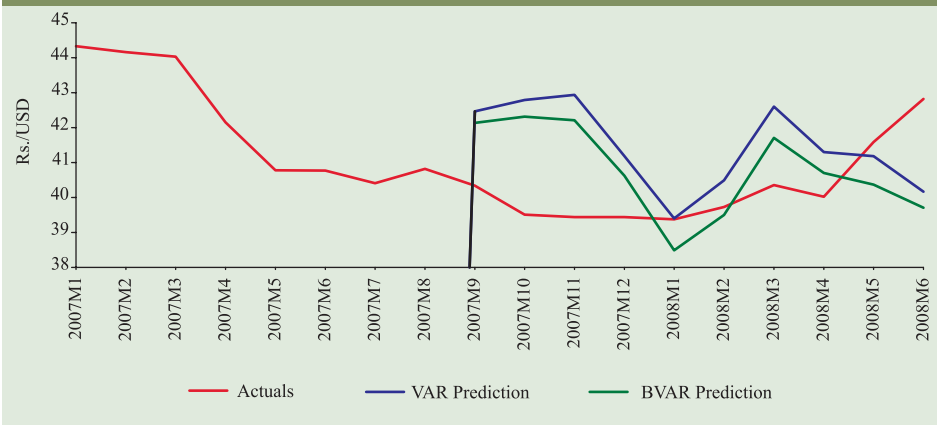
Figure 3.D: 12-Month Ahead Forecast

Rs./USD

Actuals — VAR Prediction — BVAR Prediction
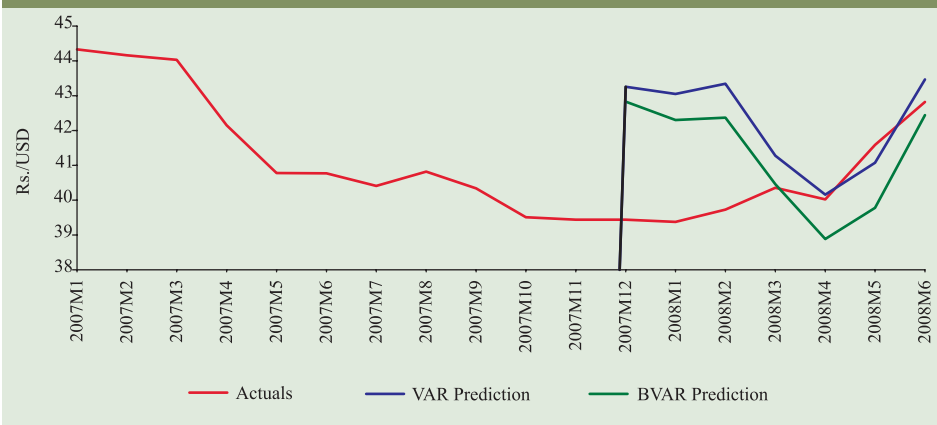
Figure 4: Model 4 -- Multi-period Forecasts made in February 2008

SECTION VIII

Concluding Observations

The study covers two main topics: first, various aspects of economic policy with respect to the exchange rate, and second, modeling and forecasting the exchange rate. Accordingly, the study analyses India's exchange rate story and discusses the structure of the foreign exchange market in India in terms of participants, instruments and trading platform as also turnover in the Indian foreign exchange market and forward premia. The Indian foreign exchange market has evolved over time as a deep, liquid and efficient market as against a highly regulated market prior to the 1990s. The market participants have become sophisticated, the range of instruments available for trading has increased, the turnover has also increased, while the bid–ask spreads have declined. This study also covers the exchange rate policy of India in the background of large capital flows,

This study then attempted to gauge the forecasting ability of economic models with respect to exchange rates with the difference that this is

done in the context of a developing country that follows a managed floating (as opposed to flexible) exchange rate regime. Starting from the naïve model, this study examines the forecasting performance of the monetary model and various extensions of it in the Vector Autoregressive (VAR) and Bayesian Vector Autoregressive (BVAR) framework. Extensions of the monetary model considered in this study include the forward premium, capital inflows, volatility of capital flows, order flows and central bank intervention. The study therefore examines, first, whether the monetary model can beat a random walk. Second, it investigates if the forecasting performance of the monetary model can be improved by extending it. Third, the study evaluates the forecasting performance of a VAR model vs a BVAR model. Lastly, it considers if information on intervention by the central bank can improve forecast accuracy. The main findings are as follows:

(i) The monetary model generally outperforms the naïve model. This negates the findings of the seminal study by Meese and Rogoff (1983) that finds that models which are based on economic fundamentals cannot outperform a naive random walk model.

(ii) The result that it is possible to beat the naïve model may be due to the fact that the intervention by the central bank may help to curb volatility arising due to the demand-supply mismatch and stabilize the exchange rate. The exchange rate policy of the RBI is guided by the need to reduce excess volatility. The Reserve Bank has been prepared to make sales and purchases of foreign currency in order to even out lumpy demand and supply in the relatively thin foreign exchange market and to smoothen jerky movements.

(iii) Forecast accuracy can be improved by extending the monetary model to include forward premium, volatility of capital inflows and order flow.

(iv) Information on intervention by the central bank helps to improve forecasts at the longer end.

(v)   Bayesian Vector Autoregressive models generally outperform their corresponding VAR variants.

(vi) Turning points are difficult to predict as illustrated using Model 4′ with predictions made in February 2008.

Thus, availability of information on certain key variables at regular intervals that affect the exchange rate can lead to a more informed view about the behaviour of the future exchange rates by the market participants, which may allow them to plan their foreign exchange exposure better by hedging them appropriately. Such key variables could include past data on exchange rates, forward premia, capital flows, turnover, and intervention by central banks etc. As regards availability of data on key variables relating to the Indian foreign exchange market, most of the data are available in public domain and can easily be accessed by market participants, academicians and professional researchers. Using these variables skillfully will help them to gain sound insight into future exchange rate movements.

In this context, it is important to recognize that the Indian approach in recent years has been guided by the broad principles of careful monitoring and management of exchange rates with flexibility, without a fixed target or a pre-announced target or a band, coupled with the ability to intervene if and when necessary, while allowing the underlying demand and supply conditions to determine the exchange rate movements over a period in an orderly way. Subject to this predominant objective, the exchange rate policy is guided by the need to reduce excess volatility, prevent the emergence of establishing speculative activities, help maintain adequate level of reserves and develop an orderly foreign exchange market.

Data Definitions and Sources		
Variable	**Definition**	**Source**
e	Rupee/ US Dollar Spot Exchange Rate	Handbook of Statistics on the Indian Economy and RBI Bulletin
i	Auctions of 91-day Government of India Treasury Bills	Handbook of Statistics on the Indian Economy and RBI Bulletin
i*	3-Month Treasury Bill of US, Secondary Market Rate	Board of Governors of the Federal Reserve System
y	Index of Industrial Production for India seasonally adjusted using Census X12.	Handbook of Statistics on the Indian Economy and RBI Bulletin
y*	Industrial Production Index for US, seasonally adjusted	Board of Governors of the Federal Reserve System
π	Year-on-year Inflation Rate calculated from Consumer Price Index for Industrial Workers for India	Handbook of Statistics on the Indian Economy and RBI Bulletin
π*	Year-on-year Inflation Rate calculated from Consumer Price Index for All Urban Consumers; All Items for US	U.S. Department of Labor: Bureau of Labor Statistics
m	Money supply(M3) for India, seasonally adjusted using Census X12	Handbook of Statistics on the Indian Economy and Weekly Statistical Supplement
m*	M2 for US, seasonally adjusted	Board of Governors of the Federal Reserve System
tb	Trade Balance of India in US $ Billion	RBI Bulletin
tb*	Trade Balance of US in US $ Billion	US Census Bureau of Economic Analysis
fdp	Three-month forward premium (% per annum)	Handbook of Statistics on the Indian Economy and Weekly Statistical Supplement
cap	Capital flows measured by Foreign Direct Investment plus Foreign Private Investment Inflows in India in US $ Billion	Handbook of Statistics on the Indian Economy and RBI Bulletin

Data Definitions and Sources		
Variable	Definition	Source
vol	Volatility of capital inflows measured by three period moving average standard deviation of sum of FDI and FII: $$V_t = [(1/m)\sum_{i=1}^{m}(Z_{t+i-1} - Z_{t+i-2})^2]^{1/2}$$ where m=3 and Z is cap	Calculated
of	Order flow - Turnover in foreign exchange market in US $ Billion	Handbook of Statistics on the Indian Economy and RBI Bulletin
int	(Purchase minus Sale) of US Dollars by RBI	Handbook of Statistics on the Indian Economy and RBI Bulletin

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