To

04.08.17

The Principal

Lakshmibai College

Ashok Vihar

Subject: Progress report

Respected Mam,

I am to inform you about my progress report from 04.08.2014 till now. I examined following three issues in my PhD dissertation:

1. Exchange Rate and Central Bank Intervention in India: An Empirical Analysis.
2. Inter-linkages between USD-INR, EUR-INR, GBP-INR and JPY-INR exchange rates and impact of R.B.I intervention.
3. Impact of Exchange Rate Volatility on India's Bilateral Exports: A Panel Study.

The summary of work done under each of these issues is as under:

Issue 1: Exchange Rate and Central Bank Intervention in India: An Empirical Analysis

- **Abstract**: This study examines the effectiveness of RBI intervention using a simultaneous equations framework that takes into account the interdependence between exchange rate, conditional volatility of exchange rate and RBI intervention. Additionally, we incorporate macro-economic fundamental variables and micro-structure variable in our model. In order to estimate our model, we apply system generalized method of moments (GMM)-IV on monthly data spreading from 1996:08 to 2016:10. Our findings indicate that exchange rate level is influenced by central bank intervention, rate of interest differential, output differential, money supply differential, inflation differential, trade balance differential, stock market index, capital flows, EUR-USD exchange rate and order flow. Further, our results suggest while an increase in RBI intervention and reserve adequacy ratio decreases exchange rate volatility, volatility in capital flows significantly increases volatility in exchange rate. We find while central bank intervention is positively influenced by exchange rate volatility, it is negatively related to

exchange rate returns and profits from intervention. We also find that RBI intervention in exchange rate market is asymmetric.

- **Conference/Seminar Presentation:**
  - ➤ Research Scholar Colloquium of the Department of Economics, DSE, May 2014
  - ➤ The Indian Econometric Society Conference held at Patalia University on December 12-14, 2014
  - ➤ CESP Young Scholar's Seminar held between March 9-11, 2015 at JNU

- **Current Status:** The chapter has been completed. The following research paper from this chapter is accepted for publication in "The Journal of Developing Areas", Tennessee State University, USA:

  "Dua, P., & Suri, R. (2017). Exchange Rate and Central Bank Intervention in India: An Empirical Analysis, *The Journal of Developing Areas*, Forthcoming."

Issue 2: Inter-linkages between USD-INR, EUR-INR, GBP-INR and JPY-INR exchange rates and impact of R.B.I intervention

- **Abstract:** This paper examines inter-linkages between four major exchange rates, namely, USD-INR, EUR-INR, GBP-INR and JPY-INR in terms of returns and volatility spillovers using vector autoregressive-multivariate GARCH-BEKK framework. In addition, we analyze the impact of RBI intervention on the returns, volatility and covariance of these exchange rates. The study finds significant bi-directional causality-in-mean and causality-in-variance between all four exchange rates. The estimation results suggest that RBI intervention in the form of net purchase of dollars leads to depreciation of INR vis-à-vis USD, EUR, GBP and JPY. Furthermore, we find that RBI intervention not only significantly affects the volatility of INR vis-à-vis USD, EUR and GBP but also explains significant amount of covariance between USD-INR and the other three exchange rates.

- **Conference/Seminar Presentation:**

➢ "Tenth Winter School", DSE, Delhi from 14-16 December, 2015

➢ Indian Econometric Society Conference held at Kozhikode, Kerala from 4-6 January, 2016

➢ Research Scholar Colloquium of the Department of Economics, DSE, April 2016

- **Current Status:** The chapter has been completed. The research paper from this chapter is accepted for publication in "Journal of Emerging Market Finance", Institute for Financial Management and Research, subject to minor revisions.

Issue3: Impact of Exchange Rate Volatility on India's Bilateral Exports: A Panel Study

- **Abstract:** This chapter empirically examines the effect of real exchange rate volatility on on growth in India's exports to developed and developing countries. We utilize panel GMM-IV technique to estimate a 'hybrid model' for India's export growth. Our findings suggest that while real exchange rate volatility significantly decreases growth in India's exports to developing countries, it has an insignificant impact on growth in India's exports to developed countries. Additionally, while we find growth in India's exports to both developed and developing economies is positively affected by growth in real exchange rate, foreign income, domestic income, FDI and infrastructure; it is negatively influenced by domestic demand. Our findings indicate that both demand as well as supply side factors are crucial for India's export growth.

- **Conference/Seminar Presentation:**

➢ 'Eleventh Winter School', DSE, Delhi,13-15 December, 2016

➢ 'Sixteenth Annual Conference on Macroeconomics and Finance', IGIDR, Mumbai, 19-20 December, 2016.

- **Current Status:** Chapter has been completed. The research paper from this chapter has been sent to "Macroeconomics and Finance in Emerging Market Economies". Their reply is awaited.

I will submit my thesis latest by 31 October, 2017. I am enclosing the draft of my thesis with this application.

Yours sincerely,

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Exchange Rate and Central Bank Intervention in India: An Empirical Analysis

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Abstract

The existing empirical studies on the effectiveness of RBI intervention in the exchange rate market are based on single equation/GARCH models. Recognizing the interdependence between exchange rate returns, conditional volatility of exchange rate and RBI intervention, this study uses a simultaneous equations framework to examine the efficacy of intervention by RBI. Additionally, we incorporate the effect of macro-economic fundamental variables and micro-structure variable on exchange rate returns and exchange rate volatility. The econometric methodology used in the study includes two steps. In the first step, DF-GLS, Ng-Perron and, Lee and Strazicich unit root tests are used to examine the stationarity of the variables. In the second step, the simultaneous equations model is estimated using the generalized method of moments (GMM)-IV. This study is based on secondary data at monthly frequency, spreading from 1996:08 to 2016:10.

The main findings of the study are as follows. The results of unit root tests suggest that all variables included in the analysis are stationary. The system GMM-IV estimates of the model indicate that exchange rate returns are influenced by RBI intervention, output growth differential, money supply growth differential, stock market returns, capital flows, EUR-USD exchange rate returns, change in trade balance differential and order flow. Additionally, the estimates of exchange rate volatility equation suggest that RBI intervention significantly decreases exchange rate volatility. Further, we find that volatility in capital flows has significant and positive impact on exchange rate volatility. The estimates of the central bank intervention equation suggests that exchange rate returns have a significant and negative impact on RBI intervention in foreign exchange rate market. We also find evidence for the presence of asymmetry in RBI intervention.

The key implications of the study indicate that RBI intervention is effective in stabilizing the Indian exchange rate market in the face of both domestic and external shocks. Furthermore, exchange rate returns are significantly affected by RBI intervention, macro-economic and micro-structure variables. The findings of this study may be useful for formulating India's monetary policy.

1. INTRODUCTION

The relationship between exchange rate and central bank intervention is an important component of contemporary exchange rate determination models. The exchange rates have had been extremely volatile in the last three decades that affects international trade, capital flows and economic growth. Further, there is a consensus in the empirical literature regarding higher vulnerability of developing economies vis-à-vis developed economies to international market shocks. Consequently, central banks in most developing economies frequently intervene to maintain stability in the exchange rate market. Thus, the issue of the impact of central bank intervention on exchange rate is relevant for exchange rate modeling as well as central bank intervention policy.

USD-INR exchange rate (INR per one USD) returns has shown massive volatility ever since the liberalization of Indian economy in 1993 (Graph 1). It is noteworthy that USD-INR exchange rate volatility was substantially higher during the global financial crisis (GFC) of 2007-09 and Euro-zone crisis of 2010-12. Given the presence of managed floating regime in India, intervention by Reserve Bank of India (RBI) has had been an important characteristic of Indian exchange rate market (Graph 2). In a bid to understand the complex inter-linkages between central bank intervention and exchange rate, this paper analyzes the impact of RBI intervention on first and second moments of USD-INR exchange rate returns.
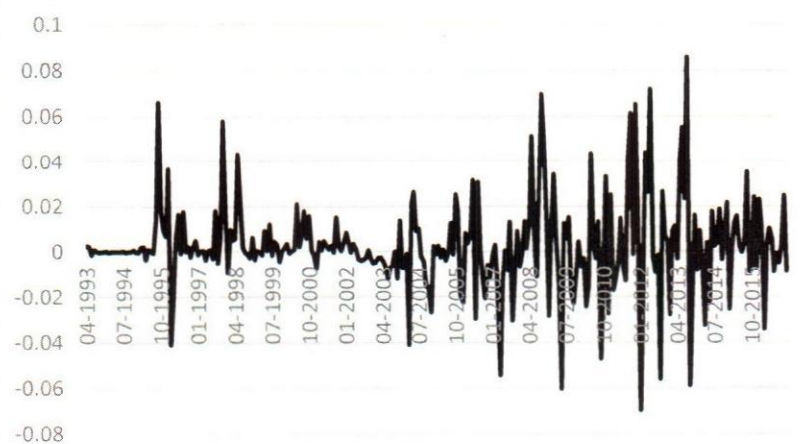

Figure 1: Exchange rate returns since 1993.
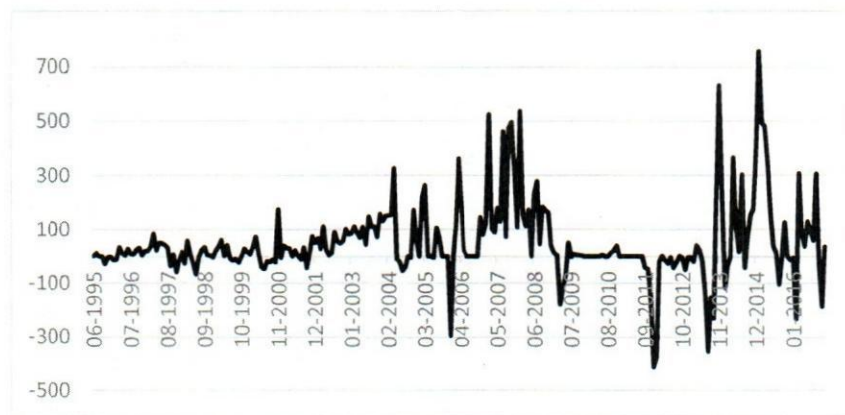Source: Author's own calculations based on RBI database

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Figure 2: Net purchase of USD by RBI since 1995. Source: RBI database

According to the asset pricing model (as utilized by Fratzscher, 2012), central bank intervention can affect the exchange rate through three broad channels, viz. portfolio balance channel, signaling channel and microstructure channel. The increasingly complex financial system makes it impossible to disentangle the different channels at work. Thus, the theoretical relationship between exchange rate and central bank intervention is ambiguous. Further, as noted by Behera *et. al.* (2008), there are two different opinions on the effectiveness of central bank intervention. Some experts believe that central bank intervention plays a pivotal role in developing economy like India as it minimizes the impact of foreign and domestic shocks on exchange rate. Others argue that central bank intervention creates uncertainty in the exchange rate market which causes an increase in exchange rate volatility.

As observed by Tsen (2014), the empirical evidence regarding the impact of central bank intervention on exchange rate and exchange rate volatility can be described as 'inconclusive'. For India too, the empirical results on the effectiveness of RBI intervention in the foreign exchange market are mixed. Goyal *et. al.* (2009) find that RBI intervention is effective in influencing USD-INR exchange rate returns. On the other hand, studies by Bhaumik and Mukhopadhyay (2000), Pattanaik and Sahoo (2003), Behera *et. al.* (2008) and Vadivel and Ramachandran (2013) do not find RBI intervention to be effective in affecting exchange rate returns. Further, while some empirical studies such as Goyal *et. al.* (2009) and Behera *et. al.* (2008) find that RBI intervention is effective in reducing exchange rate volatility, other empirical studies such as Vadivel and Ramachandran (2013) find that RBI intervention increases volatility in exchange rate.

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Given that central bank intervention in foreign exchange market is purposely done to maintain stability in the exchange rate market, it cannot be treated as exogenous. Consequently, an analysis of central bank intervention in foreign exchange rate market warrants use of simultaneous equations framework where exchange rate and intervention are endogenous variables. In contrast with the existing empirical studies on effectiveness of RBI intervention, we formulate a simultaneous equations model with exchange rate returns[1], exchange rate volatility and RBI intervention as endogenous variables. Moreover, most of the existing Indian studies do not focus on the complex interactions between the exchange rate, macro-economic variables, and central bank intervention. As noted by Bhaumik and Mukhopadhyay (2000), in order to capture such interactions, one has to build up a multi-equation macro-econometric model. The present study is an attempt in this direction. Additionally, we incorporate the impact of a micro-structure variable[2] in our simultaneous equations model[3]. Furthermore, we use GMM-IV to estimate our model as it does not require any restriction on the distribution of residuals and allows for endogenous variables.

The next section (Section2) discusses the determinants of exchange rate. The subsequent section (Section 3) outlines the determinants of central bank intervention. The underlying base model, i.e. a simultaneous equations model of exchange rate and central bank intervention, is presented in Section 4. Section 5 describes the data employed in this study while Section 6 gives the details of the econometric methodology. Section 7 summarizes the results of the estimation and Section 8 concludes the study.

2. DETERMINANTS OF USD-INR EXCHANGE RATE

An appraisal of the theoretical (viz. PPP model; Monetary model, 1976; Hooper and Morton, 1982; and Portfolio balance model) and empirical literature (Dua and Ranjan, 2012; Dua and Tuteja, 2016; Dua and Sen, 2017; and Dua *et. al.*, 2017) reveals that the potential variables

used to explain India's exchange rate behavior are income differential, rate of interest differential, money supply differential, inflation differential, trade balance differential, stock market index, capital flows and volatility of capital flows, EUR-USD exchange rate, reserve adequacy ratio and order flow. These variables are briefly discussed below.

Inflation Differential

The relationship between exchange rate and inflation differential has been emphasized in the well-known purchasing power parity (PPP) theory. An increase in relative inflation increases the relative price of exports that may dwindle volume of exports. As a result, the demand for currency decreases that in turn causes depreciation of exchange rate. Thus, inflation differential shares positive relationship with exchange rate.

Money Supply Differential

The relationship between the money supply differential and the exchange rate is ambiguous. In the portfolio balance model of exchange rate determination, an increase in domestic money supply relative to the foreign money supply creates an excess demand for foreign bonds through portfolio balance. Given sticky prices, this leads to depreciation of the domestic currency in the short run above its long run value (given by PPP) and gradual appreciation of the domestic currency in the medium run to attain the long run equilibrium level. Thus, while the expected sign of money supply differential is positive in the short run, it may be negative in the medium run[4].

Rate of Interest Differential

The relationship between rate of interest differential and exchange rate is also 'ambiguous'. The explanation for the ambiguity is similar to the money supply differential except that a decrease in the domestic rate of interest relative to foreign rate of interest leads to excess demand for foreign bonds in the short run.

Output Differential

The theoretical basis of the link between output differential and exchange rate is laid in the monetary model (Frenkel, 1976) of exchange rate determination. An increase in domestic output causes excess demand for domestic money supply that in turn leads to appreciation of domestic currency. Therefore, there is a negative relationship between output differential and exchange rate.

Trade Balance Differential

Hooper and Morton (1982) propose a fundamental based structural model where domestic and foreign trade balances play a crucial role in the exchange rate determination. An increase in the domestic trade balance vis-à-vis foreign trade balance implies excess supply for foreign currency that leads to the depreciation of the foreign currency. This implies that there is a negative relationship between the trade balance differential and exchange rate.

Order Flow

Order flow is defined as the net of buyer initiated and sellers initiated orders. An increase in order flow creates excess demand for foreign currency that causes depreciation of exchange rate. Thus, exchange rate and order flow are positively related (See Dua and Ranjan, 2012, pp.8-9).

Central Bank Intervention

Central bank intervention in the foreign exchange market is regarded as one of the key determinant of exchange rate in both theoretical and empirical literature. The dynamic asset pricing model reveals three broad channels through which central bank intervention (sterilized or non-sterilized) can affect the exchange rate, viz. portfolio balance channel, signaling channel and microstructure channel[5]. However, these different channels may affect the exchange rate in the same or opposite direction. For instance, consider an increase in net purchase of foreign currency by a central bank. This may lead to the depreciation of the domestic currency through an increase in the money supply. It may also induce dealers in the foreign exchange market to sell foreign currency that leads to an appreciation of the domestic currency[6]. Thus, the expected sign of a central bank intervention is ambiguous. Furthermore, the existing empirical studies are

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inconclusive concerning the impact of central bank intervention on exchange rate levels and exchange rate volatility (Tsen, 2014, p.1).

Stock Market Index

Stock market index is also one of the prominent variables that affects exchange rate returns. Branson (1983) provides the portfolio balance links between the stock prices and exchange rate. An increase in the stock prices causes expansion in the wealth of investors that creates higher demand for money with surging interest rates. The higher interest rates encourage capital inflows that, ceteris paribus; causes appreciation of the domestic currency.

Capital Flows and Volatility of Capital Flows

Capital flows and its volatility are other important variables that affect exchange rate. An increase in capital flows causes excess supply of foreign currency that leads to appreciation of domestic currency. Further, for developing economies like India, volatile capital flows significantly contribute to the volatility in exchange rate.

EUR-USD Exchange Rate

Given that India is a small open economy and USD is an international currency, the value of USD vis-à-vis all major world currency rates such as EUR-USD rate is expected to affect the USD-INR rate. For instance, some studies such as Dua and Tuteja (2016) find evidence for dynamic dependence between major exchange rates vis-à-vis USD. However, the theoretical sign of this variable is ambiguous as it depends on market activity.

Reserves Adequacy Ratio (RAR)

As noted by Hviding *et al.* (2004), RAR plays an important role in the movement of exchange rate of developing and emerging economies. An increase in RAR helps in smoothing fluctuations in exchange rate. Consequently, RAR and exchange rate volatility are negatively related.

3. DETERMINANTS OF CENTRAL BANK INTERVENTION/ CENTRAL BANK REACTION FUNCTION

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The determinants of central bank intervention utilized in empirical literature include deviation of exchange rate from short term target rate, deviation of exchange rate from long term target rate, exchange rate returns, exchange rate volatility, and profits from intervention. While we do not cover an exhaustive list of determinants, we attempt to include factors that are potentially important in determining RBI's intervention in exchange rate market.

Exchange Rate Returns

Frenkel *et. al.* (2005) considers absolute exchange rate returns as a very short term target of central bank intervention in foreign exchange market. If the central bank follows the policy of leaning against the wind, an increase in the exchange rate returns (exchange rate depreciation) causes decrease in the central bank intervention (net purchase of foreign currency). Thus, the expected sign of exchange rate returns in the reaction function is negative.

Exchange Rate Volatility

It is possible that the primary concern of central bank is to maintain orderly conditions in the foreign exchange market rather to target any level of exchange rate. Therefore, empirical studies such as Frenkel *et al.* (2005) include exchange rate volatility as the determinant of central bank intervention. However, while the measure of volatility is always positive, the same degree of volatility during periods of exchange rate depreciation has an opposite effect on interventions (in terms of net purchase of foreign currency) than during periods of exchange rate appreciation (Loiseau-Aslanidi, 2007, p.8). Thus, the expected sign of exchange rate volatility is ambiguous.

Profits from Intervention

A central bank may incur losses in achieving the above two objectives that may affect its intervention in the foreign exchange market. Profits from the intervention rise when the currency depreciates and vice- versa. Thus, if the objective of the central bank is to stabilize the currency, it will buy the domestic currency when the profits are rising and vice-versa. Consequently, the expected sign of profits in the reaction function (net purchase of foreign currency) is negative.

4. A SIMULTANEOUS EQUATIONS MODEL OF EXCHANGE RATE AND CENTRAL BANK INTERVENTION

Based on the theoretical and empirical literature on exchange rate and central bank intervention, we specify the following simultaneous equations model:

$$e_t^{USD} = f(e_{t-i}^{USD}, (i_{t-i} - i_{t-i}^*), (\pi_{t-i} - \pi_{t-i}^*), (y_{t-i} - y_{t-i}^*), (m_{t-i} - m_{t-i}^*), Int_t,$$
$$ed_t, (tb_{t-i} - tb_{t-i}^*), of_t, s_t, cap_t) \tag{1}$$

$$h_t = g(h_{t-i}, Int_t, vol_t, RAR_{t-i}) \tag{2}$$

$$Int_t = k(Int_{t-i}, e_t^{USD}, h_t, Profits_{t-i}) \tag{3}$$

where $i \neq 0$, 't' stands for the time subscript and 'i' denotes lags.

e_t^{USD} = log of USD-INR exchange rate

h_t = USD-INR exchange rate volatility

Int_t = Intervention by RBI

$(i_t - i_t^*)$ = difference between India's interest rate and US interest rate= interest rate differential

$(\pi_t - \pi_t^*)$ = difference between India's inflation rate and US inflation rate=inflation differential

$(y_t - y_t^*)$ = difference between log of India's output and log of US output=output differential

$(m_t - m_t^*)$= difference between log of India's money supply and log of US money supply= money supply differential

$(tb\text{-}tb^*)$= difference between India's trade balance and US trade balance= trade balance differential

s_t= log of India's stock market (BSE) index

of_t = order flow measured as net turnover in the India's foreign exchange market

ed_t= log of EUR-USD exchange rate

cap_t= Capital flows measured as the sum of foreign institutional investment (FII) and foreign direct investment (FDI)

vol_t = volatility of cap_t

$Profits_t = \sum_{t=1}^{f} \left[n_i \left(1 - \frac{e_i}{e_f} \right) \right]$ where e_f is the end of the period exchange rate and n_i is the amount of dollars purchased.

RAR_t = Ratio of India's foreign exchange reserves to imports

It is noteworthy that the above model contains lags of some explanatory variables as they are expected to be endogenous apriori. Further, we find that all equations in the above model are over-identified and the rank condition is also satisfied.

5. DATA

This study uses secondary data at monthly frequency from 1996:08 to 2016:10. Data for USD-INR exchange rate, BSE index, FII and FDI inflows into India, India's IIP index, India's money supply (M_3), order flow in India's exchange rate market, 91-day treasury bill rate of India, net purchase of dollars by RBI have been gathered from CEIC database. The data for US IIP index, US Consumer price index (industrial workers), US money supply (M_2), US's three month Treasury bill rate, and US trade balance have been obtained from St. Louis' website. The data for euro-dollar exchange rate is sourced from Eurostat database. Exchange rate volatility and capital flows volatility are measured using ARMA (1, 1)-GARCH (1, 1) model.

We also include three dummies to account for the effect of the 1997-98 crises (Dum_{97-98}), 2009-10 crises (Dum_{GFC}) and the euro zone crises (Dum_{EZ}).

6. ECONOMETRIC METHODOLOGY

In the first step, we employ the Dickey-Fuller generalized least squares (DF-GLS) test suggested by Elliot et al. (1996), Ng and Perron (2001) test and Lee and Strazicich (2003) minimum LM test to test for the presence of non-stationarity in our data . As central bank intervention in India is sporadic, the assumption that it has continuous probability distribution is inappropriate. Further, given that RBI carefully monitors the functioning of exchange rate market, its intervention in the exchange rate market can't be exogenous. Thus, in the second step, we apply system GMM-IV estimator to our model of three equations as it does not require information about the exact distribution of shocks and allows for endogenous explanatory variables.

7. RESULTS

Unit Root Test Results

We find that exchange rate returns, central bank intervention, order flow, capital flows, volatility of capital flows, EUR-USD exchange rate returns, returns on BSE index, first difference of rate of interest differential, first difference of inflation differential, first difference of trade balance differential, money supply growth differential, output growth differential, reserve adequacy ratio and growth in profits are stationary variables[7].

Empirical Model

The estimated model (Model I) for exchange rate moments and RBI intervention is as follows[8]:

$$\dot{e}_t^{USD} = \alpha_0 + \alpha_1 \dot{e}_{t-1}^{USD} + \alpha_2\Delta(i - i^*)_{t-1} + \alpha_3\Delta(\pi - \pi^*)_{t-2} + \alpha_4(\dot{y} - \dot{y}^*)_{t-1} + \alpha_5(\dot{m} - \dot{m}^*)_{t-1} + \alpha_6 Int_t + \alpha_7 \dot{ed}_t + \alpha_8\Delta(tb - tb*)_{t-1} + \alpha_9 of_t + \alpha_{10}\dot{s}_t + \alpha_{11}cap_t + \alpha_{12}Dum_{97-98} + \alpha_{13}Dum_{GFC} + \alpha_{14}Dum_{EZ} + u_t \tag{4}$$

$$h_t = \beta_0 + \beta_1 h_{t-1} + \beta_2 Int_t + \beta_3 vol_t + \beta_4 RAR_{t-1} + \beta_5 Dum_{97-98} + \beta_6 Dum_{GFC} + \beta_7 Dum_{EZ} + v_t \tag{5}$$

$$Int_t = \gamma_0 + \gamma_1 Int_{t-1} + \gamma_2 \dot{e}_t^{USD} + \gamma_3 h_t + \gamma_4 Profits_{t-1} + \gamma_5 Dum_{97-98} + \gamma_6 Dum_{GFC} + \gamma_7 Dum_{EZ} + \epsilon_t \tag{6}$$

For the exchange rate returns equation, we use $\dot{e}_{t-2}^{USD}$, Int_{t-1} and Int_{t-2} as additional instruments. For exchange rate volatility equation, we utilize Int_{t-1} and Int_{t-2} as additional instruments. Finally, for the reaction function of RBI, we choose $\dot{e}_{t-1}^{USD}$, $\dot{e}_{t-2}^{USD}$, $\dot{e}_{t-3}^{USD}$, Int_{t-2}, Int_{t-3}, h_{t-1}, h_{t-2}, h_{t-3}, and h_{t-4} as additional instruments.

Ramachandran and Srinivasan (2007), and Srinivasan *et al.* (2015) find that the asymmetric central bank intervention in India has contributed to large stockpile of foreign exchange reserves. Thus, in order to test for the presence of asymmetry in central bank intervention, we estimate Model II that consists of equations (4), (5) and (7) (given below).

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$$Int_t = \gamma_0 + \gamma_1 Int_{t-1} + \gamma_{2,1}\dot{e}^{USD}_{t,1} + \gamma_{2,2}\dot{e}^{USD}_{t,2} + \gamma_3 h_t + \gamma_4 Gr.Profits_{t-1} + \gamma_5 Dum_{97-98} +$$

$$\gamma_6 Dum_{GFC} + \gamma_7 Dum_{EZ} + \epsilon_t \qquad (7)$$

where $\dot{e}^{USD}_{t,1} = \dot{e}^{USD}_t D_1, \dot{e}^{USD}_{t,2} = \dot{e}^{USD}_t D_2$

$$D_1 = \begin{cases} 1 \ if \ \dot{e}^{USD}_t < 0 \\ 0 \ otherwise \end{cases} and \ D_2 = \begin{cases} 1 \ if \ \dot{e}^{USD}_t > 0 \\ 0 \ otherwise \end{cases}$$

For Model II, while the additional instruments utilized for the exchange rate returns equation and the volatility equation are same as Model I, we utilize $\dot{e}^{USD}_{t-1,1}, \dot{e}^{USD}_{t-2,1}, \dot{e}^{USD}_{t-1,2}, \dot{e}^{USD}_{t-2,2}$, $Int_{t-2}, h_{t-1}, h_{t-2}$ and h_{t-3} as additional instruments for the reaction function (7).

Estimation Results

The system GMM-IV estimates of the Model I are presented in Table 1, while Tables 2, 3 and 4 show the expected and empirical signs of the coefficients.

Table 1: GMM-IV estimation results of Model I

Equation	Variable	Estimate	S.E.
$\dot{e}^{USD}_t$	Constant	0.2476	0.0986**
	$\dot{e}^{USD}_{t-1}$	0.1895	0.0557*
	$\Delta(i - i^*)_{t-1}$	-0.0372	0.1195
	$\Delta(\pi - \pi^*)_{t-2}$	0.0442	0.0345
	$(\dot{y} - \dot{y}^*)_{t-1}$	-0.0267	0.0125**
	$(\dot{m} - \dot{m}^*)_{t-1}$	-0.1190	0.0498**
	Int_t	0.0027	0.0007*
	$\dot{ed}_t$	-0.2214	0.0482*
	$\Delta(tb - tb^*)_{t-1}$	-1.30E-06	1.87E-07*
	of_t	1.82E-06	3.09E-07*
	$\dot{s}_t$	-0.0372	0.1195*
	cap_t	-4.42E-06	5.77E-07*
	Dum_{97-98}	0.4312	0.1640*
	Dum_{GFC}	0.0360	0.1141
	Dum_{EZ}	0.7234	0.1754*
h_t	Constant	0.4273	0.5886

	h_{t-1}	0.7261	0.0232*
	Int_t	-0.0024	0.0006*
	vol_t	6.97E-12	2.06E-12*
	RAR_{t-1}	-0.1583	42.6187
	Dum_{97-98}	0.5189	0.2410**
	Dum_{GFC}	1.5545	0.2947*
	Dum_{EZ}	0.7438	0.2832*
Int_t	Constant	30.2617	6.5096*
	Int_{t-1}	0.5149	0.0408*
	$\dot{e}_t^{USD}$	-23.8154	11.1993**
	h_t	0.9987	1.7689
	$Profits_{t-1}$	-0.0061	0.0135
	Dum_{97-98}	-13.7958	9.4249
	Dum_{GFC}	26.2368	15.9284***
	Dum_{EZ}	-38.6929	6.8420*
J-statistic		0.0279	

*, **, *** indicate significance at 10%, 5% and 1% respectively

Table 2: Exchange rate returns ($\dot{e}_t^{USD}$)

Variable	Expected Sign	Empirical Sign
$\Delta(i - i^*)_{t-1}$	+/-	-
$\Delta(\pi - \pi^*)_{t-2}$	+	+
$(\dot{y} - \dot{y}^*)_{t-1}$	-	-
$(\dot{m} - \dot{m}^*)_{t-1}$	+/-	-
Int_t	+/-	+
$\dot{ed}_t$	+/-	+
of_t	+	+
$\dot{s}_t$	-	-
cap_t	-	-

Table 3: Exchange rate volatility (h_t)

Variable	Expected Sign	Empirical Sign
Int_t	+/-	-
vol_t	+	+
RAR_{t-1}	-	-

Table 4: Central bank intervention (Int_t)

Variable	Expected Sign	Empirical Sign
$\dot{e}_t^{USD}$	-	-
h_t	+/-	+
$Profits_{t-1}$	-	-

As shown in Table 1 and Table 2, while the theoretical sign of central bank intervention is ambiguous, its empirical sign is positive and significant at 1%. This suggests that an increase in net purchase of dollars by RBI leads to a significant depreciation of the exchange rate. This result is consistent with the findings of Goyal *et. al.* (2009). Given that RBI mostly undertook purchases of USD during the sample period, it is plausible to find a positive sign.

Turning to other parameters of the mean equation (4), we find that except the change in interest rate differential and change in inflation differential, all coefficients are significant at conventional levels of significance (Table 2). Further, while theoretical signs of change in interest rate differential, and money supply growth differential are ambiguous, it can be seen from Table 2 that the empirical signs of these coefficients are negative. Our result show that an increase in rate of interest differential leads to an appreciation of the domestic currency which is in line with the results obtained by Goyal *et. al.* (2009). Our finding that an increase in money supply growth differential causes an appreciation of the domestic currency may be due to two possible reasons. First, it may indicate the medium-run adjustment of exchange rate returns in response to an increase in money supply growth differential (See Section 2, p.5). Second, since an increase in the domestic money supply growth reflect changes in the monetary policy, an increase in domestic money supply growth may boost the domestic economic activity and lead to the appreciation of domestic currency.

Further, though the theoretical sign of EUR-USD exchange rate return is ambiguous, its empirical sign is negative. As EUR is the second topmost international currency, it is plausible to find that the depreciation of USD vis-à-vis EUR causes depreciation of USD vis-à-vis INR. For remaining coefficients of equation (4), the empirical signs are same as theoretically expected signs (Table 2). Thus, we find that an increase in output growth differential, trade balance differential,

stock market returns and capital inflows cause a decrease in exchange rate returns. Moreover, an increase in order flow and inflation differential leads to an increase in exchange rate returns.

From the reported results of exchange rate volatility equation (5) in Table 1, it is seen that the coefficient of intervention is negative and significant at 1%. Though the theoretical effect of central bank intervention on exchange rate volatility is ambiguous (Table 3), we find that RBI intervention significantly reduces USD-INR exchange rate volatility. This finding is consistent with the results obtained by Behera *et. al.* (2008) and Goyal *et. al.* (2009). Further, it can be observed from Table 1 and 3 that the coefficient of capital flows volatility has the expected positive sign and is significant at 1%. Moreover, the coefficient of reserve adequacy ratio has the expected negative sign and is insignificant. Thus, we find that while RBI intervention and reserve adequacy ratio reduces USD-INR exchange rate volatility, capital flows volatility triggers volatility in USD-INR exchange rate.

The reported results of the reaction function (6) in Table 1 reveal that the coefficient of exchange rate return has expected negative sign and is significant at 5%. Further, the coefficient of profits from intervention has the expected negative sign but is insignificant. This implies while RBI intervention is negatively and significantly influenced by exchange rate returns, it does not respond significantly to profits from intervention. Moreover, the coefficient of exchange rate volatility is positive but insignificant. Thus, we find that an increase in exchange rate volatility leads to a marginal increase in RBI intervention.

It can be observed from Table 5 that the interpretation of the mean equation and volatility equation estimates for Model II is same as Model I. Furthermore, the estimates of the reaction function (7) reveal while the coefficient of negative exchange rate returns ($\dot{e}_{t,1}^{USD}$) has expected negative sign and significant at 5% level, the coefficient of positive exchange rate returns ($\dot{e}_{t,2}^{USD}$) has expected negative sign but insignificant. This implies while negative exchange rate returns significantly affect central bank intervention, central bank do not respond significantly to positive exchange rate returns. Thus, we find that RBI intervention in foreign exchange market is asymmetric. Further, the interpretation of other estimates in (7) is similar to (6).

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Table 5: Model II

Equation	Variable	Estimate	S.E.
$\dot{e}_t^{USD}$	Constant	0.2864	0.1001*
	$\dot{e}_{t-1}^{USD}$	0.1920	0.0590*
	$\Delta(i - i^*)_{t-1}$	-0.0044	0.1306
	$\Delta(\pi - \pi^*)_{t-2}$	0.0366	0.0362
	$(\dot{y} - \dot{y}^*)_{t-1}$	-0.0229	0.0126***
	$(\dot{m} - \dot{m}^*)_{t-1}$	-0.1201	0.0519**
	Int_t	0.0025	0.0008*
	$\dot{ed}_t$	-0.2281	0.0479*
	$\Delta(tb - tb*)_{t-1}$	-1.35E-06	1.92E-07*
	of_t	1.81E-06	3.34E-07*
	$\dot{s}_t$	-0.0356	0.0126*
	cap_t	-4.49E-06	5.57E-07*
	Dum_{97-98}	0.3700	0.1682**
	Dum_{GFC}	0.0094	0.1179
	Dum_{EZ}	0.7176	0.1959*
h_t	Constant	0.4456	0.6381
	h_{t-1}	0.7304	0.0262*
	Int_t	-0.0021	0.0005*
	vol_t	6.30E-12	2.09E-12*
	RAR_{t-1}	-0.6154	44.8767
	Dum_{97-98}	0.4619	0.2710***
	Dum_{GFC}	1.4575	0.3258*
	Dum_{EZ}	0.8031	0.2805*
Int_t	Constant	25.8492	10.2318*
	Int_{t-1}	0.5360	0.0526*
	$\dot{e}_{t,1}^{USD}$	-33.5168	15.4650**

	$\dot{e}_{t,2}^{USD}$	-20.3400	19.1612
	h_t	1.4867	2.0960
	$Profits_{t-1}$	-0.0062	0.0169
	Dum_{97-98}	-16.5169	9.0120***
	Dum_{GFC}	22.4338	19.7998
	Dum_{EZ}	-47.3839	12.1143*
J-statistic	0.0291		

*, **, *** indicate significance at 10%, 5% and 1% respectively.

We conduct Hansen's test of overidentifying restrictions for the two estimated models. For model I, Hansen's test statistic = 0.027 * 237 = 6.39, while for model II, Hansen's test statistic = 0.029*237 = 6.87. As Hansen's J statistic is less than the critical value (229.21 at 5%), we do not reject the null hypothesis of valid moment conditions.

8. CONCLUSION

This paper empirically examines the effect of R.B.I's intervention on USD-INR exchange rate returns and volatility in a simultaneous equations framework that consists of three endogenous variables, viz. USD-INR exchange rate returns, USD-INR exchange rate volatility and central bank intervention. Furthermore, we consider the impact of all possible fundamental macro-economic variables and micro-structure variable that affect USD-INR exchange rate and its volatility. We utilize monthly data from 1996:08 to 2016:10 and system GMM-IV estimation technique to estimate the model.

The findings of the study suggest that intervention by RBI in foreign exchange market is effective in influencing the USD-INR exchange rate returns and its volatility, viz. RBI intervention in foreign exchange market significantly increases the exchange rate returns and significantly decreases the exchange rate volatility. Further, this study finds that besides the central bank intervention, exchange rate returns is driven by output growth differential, money supply growth differential, stock market returns, capital flows, EUR-USD exchange rate return, change in trade

balance differential and order flow. Our findings indicate that apart from central bank intervention, exchange rate volatility is positively and significantly affected by the volatility of capital flows. Moreover, we find that an increase in exchange rate returns has significant and negative impact on RBI intervention. Finally, this study finds evidence for the asymmetric RBI intervention in USD-INR exchange rate market.

We contribute to the existing literature assessing the impact of central bank intervention on the Indian foreign exchange market (such as Behera *et. al.*, 2008; and Goyal *et. al.*, 2009) by extending a single equation/GARCH model to a simultaneous equations model. Further, our study has two notable practical implications. First, central bank intervention is successful in reducing volatility in the Indian exchange rate market arising due to domestic and external shocks. Second, USD-INR exchange rate returns are significantly determined by macro-economic variables (viz. output growth differential, money supply growth differential, stock market returns, capital flows, EUR-USD exchange rate return, and change in trade balance differential), micro-structure variable (viz. order flow) and central bank intervention.

However, there are two limitations of this study. First, while it is ideal to work with daily or weekly frequency in the context of exchange rate markets, our analysis is based on monthly data since published RBI intervention data is available at monthly frequency. Second, the results cannot be generalized to other emerging market economies and developing economies due to their different exchange rate regimes and monetary policy frameworks.

Notes

1. This study uses exchange rate returns as the dependent variable because exchange rate levels are found to be non-stationary. (See endnote no. 7).

2. The macro-economic variables included in the study are income differential, rate of interest differential, money supply differential, inflation differential, trade balance differential, stock market index, capital flows, volatility of capital flows, EUR-USD exchange rate and reserve adequacy ratio while the micro-structure variable that we examine is order flow.

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3. Exchange rate returns capture directional movements in the exchange rate with increasing exchange rate returns being indicative of depreciation of domestic currency vis-à-vis foreign currency and vice versa. Thus, this study considers the determinants of exchange rate as ~~The~~ factors affecting exchange rate returns as well (having same expected signs).

4. See Taylor, 1995, pp.27-28 for the explanation of medium run adjustment of exchange rate to changes in money supply.

5. See Fratzscher (2012), pp.724-725 for details.

6. See Miyajima (2013).

7. Unit root tests on the level variables in (1) show a mix of stationary and non-stationary variables. Thus, the non-stationary variables are used in returns form or first differences.

8. "Δ' denotes first difference, ' $\cdot$' symbolizes growth rates. Thus, $\dot{e}_t^{USD}$ denotes returns on USD-INR exchange rate, $\dot{ed}_t$ denotes returns on EUR-USD rate and $\dot{s}_t$ denotes returns on stock market index.

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Inter-linkages between USD-INR, EUR-INR, GBP-INR and JPY-INR

Exchange Rate Markets and the Impact of RBI Intervention

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Abstract

This paper examines inter-linkages between four major exchange rates, namely, USD-INR, EUR-INR, GBP-INR and JPY-INR in terms of returns and volatility spillovers using vector autoregressive-multivariate GARCH-BEKK framework. In addition, we analyze the impact of RBI intervention on the returns, volatility and covariance of these exchange rates. The study finds significant bi-directional causality-in-mean and causality-in-variance between all four exchange rates. The estimation results suggest that RBI intervention in the form of net purchase of dollars leads to depreciation of INR vis-à-vis USD, EUR, GBP and JPY. Furthermore, we find that RBI intervention not only significantly affects the volatility of INR vis-à-vis USD, EUR and GBP but also explains significant amount of covariance between USD-INR and the other three exchange rates.

Keywords: Inter-linkages, foreign exchange markets, spillovers, multivariate GARCH-BEKK, RBI intervention.

JEL Classification: C32; G15; E58; F31

spillovers across exchange rates. All these studies find some evidence of spillovers across exchange rates considered.

While there are numerous studies[5] that investigate the effectiveness of central bank intervention in the exchange rate market, few studies (Beine *et al.*, 2002; Beine *et al.*, 2003; Beine, 2004; Nikkinen and Vahamaa, 2009; Antonakakis, 2010; and Kenourgios *et al.*, 2015) examine the spillover effect of central bank intervention[6]. It is noteworthy that majority of these studies have been conducted on exchange rate markets of developed countries. Further, most of these studies find that central bank intervention is not successful in influencing the returns on major exchange rates and in reducing the volatility of these exchange rates.

Menkhoff (2013) notes that the central banks of advanced countries rarely intervene in the foreign exchange market. On the other hand, the intervention by central banks in the foreign exchange market is very regular in emerging markets. However, the survey reported in Menkhoff (2013) reveals that the empirical studies on the effectiveness of central bank intervention in developing countries is still at a nascent stage. Furthermore, according to Canales-Kriljenko (2003), central bank intervention in foreign exchange market may be more effective in developing countries than in advanced countries due to higher size of intervention relative to market turnover, and greater information advantage over market participants due to exchange and capital controls. Thus, given that RBI intervention in the foreign exchange market has become very frequent during the last decade, it is expected to significantly affect the returns, volatility as well as covariance of all major exchange rates vis-à-vis INR.

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1. Introduction

It is widely acknowledged that the integration of global financial markets since the 1980s has led to an increase in exchange rate volatility. The stock market crash of 1987, the East Asian crisis of 1997-98, the global crisis of 2007-09, and the enduring Eurozone crisis have revealed that there may be spillovers between foreign exchange markets. For instance, USD, EUR, GBP and JPY vis-à-vis INR have shown substantial comovement during the last decade (Figure 1). Further, emerging market economies resort to central bank's intervention in the foreign exchange market to guard them against the vulnerabilities of global shocks. Thus, the issues concerning inter-linkages across exchange rate markets and the impact of central bank intervention on these markets are critical for macro-economic modeling, portfolio management and central bank intervention policy.

A majority of the prior empirical literature such as Perez-Rodriguez (2006), McMillan and Speight (2010) and Antonakakis (2012) have focused on the spillovers across exchange rate markets of developed economies. Sahoo (2012), Kavli and Kotze (2014), D. Kumar (2014), and S. Kumar (2016) are some recent studies that consider spillovers in the exchange rate markets of developing economies[1]. For India, there are few studies (Sahoo, 2012; D. Kumar, 2014; S. Kumar, 2016; and Dua and Tuteja, 2016[2]) that examine linkages between exchange rate markets. It is noteworthy that Dua and Tuteja (2016) focus on the "contagion" between the markets as against the "spillovers" investigated in other studies[3]. While Sahoo (2012) examine only volatility spillovers, D. Kumar (2014) and S. Kumar (2016)[4] analyze both returns as well as volatility

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In this paper, we examine the inter-linkages between USD-INR, EUR-INR, GBP-INR and JPY-INR markets in terms of returns, shock and volatility spillovers. Additionally, we investigate the impact of intervention by Reserve Bank of India (RBI) on the conditional returns, volatility and covariance of these exchange rates. These four exchange rates are selected because of two reasons. One, Europe, US, UK and Japan are key trading partners of India[7]. Two, the currencies USD, EUR, GBP and JPY are top four traded currencies in the international market since 2004[8].

The currency rates w.r.t. INR are expected to be determined together with spillovers across returns and volatility[9]. In this study, we empirically examine these inter-linkages between exchange rate markets using vector autoregressive (VAR)-multivariate GARCH-BEKK methodology that has a parsimonious specification as compared to the VAR-multivariate GARCH-VECH model, ensures positive definite covariance matrix and enables examination of own market and cross market returns and volatility spillovers in an integrated framework. Moreover, by adding RBI intervention as explanatory variable in the VAR-multivariate GARCH-BEKK model, we examine the impact of RBI intervention on returns, volatility and covariance of exchange rates.

This paper contributes to the literature in three different aspects. First, empirical research on the interlinkages between exchange rate markets is scarce and thus this study complements the literature in this respect. Second, this study adds to the scant literature on the impact of central bank intervention in the exchange rate markets of developing countries. Third, we investigate the issues of spillovers across exchange rate markets and impact of central bank intervention in an integrated framework unlike the existing literature that considers each of them separately.

The rest of the paper is organized as follows. Section 2 briefly discusses the stylized facts pertaining to exchange rate markets in India and RBI intervention in the foreign exchange market. Section 3 outlines the model for exchange rate determination. Section 4 covers data and describes the methodology. Section 5 presents the estimation results and section 6 discusses the inferences from our analysis. The last section concludes the study.

2. Exchange Rate Markets in India and RBI intervention : Some Stylized Facts

The exchange rate market in India has undergone major transformations ever since the adoption of a managed float regime in 1993. For instance, as per the RBI database, the annual turnover in Indian exchange rate market increased from 1,306 USD million in 1997-98 to 13,400 USD million in 2014-15. However, the database reveals that the percentage share of spot transactions has remained constant at approximately 52% since 1997-98. Further, according to the RBI Report on Currency and Finance (2005-06), the off-shore turnover grew in tandem with the on-shore turnover in Indian exchange rate market since 1997-98. Additionally, there are some developments in Indian exchange rate market that are primarily led by changes in the international currency market. Though USD has a long history of being the international currency, other currencies such as EUR and JPY are becoming popular currencies in the international market[10]. Accordingly, there are apparent inter-linkages between the major currencies such as USD, EUR, GBP and JPY. Thus, the USD-INR exchange rate that is considered to be the prime reference rate in India is influenced by other major exchange rates such as EUR-INR, GBP-INR and JPY-INR. The testimony to this lies in the effect of global crisis 2007-09 and Eurozone crisis 2010-12 on Indian exchange rate market. Following the outbreak of global crisis in December 2007, INR

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depreciated considerably vis-à-vis major currencies such as USD, EUR, GBP and JPY and has had been extremely volatile.

Following the adoption of managed floating regime in 1993, RBI intervention in foreign exchange market has always been guided by the objective of maintaining stability in the exchange rate market. For instance, Prakash (2012) summarizes six phases of exchange rate volatility in India where RBI resorted to quantitative or qualitative measures or both to minimize the impact of global or domestic shocks on Indian exchange rate market. Further, as noted by Tripathy (2013), RBI does track the trade based Real Effective Exchange Rate that indicates the movements of INR vis-a-vis other currencies such as EUR, GBP and JPY.

3. Determinants of Exchange Rate

According to the monetary model (Frenkel, 1976) of exchange rate determination, exchange rate is a function of relative output, relative money supply and relative interest rates. This explanation of the exchange rate behavior came under major scrutiny with the seminal paper of Meese and Rogoff (1983) which argues that the forecasts based on economic fundamentals are worse than the random walk model at least in short to medium term. Many studies since then have tried to explain this "exchange rate disconnect puzzle" by taking different combination of variables or by using different econometric techniques. For instance, Dua and Ranjan (2012) extend the monetary model framework to include order flow, forward rate, relative trade balance, capital flows, volatility of capital flows and central bank intervention as additional determinants of exchange rate. Dua et al. (2017) further extend this model to include the difference in stock prices in the domestic economy and the foreign economy as additional factor that can influence the exchange rate.

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Recognizing that there are complex inter-linkages between the exchange rates, we investigate the importance of 'third currency' in explaining the bilateral exchange rate. MacDonald and Marsh (2004)[11]investigate the 'third currency effects' in their study, according to which the exchange rate between currencies 'i' and 'j' is a function of the exchange rate between currencies 'i' and 'k' and fundamentals (such as output, interest rates and prices) of countries having currencies 'i', 'j' and 'k'. Further, intervention by the central bank of some or all three countries in the exchange rate market of currency 'i' and 'j' can affect bilateral exchange rate between currency 'i' and 'j', and currency 'i' and currency 'k' through portfolio balance channel, signaling channel and microstructure channel[12]. This warrants the inclusion of intervention by central bank of all three countries in the exchange rate determination model of currency 'i' and 'j', and currency 'i' and 'k' (Dominguez, 1998; Beine *et al.*, 2002; Beine *et al.*, 2003; Beine, 2004; Antonakakis, 2010; and Chortareas, 2013).

Following Dominguez (1998), Beine *et al.* (2002), Beine *et al.* (2003), Beine (2004), MacDonald and Marsh (2004), Antonakakis (2010), and Chortareas (2013), the determinants of exchange rate between currency 'i' and 'j' consist of exchange rate between currency 'i' and 'k', fundamentals (such as output, money supply, interest rates and prices) of countries having currencies 'i', 'j' and 'k', and central bank intervention in countries having currencies 'i', 'j' and 'k'. Since the focus of this study is to examine the inter-linkages between the exchange rate markets and the impact of central bank intervention on these markets, the variables of interest are as follows:

$$e_t^j = f(e_t^k, Intr_t) \hspace{6cm} (1)$$

If the base currency is 'i', the exchange rates are defined as

e_t^j= log of bilateral exchange rate between currency i and currency j

e_t^k= log of bilateral exchange rate between currency i and currency k, $j \neq k$.

$Intr_t$= log of central bank intervention in country 'i'[13]

However, in accordance with the recent empirical literature (such as Hafner and Herwartz, 2006 and Antonakakis, 2012), we examine the linkages between exchange rate markets in terms of returns spillovers. Thus, the above model can be converted into the following form

$$\Delta e_t^j = f(\Delta e_t^k, \Delta Intr_t) \hspace{5cm} (2)$$

where Δ denotes first differences.

The expected sign of Δe_t^k in the above model is ambiguous since it depends on market activity which is influenced by several factors such as domestic policies and financial stability in concerned countries. For instance, Laopodis (2003) finds negative relationship between Italian Lira-German Mark and French Franc-German Mark, and Belgian Franc-German Mark and French Franc-German Mark. On the other hand, Melecky (2007) finds positive relationship between EUR -JPY and JPY-USD. Further, given that central bank intervention may affect exchange rate through diverse channels (Canales-Kriljenko *et al.*, 2003) in different directions, the sign of intervention in the above model is also ambiguous. For instance, Beine *et al.* (2003) find negative impact of

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Bundesbank intervention on DEM-USD returns while Antonakakis (2010) finds that the unilateral intervention by Bank of England significantly increases returns of EUR and JPY against USD.

The different episodes (such as global crisis 2007-09 and Eurozone crisis 2010-12) around the world have revealed that spillovers across exchange rate markets may take place in the second moment of exchange rate returns. Thus, this study also tests for volatility spillovers between the exchange rate markets[14]. Further, central bank intervention can affect the volatility and covariance of all the exchange rates linked with the domestic currency through signaling channel (Beine, 2004; and Chartoreas, 2013). For this purpose, we specify another two heuristic models as follows

$$h_t^j = g(h_t^k, \Delta Intr_t) \tag{3}$$

$$h_t^{j,k} = l(\Delta Intr_t) \tag{4}$$

where h_t^j = volatility of Δe_t^j

h_t^k = volatility of Δe_t^k

$h_t^{j,k}$ = covariance between Δe_t^j and Δe_t^k

As discussed before, the expected sign of h_t^k in (3) is ambiguous. However, the significance of its coefficient signifies the presence of volatility spillovers. Further, the expected sign of $\Delta Intr_t$ in (3) and (4) is also ambiguous. Nonetheless, the significance of its coefficient in (3) and (4) shows impact of central bank intervention in all the exchange rate markets linked with the domestic currency. Beine (2004) finds that coordinated Bank of Japan (BOJ) and Federal

Reserve (FED) interventions in the JPY market and coordinated European Central Bank (ECB)-FED intervention in EUR market increases volatility in their target market. In addition, the study finds that the coordinated BOJ-FED interventions significantly increase the covariance between EUR and JPY relative to USD. Nikkinen and Vahamaa (2009) obtain that interventions by BOJ temporarily increases the ex-ante correlations between JPY, EUR and GBP against USD. Antonakakis (2010) finds that the unilateral intervention by BOJ in JPY-USD market significantly increases EUR-USD volatility and unilateral intervention by ECB in EUR-USD market significantly reduces JPY-USD volatility. Moreover, the study finds that the unilateral central bank interventions increase the correlation between EUR-USD and JPY-USD. Kenourgios *et al.* (2015) discovers significant negative impact of the announcements by Bank of England and Bank of Japan on the GBP-USD and JPY-USD respectively. Further, they find that the announcements by Bank of England lead to a decline in the correlations between EUR and GBP vis-à-vis USD.

4. Data and Econometric Methodology

4.1 Data

Our analysis is based on the secondary data at weekly frequency sourced from Reserve Bank of India (RBI) website. Daily data for USD-INR, EUR-INR, GBP-INR and JPY-INR exchange rates is converted into weekly data using averages. We use 'Foreign Currency Assets' as a measure of RBI intervention. In accordance with our model (2), (3) and (4), all four exchange rates and foreign currency assets are converted into logarithmic first differences. The sample under study is from May, 2004 to February, 2015.

Descriptive statistics and features of exchange rate returns are worth mentioning. It may be seen from the reported descriptive statistics of exchange rate returns in Table 1 that the mean

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level of USD-INR returns is highest and that of GBP-INR returns is lowest among all four exchange rate returns over the study period. Furthermore, USD-INR returns show least volatility while JPY-INR returns show maximum volatility among all four exchange rate returns over the study period. All the exchange rate returns show significant positive skewness except GBP which is negatively skewed. In addition, there is evidence of significant excess kurtosis which confirms the leptokurtosis in the distribution of all four exchange rate returns.

4.2 Econometric Methodology

Unit Root Tests

As in any time series analysis, we begin with the examination of statistical properties of exchange rate returns and growth in foreign currency assets[15]. In this study, we employ the Dickey-Fuller Generalized Least Squares (DF-GLS) test proposed by Elliot *et al.* (1996) and KPSS test proposed by Kwiatkowski *et al.* (1992). In light of the structural breaks generally found in time series, we also use Lee and Strazicich (2003) structural break unit root test (we assume two structural breaks).

VAR (p)-multivariate GARCH-BEKK Methodology

In the second step, we use VAR(p) model to analyze the interconnections between exchange rate markets in returns, where the lag order p is selected using SBC and HQ lag selection criteria. A broad consensus has emerged in literature regarding volatility clustering found in exchange rate markets that warrant use of GARCH models. Moreover, there are inter linkages between exchange rate markets in second moments (volatility) that can be analyzed using

multivariate GARCH models. Thus, VAR (p) - multivariate GARCH methodology appropriately captures both the returns and volatility spillovers between exchange rate markets. However, the application of multivariate GARCH model requires testing for multivariate GARCH effects (Hacker and Hatemi , 2006) and time varying conditional correlations (Tse, 2000). Hence, in the third step, we test for the presence of multivariate GARCH effects and time varying conditional correlations in VAR (p) residuals using LM test.

see space

Finally, in this study, we employ VAR (p) / multivariate GARCH-BEKK specification as it enables us to estimate and analyze models (2), (3) and (4) in an integrated framework (see next section for details). This implies that BEKK specification allows us to examine returns, shock and volatility spillovers among exchange rate markets and the impact of RBI intervention on these markets in an integrated structure. Besides, there are several other advantages of BEKK specification vis-à-vis other models such as VECH, diagonal VECH and Dynamic conditional correlations (DCC). First, the number of variables in this study are large enough to give convergence issues with more general VECH model. Second, diagonal VECH do not allow the examination of volatility spillovers. Third, BEKK estimates are obtained in a single step that makes them more efficient as compared to DCC estimates based on the two step procedure. Fourth, while the literature on properties of DCC estimates is still growing, asymptotic properties of BEKK are well established in literature. Lastly, unlike VECH, diagonal VECH and DCC, BEKK do not require any restriction on the model to ensure positive definite variance covariance matrix.

5. Empirical Results

From the reported results of DF-GLS, KPSS and Lee and Strazicich unit root tests in Table 2, it can be interpreted that all four exchange rate returns and growth in foreign exchange reserves

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are stationary. Further, SBC and HQ lag selection tests [15] indicate that VAR (1) model is appropriate for our exchange rate mean equations. Lastly, LM test on the residuals of VAR (1) model show the presence of significant multivariate ARCH effects and the LM test by Tse (2000) indicate that our data exhibits time varying conditional correlation [16]. In view of these preliminary findings, we employ VAR (1)-multivariate GARCH (1, 1) [17] -BEKK model to empirically analyze (2), (3) and (4) in an integrated framework. The underlying empirical model used in this study is specified as follows

$$\Delta e_t = \alpha + A\Delta e_{t-1} + \delta_1 \dot{R}_{t-1} + \delta_2 D_{1t} + \delta_3 D_{2t} + \varepsilon_t \tag{5}$$

where $\Delta e_t = \begin{pmatrix} \Delta e_t^{USD} \\ \Delta e_t^{EUR} \\ \Delta e_t^{GBP} \\ \Delta e_t^{JPY} \end{pmatrix}$ is a 4×1 vector of USD-INR, EUR-INR, GBP-INR and JPY-INR

exchange rate returns. $\dot{R}_{t-1}$ is one week lag of growth in foreign exchange reserves.

$$D_{1t}{}^{18} = \begin{cases} 1 \ if \ t \ \epsilon \ 07/12/2007 - 06/26/2009 \\ 0 \ otherwise \end{cases}$$

$$D_{2t}{}^{19} = \begin{cases} 1 \ if \ t \ \epsilon \ 09/04/2010 - 28/12/2012 \\ 0 \ otherwise \end{cases}$$

α is a 4×1 vector of constants while A is a 4×4 matrix of parameters in the VAR (1) model that measure conditional mean spillovers. δ_1 is a 4×1 vector representing the effect of lagged RBI intervention [20] on USD-INR, EUR-INR, GBP-INR and JPY-INR exchange rate returns. δ_2

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and δ_3 are 4×1 vectors that represent the effect of global crisis and Eurozone crisis respectively on all four exchange rate returns. The error term ε_t in (5) is a vector of four variables having an underlying t-distribution with $\varepsilon_t/\Omega_{t-1} \sim t(0, H_t)$, where $\Omega_{t-1} = \{\varepsilon_{t-1}, \varepsilon_{t-2}, \varepsilon_{t-3}, \dots \dots\}$ is the past information on errors. Further, $\varepsilon_t = H_t^{-\frac{1}{2}}(\theta)\, z_t$ such that E $(\varepsilon_t/\Omega_{t-1}) = 0$ and E $\left(\varepsilon_t\varepsilon_t' \middle/ \Omega_{t-1}\right) = H_t$. In our case, H_t can be written as follows

$$H_t = \begin{bmatrix} h_t^{USD} & h_t^{USD,EUR} & h_t^{USD,GBP} & h_t^{USD,JPY} \\ h_t^{EUR,USD} & h_t^{EUR} & h_t^{EUR,GBP} & h_t^{EUR,JPY} \\ h_t^{GBP,USD} & h_t^{GBP,EUR} & h_t^{GBP} & h_t^{GBP,JPY} \\ h_t^{JPY,USD} & h_t^{JPY,EUR} & h_t^{JPY,GBP} & h_t^{JPY} \end{bmatrix}$$

The associated variance-covariance equation is represented by:

$$H_t = C'C + G'\varepsilon_{t-1}\varepsilon_{t-1}'G + FH_{t-1}'F + \psi_1\dot{R}_{t-1}'\psi_1 + \psi_2'D_{1t}D_{1t}'\psi_2 + \psi_3'D_{2t}D_{2t}'\psi_3 \qquad (6)$$

where G and F are 4×4 matrices while C, ψ_1, ψ_2 and ψ_3 are 4×4 upper-triangular matrices. The elements g_{ij} of matrix G measure the degree of cross innovation or shocks (lagged by period) from market i to market j. The diagonal elements in matrix G represent the ARCH effect and the off-diagonal elements in matrix G the cross-spillover effects (short-term volatility spillover effects). The elements f_{ij} of matrix F show the persistence in conditional volatility between market i and market j. The diagonal elements in matrix F measure the GARCH effect, and the off-diagonal elements measure cross-volatility spillover effects (long term volatility spillover effects). ψ_1 measures the effect of lagged RBI intervention on conditional volatility and covariance of exchange rate returns while ψ_2 and ψ_3 measure the effect of global crisis and Eurozone crisis respectively on conditional volatility and covariance of all four exchange rate returns.

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The parameters of (5) and (6) are estimated using method of maximum likelihood using a simplex algorithm for a few initial iterations and then shift to the BFGS algorithm. It is noteworthy that since exchange rate returns are characterized by fat tails, we utilize t- distribution rather than the usual Gaussian distribution.

The estimates of model (5) and (6) are given in Table 3.The diagnostic statistics, viz., multi-variate Q statistic for standardized residuals and squared standardized residuals of the model is reported that indicates the absence of serial correlation in standardized and squared standardized residuals. Moreover, the shape parameter of the t-distribution is estimated and significant in the model specification.

Mean spillovers (causality in mean)

From the results of mean equations presented in Table 3, Panel A, it is seen that own lagged terms are significant for all four exchange rate returns. We find bi-directional returns spillovers between all exchange rate returns[21]. Further, mean equation estimates (Table 3, Panel A) indicate that an increase in USD-INR returns leads to a decrease in EUR-INR, GBP-INR and JPY-INR returns. Similarly, an increase in EUR-INR and JPY-INR returns leads to a decrease in the remaining exchange rate returns. On the other hand, an increase in GBP-INR returns causes an increase in USD-INR, EUR-INR and JPY-INR returns.

Effect of intervention on exchange rate returns

The estimates of mean equations reported in Table 3, Panel A suggest that intervention is significantly and positively related to USD-INR, GBP-INR, EUR-INR and JPY-INR. Thus, an

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increase in the intervention by RBI in the form of net purchase of USD causes depreciation of INR vis-à-vis USD, GBP, EUR and JPY.

Shock Spillovers (short term volatility spillovers)

From the results of the variance equations reported in Table 3, Panel B it is seen that the ARCH effect or the own news effect, given by g_{ii} is significant for all the markets except EUR-INR market. Therefore, these markets seem to respond to their own-past innovations and a shock in the market during the previous period results in an increase in its volatility in the current period. We find while the cross-news effects are lower than the own previous period own news effect for USD-INR and JPY-INR markets, GBP-INR and EUR-INR markets respond more to other markets previous period shock than its own previous period news. Further, results in Table3, Panel B suggest bi-directional shock spillovers between USD-INR and JPY-INR, EUR-INR and GBP-INR and EUR-INR and JPY-INR. We also find cross news effects from USD-INR to EUR-INR and GBP-INR to USD-INR.

Volatility spillovers (long term volatility spillovers)

The results of variance equations reported in Table 3, Panel B show that the GARCH effect or own previous period volatility effect, given by f_{ii} is significant for all markets. We find while the cross-volatility effects are lower than the own previous period volatility effect for USD-INR, EUR-INR and JPY-INR markets, GBP-INR market responds more to other markets previous period volatility than its own previous period volatility. Further, variance equation estimates (Table 3, Panel B) suggest bi-directional volatility spillovers between all four exchange rate markets.

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Effect of intervention on volatility and covariances of all exchange rates

From the results of variance equations in Table 3, Panel B, it is seen that intervention by RBI in foreign exchange market significantly affects volatility of USD-INR, EUR-INR and GBP-INR exchange rates[22]. Further, we find that the coefficient ψ_{144} is negative and insignificant implying negligible impact of RBI intervention on volatility of JPY-INR exchange rate. Additionally, the results in Table 3, Panel B suggest that RBI intervention in foreign exchange market significant affects the covariance between USD-INR and EUR-INR, USD-INR and GBP-INR, USD-INR and JPY-INR, and GBP-INR and JPY-INR. Thus, we find evidence for the spillover effect of RBI intervention (in USD-INR market) on EUR-INR, GBP-INR and JPY-INR exchange rate markets[23].

Causality Tests and the Effect of Crisis

The results of causality in mean are reported in Table 4. We find that the mean spillovers between all exchange rate markets are Granger causal-in-mean[24]. Subsequently, we tested for causality in variance using VAR (1)-multivariate GARCH (1, 1)-BEKK model and the results are given in Table 5. The null hypothesis of no volatility spillovers (causality in variance) is rejected for all the exchange rate pairs[25].

Finally, we tested for the impact of global financial crisis (GFC) and Eurozone debt crisis (EZDC) on returns and conditional covariance matrix of all four exchange rates. Results reveal that GFC and EZDC led to an increase in USD-INR, EUR-INR, GBP-INR and JPY-INR exchange

rate returns (i.e. depreciation of rupee vis-à-vis USD, EUR, GBP and JPY)[27]. Further, we find that GFC and EZDC had a significant impact on the variance-covariance matrix of returns as the null hypothesis of no impact is rejected at 1% level (value of χ^2 test statistic for GFC is 76.66 and for EZDC is 67.26).

Volatility Plots

The volatility plots of all four exchange rates are shown in Figures 2A-D. It is observed from the Figures that the volatility of all four exchange rates substantially increased during the global crisis of 2007-09. It appears from the Figures that the maximum brunt of the global crisis was born by JPY-INR market. It is interesting to note that all the markets quickly recovered from the uncertainty of the global crisis. However, the calmness did not last long for the exchange rate markets. The uncertainty that engulfed the Eurozone in 2010 again affected all exchange rate markets. In particular, it is seen from the graphs that volatility in all markets was substantially high during 2010-2012. The Figures show that the maximum impact of Eurozone crisis was again on JPY-INR market.

Correlation Plots

The conditional correlations amongst the markets are presented in Figures 3A-F. It is observed from the Figures that correlation between all exchange rate markets except USD-INR and JPY-INR decreased during the global crisis of 2007-09. It is seen that the correlation between USD-INR and JPY-INR substantially increased during 2007-09. It is noteworthy that correlation between all exchange rate markets except USD-INR and JPY-INR quickly increased as the

markets recovered from the global crisis. Further, it appears from the Figures that the Eurozone crisis has negligible impact on the correlation between all other exchange rate markets.

6. Inferences and Discussion

For a small open economy like India, the inter-linkages between USD-INR, EUR-INR, GBP-INR and JPY-INR exchange rates are primarily driven by the economic linkages between the countries and currencies of US, EU, UK and Japan. It may be seen from Table 6 and 7 that there are significant trade and financial linkages between all four developed economies. A significant feature of the Japanese market is the presence of carry trade[28] that lends considerable volatility to JPY vis-à-vis other currencies. Further, it is seen from Table 8 that the ranking of USD, EUR, JPY and GBP currencies in the international market have been constant in the last decade. It is observed while USD have had a maximum share, EUR and JPY have been the second largest and third largest traded currencies in the world market. Though USD is historically considered as 'safe haven currency', many studies like Ranaldo and Soderlind (2010) and Botman *et al.* (2013) have claimed that JPY has emerged as a 'safe haven currency'.

The mean and volatility spillovers results discussed in the last section broadly corroborate these observations. The bi-directional returns and volatility spillovers found between all four exchange rate markets exemplify the strong trade and financial linkages between US, EU, UK and Japan (Table 6 and 7)[29]. Further, we find that appreciation (depreciation) of USD leads to depreciation (appreciation) of EUR, GBP and JPY. It may be due to dominance of USD in the international foreign exchange market as the world's top traded currency (or international

currency). Similarly, we find that appreciation (depreciation) of EUR causes depreciation (appreciation) of the remaining three currencies. This may be due to EUR being the second most traded currency in the international market. We also find an inverse relationship between JPY-INR and the remaining three exchange rate that may be due to the 'safe currency' status of JPY in the international market. Finally, our results reveal positive relationship between GBP-INR and the remaining three exchange rate that possibly reflects the subdued importance of GBP in the international market and the subsequent complementarity between GBP and the remaining three currencies. The results of variance equations suggest that USD-INR and JPY-INR respond more to own market shocks and volatility than to cross market shocks and volatility which may be attributed to the fact that both U.S and Japan are one of the largest and most technologically powerful economies of the world that makes them less vulnerable to external shocks.

Our analysis reveals significant impact of global crisis 2007-09 and Eurozone crisis 2010-12 on mean and conditional covariance matrix of all four exchange rate returns. As expected, we find that the volatility of all the markets substantially increased in both the crisis periods. Further, we find that JPY-INR market was worst hit during the global crisis 2007-09 and Eurozone crisis 2010-12. The maximum volatility observed in JPY-INR market during the global crisis may be explained using the movement of interest rates in US, UK, Eurozone and Japan in the pre-crisis and crisis phase. It may be seen from Figures 4 and 5 that in the pre-crisis phase, interest rates in US, UK and Eurozone vis-à-vis Japan were very high and increasing steadily. This led to the occurrence of carry trade in Japan that caused higher volatility in JPY-INR market vis-à-vis other markets. The outbreak of crisis was followed by a sudden decrease in the interest rates of US, UK and Eurozone. As a result, there was unwinding of the yen carry trade and subsequent appreciation of yen against other currencies. Thus, while all markets experienced sudden increase in volatility

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during the global crisis, JPY-INR market was worst hit. It is seen from Figure 4 and 5 that post global crisis there was smooth movement in the interest rates of all economies before the outbreak of EZDC when interest rates again started going down. Consequently, during EZDC also, JPY-INR market experienced maximum volatility. As regards the effect of global crisis on the correlations of four exchange rates, our results show decrease in the correlations of all exchange rate pairs except USD-INR and JPY-INR that indicates 'flight to quality[30]'. In case of USD-INR and JPY-INR, there was a substantial increase in the correlation that shows 'contagion' effect. The flight to quality effects in currencies are in line with the findings of Dimitriou and Kenourgios (2013), and Dua and Tuteja (2016)[31].

Our results also bring to the fore evidence regarding the impact of RBI intervention on all major Indian exchange rate markets. RBI intervention is found to significantly increase returns on all exchange rates. RBI intervention is also found to significantly affect volatility of USD-INR[32], EUR-INR and GBP-INR markets. The insignificant impact of RBI intervention on the volatility of JPY-INR market may be due to the presence of carry trade in Japan. Furthermore, we find that RBI intervention significantly affects the covariance between USD-INR and EUR-INR, USD-INR and GBP-INR, and USD-INR and JPY-INR markets[33]. This may be attributed to the fact that RBI primarily intervenes in USD-INR market and thus has maximum impact on USD-INR volatility (as $\psi_{111} > \psi_{122} > \psi_{133} > \psi_{144}$).

Conclusions

Conclusions

This paper examines the returns, shock and volatility spillovers between USD-INR, EUR-INR, GBP-INR and JPY-INR exchange rates, and the impact of RBI intervention on the returns, volatility and covariances of these exchange rates using VAR (1)-multivariate GARCH (1, 1) - BEKK model.

The bi-directional returns and volatility spillovers found between all four exchange rate markets are indicative of the trade and financial linkages between the economies. The results of the mean equation reveal an inverse relationship between USD-INR and the other three exchange rates may be due to the fact that USD is the international currency. Similarly, the inverse relationship between EUR-INR and the remaining three currencies may be due to the growing importance of EUR in the international market. We also find inverse relationship between JPY-INR and the remaining three exchange rate that may be due to the 'safe currency' status of JPY in the international market. Thus; our findings exemplify the dominance of USD, EUR and JPY in the international market. Furthermore, we find currency complementarity between GBP and other three currencies that reflects the subdued importance of GBP in the international market.

Using VAR (1)-MGARCH (1, 1)-BEKK model, we test for the impact of global crisis and Eurozone crisis on the mean equations and conditional covariance matrix of four Indian exchange rates. The results indicate that the returns and volatility of all four exchange rates increased during the crisis. We find that the brunt of GFC and EZDC was borne by JPY-INR market that may be linked to the movement of interest rates in US, EU, UK and Japan during the two crisis periods. Further, we find evidence for 'flight to quality' during the global crisis as the correlation between all exchange rate pairs except USD-INR and JPY-INR decreased during 2007-09. There is

evidence of 'contagion' between USD-INR and JPY-INR markets as the correlation between these markets increased during the global crisis.

The key finding of the study is that intervention by RBI in USD-INR market has significant spillovers to other exchange rate markets. We find that RBI intervention significantly increases USD-INR, EUR-INR, GBP-INR and JPY-INR exchange rate returns. Furthermore, we find that RBI intervention in foreign exchange market significantly affects the volatility of USD-INR, EUR-INR and GBP-INR markets. The effect of RBI intervention on volatility of JPY-INR rate is found to be insignificant. Lastly, we find that RBI intervention significantly affects covariance between USD-INR and EUR-INR, USD-INR and GBP-INR and USD-INR and JPY-INR markets.

The results of the study have important implications both from investor's and policy maker's perspective. Our finding that there are significant inter-linkages between exchange rate markets in India and significant impact of RBI intervention on all four exchange rate markets may be useful for short run portfolio management and possibly influence RBI's intervention policy. According to the Capital Asset Pricing Model (Campbell *et al.* 1997), the optimal vector of portfolio weights is a function of the covariance matrix of the returns. Thus, failing to account for the inter-linkages between the markets (in terms of second moment of exchange rate returns) and the impact of RBI intervention on these markets may lead to a suboptimal portfolio. Moreover, this study points to the need for a comprehensive central bank intervention policy that accounts for the linkages found in this paper. Lastly, the 'flight to quality' effects found in this paper indicate the opportunity of portfolio diversification across the major world currencies.

Acknowledgement

1. Several recent empirical studies such as Eissa *et al.* (2010) and Ely (2015) have analyzed the linkages between stock returns and exchange rates using multivariate GARCH models. However, only some empirical studies have analyzed the linkages between the exchange rate markets.

2. While Sahoo (2012) and Dua and Tuteja (2016) analyze the linkages between currencies vis-a-vis USD, D. Kumar (2014) examine the currencies vis-à-vis INR.

3. Spillovers in international finance are defined as "the phenomena where change in asset price (or asset price volatility) in one country leads to a change in asset price (or asset price volatility) in another country." Contagion, as defined in Pericoli and Sbracia (2003, pp.575) "is a significant increase in the co movement of prices and quantities across markets, conditional on a crisis occurring in one market or a group of markets".

4. While D. Kumar (2014) consider the spot exchange rates vis-à-vis INR, S. Kumar (2016) analyze the future exchange rates vis-à-vis INR.

5. For instance, see Galati *et al.* (2005), Pattanaik and Sahoo (2003), Hillebrend *et al.* (2009), and Goyal *et al.* (2009).

6. Central bank intervention which is primarily done in one particular exchange rate market, may affect the volatility of other major exchange rate markets and also the covariance between exchange rate markets, known as spillovers of intervention (Beine, 2004).

7. The average share of US, Europe, UK, and Japan in India's total exports of last five years stand at 12.11%, 16.95%, 2.95% and 2.01% respectively (Author's own calculations based on Directorate General of Foreign Trade, GOI database).

8. Triennial Central Bank Survey of foreign exchange and OTC derivatives markets, 2016.

9. In general, there is an inherent volatility clustering in financial markets.

10. According to the Triennial Central Bank Survey of foreign exchange and OTC derivatives markets, 2016, global foreign exchange rate market turnover grew substantially since 2004 with USD, EUR, GBP and JPY being the top four traded currencies.

11. Lindblad and Sellin (2007) and Melecky (2008) examine the 'third currency effects' on bilateral real exchange rates. The focus of this study, however, is the interlinkages between the nominal exchange rates. Kuhl (2008) also theoretically and empirically investigates comovements between exchange rates and explores the economic variables that cause these interlinkages.

12. See Canales-Kriljenko *et al.* (2003) for channels of central bank intervention.

13. Given that $Intr_t$ is not in percentage, is not a dummy variable or has negative observations.

14. The empirical literature that examines the volatility spillovers across exchange rate markets, consists of studies such as Hafner and Herwartz (2006), Perez-Rodriguez (2006), and Antonakakis (2012). Among the studies that examine the returns (or currency spillovers) as well as volatility spillovers across exchange rate markets are Laopodis (2003), Bekiros and Diks (2008), D. Kumar (2014) and S. Kumar (2016).

15. We use the term 'growth in foreign exchange assets' for the logarithmic first differences of foreign exchange assets.

16. Results of VAR lag selection tests are not reported for brevity. They are available from authors on request.

17. Results of multivariate ARCH test and the LM test by Tse (2000) are not reported for brevity. They are available from authors on request.

18. Though the lag order of VAR model is based on SBC and HQ lag selection test, the order of multivariate GARCH model is taken as 1 due to practical computational issues.

19. The period from December 2007 to June 2009 represents global crisis period. It is based on U.S business cycle peak and trough dates available from ECRI. Same period is given by U.S coincident index available from Federal Reserve Bank of Philadelphia.

20. The period from April 2010 to December 2012 represents Eurozone crisis period. It is derived from the Bryboschan procedure of calculating business cycle dates.

21. Since RBI intervention is not exogenous, we take lagged RBI intervention in the mean and variance equations to avoid the simultaneity bias.

22. Coefficients a_{ij} , $i \neq j$ except a_{21} , a_{24} and a_{41} are significant at conventional levels of significance (1, 5 or 10%). However, the t - statistic of a_{21} (effect of USD-INR returns on EUR-INR returns) is greater than 1 and significant at 11%, the t-statistic of a_{24}(effect of JPY-INR returns on EUR-INR returns) is greater than 1 and significant at 14% and the t-statistic of a_{41} (effect of USD-INR returns on JPY-INR returns) is greater than 1 and significant at 18%.

23. The coefficients ψ_{111}, and ψ_{133} are significant at 1%, while the coefficient ψ_{122} is significant at 12%.

24. In order to know whether RBI intervention has negative or positive impact on volatility and covariance of exchange rate markets, we compared estimated volatility, covariance and correlation of all four exchange rates implied by VAR (1)-multivariate GARCH-BEKK model, estimated with and without RBI intervention. It seems from the graphs that RBI intervention causes decrease in volatility, covariance and correlation of all four exchange rates. However, further research is required for an affirmative answer.

25. All χ^2 test statistics except for $a_{24} = 0$ and $a_{41} = 0$ are significant at conventional levels of significance. However, we reject $a_{24} = 0$ and $a_{41} = 0$ at 13% and 17% respectively.

26. All χ^2 test statistics except for $g_{14} = f_{14} = 0$ are significant at conventional levels of significance. However, the null hypothesis of '$g_{14} = f_{14} = 0$' is rejected at 14%.

27. Coefficients of the dummy variables in the mean and volatility equations are not reported for brevity. They are available from authors on request.

28. The differences between the interest rates of Japan and other major economies contribute to significant carry trade in Japan. As on 23 July, 2015, the interest rate on three month government securities in the US is 0.03% per annum, in India it is 7.47%, while in UK its 0.472%. The interest rate on one year bonds in Japan stands at 0.008% on 23 July, 2015.

29. Kumar (2014) uses VAR (1)-DCC-Multivariate GARCH (1, 1) model and weekly data from 13January 1999-31 August 2012 to examine spillovers among USD-INR, EUR-INR, GBP-INR and JPY-INR exchange rates. The study finds significant unidirectional return spillover from EUR-INR and JPY-INR to USD-INR and bidirectional return spillover between GBP-INR and JPY-INR. It also finds significant volatility spillovers from USD-INR to GBP-INR,

EUR-INR and JPY-INR and from GBP-INR and EUR-INR to USD-INR. Further, Mac Donald and Marsh (2004), Perez-Rodriguez (2006), McMillan and Speight (2010), and Antonakakis (2012) provide evidence for significant spillovers between exchange rate markets of developed countries.

30. See Favero and Giavazzi (2002) for details of flight to quality effect.

31. While Dimitriou and Kenourgios (2013) find flight to quality effects between EUR-USD, JPY-USD, GBP-USD, CHF-USD and AUD-USD exchange rates, Dua and Tuteja (2016) find significant decrease in correlations between EUR-USD,JPY-USD and INR-USD during all crisis periods.

32. Bhaumik and Mukhopadhyay (2000) utilizing OLS and monthly data from April 1996 to March 1999 find that RBI intervention is ineffective in influencing USD-INR exchange rate returns. Goyal *et al.* (2009) find RBI intervention to be effective in influencing USD-INR exchange rate returns and its volatility using GMM-IV, monthly data (2002- 2008) and daily data (November 2005-May 2008). Pattanaik and Sahoo (2003) using OLS and 2SLS on monthly data since June 1995 finds that RBI intervention is not effective in affecting USD-INR exchange rate returns but is successful in influencing its volatility. Behera *et al.* (2008) and Vadivel and Ramachandaran (2013) also find the same result as Pattanaik and Sahoo (2003) using univariate GARCH models during April 1995-December 2006, and December 1996-April 2013 respectively.

33. Studies by Beine (2004), Antonakakis (2010), and Chortareas *et al.* (2013) find central bank intervention in developed countries influence volatility of major exchange rates and linkages among them.

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Exports of India to Developed and Developing Economies: An Analysis

Abstract

This paper analyzes the determinants of growth in India's exports to developed and developing countries using panel data. We utilize panel GMM-IV technique to estimate a 'hybrid model' for India's export growth. Our findings suggest that while real exchange rate volatility significantly decreases growth in India's exports to developing countries, it has an insignificant impact on growth in India's exports to developed countries. Additionally, while we find growth in India's exports to both developed and developing economies is positively affected by growth in real exchange rate, foreign income, domestic income, FDI and infrastructure; it is negatively influenced by domestic demand. Our findings indicate that both demand as well as supply side factors are crucial for India's export growth.

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1. Introduction

International trade plays a significant role in an economy's growth (Frankel and Romer, 1999; Dollar and Kraay, 2004; and Clift and Diehl, 2007). Recognizing the importance of international trade, many developed and developing countries have drastically reduced their trade barriers in the last two decades. However, the liberalization process has been accompanied by higher exchange rate volatility. Hence, a thorough analysis of the determinants of international trade is crucial for the policy decisions taken by the government and for all other economic agents linked with the international trade.

There are two sets of factors that affect exports, viz. internal and external factors. External factors are broadly represented by foreign demand while internal factors are related to the supply-side conditions such as production capacity and domestic demand. The existing empirical literature consists of three kinds of studies, viz. studies that are based on export demand function (such as Grier and Smallwood, 2013; Bahmani-Oskooee et al., 2015; and Hooy et al., 2015), studies that examine the export supply function (such as Cerra and Saxena, 2003; and Edwards and Phil Elves, 2006) and the studies that consider both demand and supply side factors (such as Sharma, 2003; Jongwanich, 2007; Nayak et al., 2013; Shah, 2013; Raissi and Tulin, 2015; and Sahoo et al., 2015) in the export model. Furthermore, the last category consists of two kinds of studies, viz. studies based on structural approach (such as Sharma, 2003; Jongwanich, 2007; and Shah, 2013) in which export demand and export supply functions are modeled separately; and the studies that adopt the non-structural approach; also called the eclectic or hybrid approach (Nayak et al., 2013; Raissi and Tulin, 2015; and Sahoo et al., 2015) in which demand and supply side factors are examined in a single equation. However, as noted by Basarac Sertić et al. (2015, p.389); it has been broadly recognized in the literature that the determinants of export demand are far from being able to entirely explain the export behavior.

A majority of the empirical studies have used time series data to analyze the determinants of international trade. The time series analysis, however, has certain limitations such as difficulty in inferential procedures arising from non-availability of sufficient data or presence of multicollinearity among explanatory variables (Hsio, 2014, pp.5-10). In particular, regarding the issues related to trade, the use of panel data has several advantages vis-a-vis time series data such

as its ability to control for country-specific effects like distance and cultural relationships and to analyze the impact of trade agreements on trade. Thus, recent empirical studies such as Hooy *et al.* (2015), Xing (2012) and Byrne *et al.* (2008) have employed panel data techniques to overcome the problems that may arise in time series analysis[1].

Most of the early empirical studies on India's trade (such as Joshi and Little, 1994; Sharma, 2003; and Roy, 2007) are based on a structural model of export demand and supply. However, recent Indian studies (such as Kumar, 2010; Eichengreen and Gupta, 2012; and Bhanumurty and Sharma, 2013) use the electic approach in their analysis. Furthermore, majority of these studies (such as Panda and Mohanty, 2015; Gupta *et al.*, 2015; and Sahoo *et al.* 2015) have used time series data to examine the determinants of India's exports. Cheung and Sengupta (2013), Tripathi and Leitao (2013), and Nayak *et al.* (2013) are among the very few panel data studies based on India. Nonetheless, there is no consensus in the literature on the impact of demand and supply side factors on India's exports. For instance, while Tripathi and Leitao (2013) and Nayak *et al.* (2013) find the effect of India's GDP to be positive and significant, Roy (2007) and Sahoo *et al.* (2015) find it to be positive and insignificant.

According to RBI's Annual Report (2015), Anand *et al.* (2015), and a study by PHD research bureau, PHD chamber of commerce and industry (2015), India has diversified its exports over the years in terms of exports destinations. Furthermore, the latter study shows while the share of developed countries in India's exports has declined, the share of developing countries in India's exports has increased over the years. This may be attributed to several factors such as macro-economic differences between the two set of countries in the last decade and the trade agreements of India with the developing countries. However, there is no study so far that analyzes the determinants of India's export growth vis-à-vis developed and developing countries.

With this backdrop, the purpose of this study is to analyze determinants of growth in India's exports to developed and developing economies respectively using panel data from 2004Q3 to 2016 Q1. For this purpose, we divide India's 12 major trading partners[2], viz. US, China, Hong

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[1] It is noteworthy that very few panel studies (such as Chit *et al.*, 2010) analyze the stationarity properties of the variables utilized in their analysis.

[2] In the first step, the countries are ranked on the basis of their average share in India's exports of last five years (2010-2015), ten years (2005-2015) and fifteen years (2000-2015) where the average share has been calculated from the share of countries in total exports (obtained from the online database of India's Directorate General of Foreign Trade) in each respective year. Thereafter, the

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Kong, Singapore, Eurozone (EZ), UK, Japan, Indonesia, Brazil, South Africa, Malaysia and Thailand into two subgroups, viz. developed economies (US, EZ, UK, Japan, Hong Kong, and Singapore) and developing economies (China, Indonesia, Brazil, South Africa, Malaysia and Thailand). This study uses a hybrid export model, where all the likely determinants of demand for exports and supply for exports are considered as the explanatory variables. Thus, in addition to the traditional determinants of exports, viz. foreign income, domestic income, relative price and exchange rate volatility, our model contains FDI and infrastructure as measures of export supply capacity, domestic demand pressure and India's major free trade agreements during last decade. Volatility of the real exchange rate is estimated using a univariate GARCH model. Panel GMM-IV technique is used to estimate the model as it does not make any assumption about the variance-covariance matrix of residuals and allows for endogenous variables.

This paper contributes to the existing literature in four different aspects. First, this study uses a hybrid model to examine the determinants of India's export growth that enriches the scant literature on determinants of export growth based on the eclectic approach. Second, it is the first study that examines the determinants of growth in India's exports to developed and developing economies. Third, the econometric methodology used in this analysis explicitly considers the stationarity properties and cross-sectional dependence of variables usually ignored in existing panel studies on this issue. Fourth, we incorporate the effect of ASEAN-India Free Trade agreement (FTA) and India-Japan comprehensive economic partnership agreement on India's export growth during the last decade.

The rest of this paper is organized as follows: Section 2 briefly discusses trends in India's exports, policy reforms and trade agreements. Section 3 discusses the export function utilized in this study and the expected signs. Data, empirical model and econometric methodology are presented in Section 4. Section 5 discusses the empirical results and Section 6 outlines concluding remarks.

2. Trends in India's exports

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common set of first 12 countries having average share of more than 1% is selected as India's major trading partners. United Arab Emirates ranked second but it is not included in the analysis because of the non-availability of data.

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Figure 1 and 2 depict the trend in the level of India's exports and India's export growth respectively during 2001Q3-2016Q1. It can be seen from Figure 1 that India's exports have shown an increasing trend during 2001Q3-2016Q1. However, with the outbreak of Eurozone crisis in 2010, India's exports increased marginally till December 2014 and has been declining thereafter. In terms of the growth rates, Figure 2 reveals that India's export growth depicts an increasing trend before a substantial drop during 2007Q4-2008Q1 that may be due to the outbreak of global financial crisis in 2007Q4. After showing an increase till 2010Q2, India's export growth has again shown a declining trend which may be attributed to the effect of Eurozone crisis.

India's Bi-lateral Exports: Developed versus Developing countries

Figure 3 shows average exports of India to EU, UAE, US, UK, Japan, Indonesia, Singapore, Hong Kong, China, Malaysia, Thailand, South Africa and Brazil during 1980-1990, 1990-2000, 2000-10, and 2010-15 respectively while Figure 4 depicts average Indian exports to developed and developing economies during the four time periods. It can be seen from Figure 3 that even before the liberalization of Indian economy in 1991, the major destination countries for India's exports have been US, EU, UK and Japan. However, during 1990-2000, in addition to these economies, India's exported to Hong Kong and Singapore. Further, Figure 3 shows that since year 2000, India's exports have diversified considerably with additional destinations such as South East Asian economies, (viz. Thailand, Malaysia and Indonesia), China, UAE, Brazil and South Africa. As a result, Indian exports to both developed and developing economies have increased tremendously since 2000 (Figure 4).

However, it can be observed from Figure 5 that the share of US, UK, EU, Japan and Hong Kong in India's exports has decreased substantially since 2001. Furthermore, the share of Thailand, Malaysia, Singapore, Indonesia, China, Brazil and South Africa in India's exports has increased during the same period. Overall, Figure 6 reveals while the share of developed countries in India's exports has decreased, the share of developing countries in India's exports has increased during 2000-2015.

Policy reforms and Trade agreements

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India's trade policy (Export Import policy) was initiated in 1991 by Government of India to promote exports and regulate imports. Liberalization has always been the main feature of all the EXIM policies formulated so far. Furthermore, in order to promote trade in India, EXIM policy 2004-09 launched several schemes such as Duty Exemption and Export Promotion Capital Goods Schemes and established special economic zones and free trade warehousing zones. The EXIM policy 2009-14 contained additional measures such as simplification of procedures and addition of new markets and products under Focus Market Scheme and Focus Product Scheme to combat the impact of crisis on India's exports.

Additionally, due to incessant failure of Doha round negotiations, many developing countries including India have embarked upon free trade agreements with other countries to promote trade. According to Asia Regional Integration Center FTA database, India tops the list of countries engaged in FTA's with a total of 28 agreements out of which 14 are signed and in effect. Some of the major agreements concluded in the last decade are South Asian Free Trade Area in January 2006, Japan-India comprehensive economic partnership agreement in August 2011 and ASEAN-India comprehensive economic cooperation agreement in January 2010. Furthermore, India is engaged in ISBA (India, Brazil and South Africa) and BRICS (Brazil, Russia, India, China and South Africa) dialogue forums launched in 2006[4] respectively to further enhance trade with South Africa, Brazil, Russia and China.

3. Export Function

For analyzing the determinants of India's export growth, we develop an export function based on the recent theoretical and empirical literature. Thus, the ensuing discussion briefly describes the trade models employed in literature. The two main theoretical models utilized in the existing literature are standard export demand model and 'Gravity model'. According to standard export demand model, country's exports are determined by foreign demand and real exchange rate. Armington (1969), Goldstein and Khan (1978, 1985), and Senhadji and Montenegro (1998) are some studies that provide theoretical foundations to the export demand model. In the 'Gravity model', country's bilateral exports are function of the GDP of the two countries and the distance

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[4] ISBA was formally formed in 2003 while its first meeting took place in 2006. BRICS was formed in 2006 while its first meeting took place in 2009.

between them. Anderson (1979), Krugman (1980), Eaton and Kortum(2002), and Chaney (2008) are some studies that provide theoretical validation to the gravity model.

A majority of the recent empirical studies (such as Wong, 2016; Verheyen, 2014; and Baum and Caglayan, 2010) use standard export demand model for analyzing country's export behavior. On the other hand, 'Gravity model' is primarily used in empirical literature (see for instance, Feenstra *et al.*, 2001, Benassy-Quere and Lahreche-Revil 2003; Tenreyo, 2007; and Yang and Gu. 2016) for examining determinants of country's bilateral exports. Further, several extensions to the standard export demand model (Byrne *et al.*, 2008, Fang *et al.*, 2009 and Hall *et al.*, 2010) and gravity model (Chit *et al.*, 2010 and Nicita, 2013) have been utilized in the empirical literature in which variables such as exchange rate volatility, foreign trade agreements (FTA's), presence of common borders, colonial links have been added as the additional explanatory variables in the model.

Some recent studies such as Tran *et al.* (2012) and Raissi and Tulin (2015) emphasize the role of supply constraints in explaining the exports behavior of developing economies like India. There are several variables that augment the country's export supply capacity such as domestic income (Cerra and Saxena, 2003; Athukorala and Menon, 2010; and Shah, 2013[5]), infrastructure (Tran *et al.*, 2012; Raissi and Tulin, 2015; and Ang *et al.*, 2015) and foreign direct investment (FDI) (Sharma, 2003; Xing, 2012; and Shah, 2013). Lastly, domestic demand is another important variable that affects a country's exports behavior. Though domestic demand is considered to be an essential part of the export model in the theoretical literature (Ball, 1961; Artus; 1970 and Faini, 1994), there are few empirical studies (Tsen, 2007; Shah, 2013; and Esteves and Rua, 2015[6]) that incorporate this variable in the export model.

Thus, on the basis of above discussion, the potential determinants of exports can be divided into two categories, viz. demand-side and supply-side factors. While we do not cover an exhaustive

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[5] While Serra and Saxena (2003) use Industrial Production index, Athukorala and Menon (2010) use per capita GDP, and Shah (2013) uses growth in domestic GDP and as a proxy for export supply capacity.
[6] While Shah (2013) uses output gap, Tsen (2007) and Esteves and Rua (2015) use consumption and investment expenditure as a proxy for domestic demand.

list of determinants[7], we attempt to include factors that are potentially important in determining export growth of developing economies like India.

Demand-side Factors

i. Real Exchange rate
ii. Volatility of exchange rate
iii. Foreign income
iv. Free trade agreements

Supply-side factors

i. Real exchange rate
ii. Volatility of exchange rate
iii. Domestic income
iv. Infrastructure
v. Foreign direct investment
vi. Domestic demand
vii. Free trade agreements

The export function, can be expressed as a hybrid model as follows:

$$X_t = f\big(REX_t(+), VEX_t(+/-), Y_t^*(+), Y_t(+), FTA(+), Infr_t(+), FDI_t(+/-), DD_t(+/-)\big) \tag{1}$$

where

X_t = Bilateral exports of a country at time t

REX_t = Real exchange rate

Y_t^* = Foreign income at time t

Y_t = Domestic income at time t

FTA = Foreign trade agreements

VEX_t = Volatility of exchange rate

$Infr_t$ = Infrastructure

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[7] Some variables such as tariffs and expenditure on research and development are not included in the model due to the non-availability of quarterly data.

FDI_t = Foreign Direct Investment

DD_t = Domestic Demand

Equation (1) indicates the expected theoretical signs of variables in brackets. We briefly discuss each of these variables below.

Real Exchange Rate: The standard demand function postulates that an increase in real exchange rate makes exports more competitive, leading to an increase in exports. Majority of the empirical studies (such as Wong, 2016; Bahmani-Oskooee *et al.*, 2015; and Nazlioglu, 2013) find significant and positive effect of real exchange rate on exports. However, few studies like Sarkar (1994), Roy (2005) and Bhanumurty and Sharma (2013)[8] find that Indian exports are not price responsive.

Foreign Income: Foreign income proxies for the foreign demand for exports. The standard demand function and gravity model suggest that an increase in foreign income leads to an increase in exports. Furthermore, almost all empirical studies (such as Chit *et al.*, 2010 and Verheyen, 2012, 2014) find positive and significant impact of foreign demand on exports.

Domestic Income: Gravity model advocates positive impact of domestic income on exports. However, as noted by Srinivasan (1998, pp.235); there are two ways in which domestic income can affect exports. One, an increase in domestic income raises domestic demand, thereby decreases exports. On the other hand, an increase in domestic income is indicative of an increase in productive capacity which has positive impact on exports. Nonetheless, majority of the existing empirical studies (such as Srinivasan, 1998; Chit *et al.*, 2010; and Athukorala and Menon, 2010) find positive effect of domestic GDP on exports.

Exchange Rate Volatility: There is a huge theoretical and empirical literature that emphasizes the prominent role of exchange rate volatility in explaining export behavior. The earliest model was developed by Clark (1973), according to which, if an exporter is risk averse, an increase in exchange rate volatility decreases exports. However, as noted by Marc and Ruta (2013), his model was based on several strong assumptions such as perfect competition, the large role of the invoicing currency, the absence of imported inputs, the high aversion to risk, and the absence of

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[8] Bhanumurty and Sharma (2013) find insignificant and negative effect of real exchange rate on India's manufacturing exports.

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exchange rate hedging financial instruments. Dropping some or all of these assumptions makes the relationship between exchange rate volatility and exports ambiguous that can be observed in the five categories of models appraised by Marc and Ruta (2013). For instance, in the first category, De Grauwe (1988) and Dellas and Zilberfarb (1993) develop models in which the effect of increased volatility of exchange rates on trade depends heavily on the level of risk aversion of traders. According to their models, if the producers are sufficiently risk averse, an increase in exchange rate risk raises the expected marginal utility of revenue inducing them to increase their exports while if producers are not very risk averse, an increase in exchange rate risk reduces the expected marginal utility of revenue leading them to decrease their exports. Furthermore, a survey by Marc and Ruta (2013) and Tsen (2014) reveals that the empirical literature is inconclusive regarding the effect of exchange rate volatility on trade. Thus, in general, the impact of exchange rate volatility on international trade is theoretically and empirically ambiguous.

FTA: In the last few years, developing countries have embarked upon the regional free trade agreements for promoting their growth. In general, these agreements involve abolition of trade barriers and incentives for exporting to the concerned country. Thus, these agreements signed by a country are expected to increase its exports. Most of the empirical studies such as Chit *et al.* (2010) and Nicita (2013) find positive impact of these agreements on exports. However, for India, Nayak *et al.* (2013) find that the effect of India's regional trade agreements on its manufacturing exports is negative and insignificant.

FDI: FDI flows are an essential part of the globalization process in which the developing countries majorly act as the main hosts for FDI from developed world. The theoretical literature is inconclusive on the relationship between FDI and exports. Markusen (1984) develops a general equilibrium model of a multinational firm that produces same good in multiple countries (also known as horizontal FDI). According to this model, FDI has a negative effect on exports when the foreign affiliates set up by the multinationals cater to the export markets of the host country. However, Helpman (1984), Aitken *et al.* (1997) and Fosfuri *et al.* (2001) conclude that FDI contributes to export growth through various sources such as augmenting domestic capital for exports, helping transfer of technology and new products for exports, facilitating access to new and large foreign markets, and providing training for the local workforce. Further, the empirical evidence on the effect of FDI on exports is mixed. For instance, while Sharma (2003), Eichengreen

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and Gupta (2012), and Zang (2015) find positive impact of FDI on exports, Gupta *et al.* (2015) and Nayak *et al.* (2013) find the negative effect.

Infrastructure: Infrastructure plays an important role in determining country's productive capacity. Several studies such as Bougheas (1999), and Raissi and Tulin (2015) illustrate positive effect of good infrastructure on the level of exports.

Domestic Demand: In a developing and emerging economy like India, domestic demand is expected to play a crucial role in its export performance. In its naïve form, domestic demand is expected to decrease exports as it diverts resources available for the export sector towards domestic consumption and also it decreases export competitiveness by fuelling inflation. However, the theoretical literature is inconclusive regarding the relationship between domestic demand and exports. Ball (1961) finds that the effect of domestic demand on exports depends on the slope of firm's marginal cost curve at the initial equilibrium position. If MC curve is positively sloped, an increase in domestic demand will decrease firm's exports while if MC curve is negatively sloped or constant, domestic demand will either increase or have no effect on firm's exports. A similar conclusion was made by Artus (1970) and Faini (1994) in their study. Further, almost all empirical studies (such as Sharma, 2003; Shah, 2013; and Esteves and Rua, 2015) find negative impact of domestic demand on exports.

4. Data, Empirical Model and Econometric Methodology:

4.1 Data

This study is based on secondary data at quarterly frequency sourced from CEIC database and www.exchangerate.com. The sample under study is from 2004Q3 to 2016Q1. The dependent variable (X_t) is the value of India's exports (in U.S dollar million)[9]. The bilateral real exchange rate between India and trading partner i is measured as $(P_i^* . e_i)/P$, where P_i^* and P are the foreign and domestic GDP deflator indices, respectively (2010=100), and e_i (INR per unit of trading partner's currency) is the bilateral nominal exchange rate. Foreign income (Y_t^*) is measured as real

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[9] Due to problems in obtaining an appropriate price deflator for bilateral exports, several studies such as Bahmani-Oskooee and Goswami (2004), Nazilugu (2013) and Baek (2013) use nominal value of exports rather than real exports in the analysis.

GDP (with 2010 as the base year) of the trading partner weighted by their respective share in India's exports. Domestic Income (Y_t) is India's real GDP in U.S dollar million (2010 as the base year). FDI_t is India's FDI in U.S.D million. $Infr_t$ is India's infrastructure index which is a combined index of eight core industries, viz. coal, crude oil, natural gas, refinery products, fertilizers, steel, cement and electricity. Domestic demand pressure (DD_t) is measured as the output gap. Output gap is defined as the deviation of India's real GDP (Y_t) from natural output[10]. Trend level of real GDP is taken as a proxy for natural output. Natural output is measured using Hodrick–Prescott filter (Hodrick and Prescott, 1997).

Volatility of real exchange rate is measured as conditional volatility estimated using the appropriate GARCH model for each country. The GARCH models considered are GARCH model, Exponential GARCH model, Power ARCH model and Component GARCH model. The specification of the mean equation in GARCH model for each country is based on the appropriate ARMA model selected using AIC, SBC, significance of ARMA coefficients and autocorrelation tests. Subsequently, the best GARCH model for each country is selected on the basis of AIC, SBC, Log likelihood, significance of coefficients and autocorrelation tests. We find while component GARCH (1, 1) model is the best model for US, China, South Africa and Brazil, PARCH(1,1) model for UK and EGARCH (1, 1) is the best model for Indonesia, Japan, Thailand, Malaysia, Singapore, Eurozone and Hong Kong.

Finally, we also utilize ASEAN-India FTA and Japan-India trade agreement that is expected to positively affect India's bilateral exports during 2004Q3-2016Q1. The dummy for these agreements are constructed using ARIC-FTA database.

4.2 Empirical Model

The model estimated is of the following form:

$$\dot{X}_{it} = \omega + \sum_{k=1}^{n} \alpha_k \dot{X}_{it-k} + \sum_{l=0}^{n} \beta_l R\dot{E}X_{it-l} + \sum_{p=0}^{n} \gamma_p V_{it-p} + \sum_{q=0}^{n} \delta_q \dot{Y}_{t-q} +$$
$$\sum_{r=0}^{n} \theta_r \dot{FDI}_{t-r} + \sum_{s=0}^{n} \varphi_s \dot{Y}_{it-s} + \sum_{u=0}^{n} \vartheta_u GAP_{t-u} + \sum_{v=0}^{n} \partial_v IN\dot{F}R_{t-v} + \tau D_{it} + T_{it} + \varepsilon_{it} \quad (2)$$

where

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[10] As utilized by several studies such as Belke *et al.* (2014); and Shah (2013).

$\dot{X}_{it}$ = Growth in value of total exports from India to country i

$R\dot{E}X_{it}$ = Growth in real exchange rate of rupee vis-à-vis currency of country i

V_{it} = Volatility in real exchange rate of rupee vis-à-vis currency of country i

$\dot{Y}_{it}$ = Growth in weighted real income of country i, where weights are the share of country i in total exports of India at time period t.

$\dot{Y}_t$ = Growth in India's real income

$GAP_t = Y_t - Y_t^*$ where Y_t^* represents natural output level measured by trend level of India's real GDP

$IN\dot{F}R_t$ = Growth in India's infrastructure index

$F\dot{D}I_t$ = Growth in India's foreign direct investment

$$D_{it} = \begin{cases} 1 \ if \dot{X}_{it} < \mu - 2\sigma \\ o \ otherwise \end{cases}$$

where μ and σ are mean and standard deviation of export growth over the sample period.

T_{it} = Free trade agreements of India with ASEAN and Japan. We make separate dummies for ASEAN and Japan as follows

$$\text{Japan} = \begin{cases} 1 \ if \ t \geq 2010Q4 \ and \ i = Japan \\ o \ otherwise \end{cases}$$

$$\text{ASEAN} = \begin{cases} 1 \ if \ t \geq 2010Q1 \ and \ i = Malaysia, Indonesia \ and \ T\Box ailand \\ o \ otherwise \end{cases}$$

4.3 Econometric Methodology

Unit root testing is becoming increasingly important in panel data studies. Since this study is based on macro-panel data that has long time dimension, non-stationarity deserves more attention (Baltagi, 2001) .We utilize Fisher (2001) ADF, Hadri (2000), Breitung and Das (2005), and Pesaran (2007) panel unit root tests to analyze the stationarity properties of our panel variables (Exports, Real Exchange Rate, Volatility of real exchange rate and foreign income) where the latter three unit root tests are robust in the presence of cross sectional correlation. Furthermore, for checking the stationarity property of our time series variables (Domestic GDP, FDI, Infrastructure and Domestic Demand), we utilize Dickey-Fuller generalized least squares (DF-GLS) test suggested by Elliott et al. (1996), Ng-Perron (2001) and Lee and Strazicich (2003) test.

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As explained in Hsaio (2014, p.12 and p.340), ignoring cross-sectional dependence in panel data can cause substantial bias in the estimates. Thus, in the second step, we employ Pesaran (2004) CD test for testing cross-sectional dependence in our panel data. In the final step, we employ panel GMM-IV estimator developed by Driscoll and Kraay (1998) that is robust to the presence of heteroscedasticity, serial correlation and cross-sectional dependence in panel data. Under this approach, the standard Newey and West (1987) consistent covariance matrix estimator is applied to the sequence of cross-sectional averages of the moment conditions. Finally, for diagnostic testing, we utilize Cumby-Huizinga general test for serial autocorrelation, Pagan-Hall heteroskedasticity test, Durbin-Wu-Hanusman endogeneity test, Hansen-J test of overidentifying restrictions and Sanderson-Windmeijer underidentification test.

5. Results

The descriptive statistics for exchange rate volatility are shown in Table 1. It can be seen from Table 1 that mean and standard deviation of real exchange rate volatility for developing countries is considerably higher as compared to mean and standard deviation of real exchange rate volatility for developed countries. Further, real exchange rate volatility is maximum for Japan among developed countries and for Brazil among developing countries. Figure 7 and 8 show the line plots of quarterly export growth and real exchange volatility of India with developing and developed countries respectively. It can be observed from Figure 7 while real exchange rate volatility depicts an increasing trend (particularly after global crisis 2007-09), India's export growth with developing countries has had been declining, mainly since 2011 . Thus, there exists a negative relationship between export growth and real exchange rate volatility in case of developing countries. However, it can be seen from Figure 8 while real exchange rate volatility shows no clear trend till 2007Q1, export growth shows increasing trend till 2007Q1. Furthermore, both export growth and real exchange rate volatility depict decreasing trend since 2012. Thus, the picture is not very clear in case of developed countries. These differences can be attributed to the institutional and structural differences between developed and developing countries. We therefore attempt to examine the determinants of growth in India's exports to developed and developing countries.

5.1 Unit Root Tests and Cross Sectional Dependence Test

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The results of unit root tests by majority rule indicate that export growth, real exchange rate growth, real exchange rate volatility, domestic income growth, foreign income growth, FDI growth, infrastructure growth and output gap are stationary in all the three panels[11]. Pesaran's CD test on panel variables for India vis-à-vis developed countries, developing countries and the total panel of twelve countries is shown in Table 2. The test shows presence of considerable cross sectional dependence in export growth, real exchange rate and volatility of real exchange rate for all the three panels.

5.2 Panel Estimation Results

In view of the above findings, we apply GMM-IV technique to three panels, viz. India vis-a-vis six developed economies, India vis-à-vis six developing economies and India vis-à-vis its twelve major export destinations[12]. The results of each of these panels are discussed below.

India vis-à-vis Developed Countries

The results of pooled GMM-IV estimation of (2) for the panel of India vis-à-vis developed countries are presented in Table 3. We find that in case of developed countries, the coefficient of exchange rate volatility is positive and statistically insignificant. Turning to other parameters in (2), we find that all the estimated coefficients have expected signs. Further, all the estimated coefficients except[13] β_0 (coefficient of real exchange rate growth), and θ_0 (coefficient of FDI growth) are significant at 1% or 5% level of significance.

The diagnostic tests reported in Table 3 reveal no serial correlation and heteroscedasticity in residuals. Hansen's J statistic is small and insignificant which shows that all instruments utilized are relevant. Rank condition is satisfied as the under identification test on all the variables rejects the null hypothesis. The results of GMM-IV estimation with fixed effects are reported in second

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[11] The unit root tests on the level variables in (1) show while exports, real exchange rate, domestic GDP, foreign GDP, FDI and infrastructure are non-stationary, exchange rate volatility and output gap are stationary. Thus, we utilize export growth, real exchange rate growth, domestic income growth, foreign income growth, infrastructure growth, exchange rate volatility and output gap in our analysis. The results of unit root tests are available from authors upon request.

[12] India vis-à-vis six developed countries panel implies panel of India's exports to six major developed export destinations. Similarly, India vis-à-vis developing countries panel implies panel of India's exports to six major developing export destinations and India vis-à-vis twelve major export destinations implies panel of India's exports to twelve major developing and developed export destinations.

[13] Though α_4 and α_7 are insignificant, their t-statistic is greater than one.

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column of Table 3. We find that the estimates are similar to pooled GMM estimates. This implies that our results are robust to the inclusion of fixed effects in the model.

For analyzing the relative importance of demand side and supply side determinants of India's export growth vis-à-vis developed countries, we also conduct Wald exclusion test. From the results of Wald tests reported in Table 3, it is seen that the null hypothesis of insignificant demand side and supply side factors is rejected at 1% level of significance.

India vis-à-vis Developing Countries

The results of pooled GMM-IV estimation of (2) for the panel of India vis-à-vis developing countries are reported in Table 4. We find that in case of developing countries, the coefficient of exchange rate volatility is negative and statistically significant at 10%. Further, we find that other estimated coefficients of (2) for this panel are similar to the corresponding coefficients in the panel of developed countries, viz. the signs of all coefficients are consistent with our expectations and all estimated coefficients except β_0 (coefficient of real exchange rate growth), θ_0 (coefficient of FDI growth) and ϑ_0 (coefficient of output gap) are significant at 1%, 5% or 10% level of significance[14].

The diagnostic tests reported in Table 4 reveal no serial correlation and heteroscedasticity in residuals. Further, as before, we do not find presence of irrelevant instruments and violation of rank condition in the model (Table 4). Finally, as found in the panel of developed countries, GMM-IV estimates of (2) in this panel are robust to the inclusion of fixed effects in the model (Table 4) and that both demand as well as supply side factors are important for India's export growth vis-à-vis developing countries (Table 4).

India vis-à-vis twelve major export destination countries

From the reported results of pooled GMM-IV estimation in Table 5, it is seen that for the whole panel of India vis-à-vis twelve countries, the coefficient of exchange rate volatility is negative but insignificant. Turning to other parameters in (2), we find that all the estimated coefficients have expected signs. Further, all the estimated coefficients except β_0 (coefficient of

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[14] Though β_4 and β_7 are insignificant, their t-statistic is greater than one.

real exchange rate growth), θ_0 (coefficient of FDI growth), φ_1(coefficient of one quarter lagged foreign income) and ϑ_4 (coefficient of four quarter lagged output gap) are significant at 1% or 5% level of significance[15].

As shown in Table 5, we do not find any evidence of serial correlation and heteroscedasticity in residuals, irrelevant instruments and violation of rank condition. Further, as found in previous panels, GMM-IV estimates of (2) in this panel are robust to the inclusion of fixed effects in the model (Table 5). Finally, as shown in Table 5, our results on the significant impact of both demand as well as supply side variables on India's export growth holds in this panel.

5.4 Inferences and Discussion

Our findings indicate important similarities and differences between the determinants of growth in India's exports to developed and developing countries. We find that growth in India's exports to developed as well as developing countries is adversely affected by domestic demand. Furthermore, we find that domestic income growth, foreign income growth, real exchange rate growth, infrastructure growth and FDI growth has positive impact on growth in India's exports to developed and developing countries. We also find positive impact of ASEAN-India FTA and Japan-India trade agreement on India's export growth. However, we find while exchange rate volatility adversely affects growth in India's exports to developing countries, growth in India's exports to developed countries is not affected by exchange rate shocks. This may be due to higher vulnerability of developing countries vis-à-vis developed countries to shocks in exchange rate markets (Grier and Sallwood, 2013; and Broda and Romalis, 2011). Regardless of the enduring liberalization drive world over, developed countries have less capital account restrictions as compared to developing countries. For instance, according to Chit and Ito financial openness index (Table 6), developing countries rank very low in financial openness as compared to developed countries. Thus, traders in developed countries tend to have lower portfolio risk vis-à-vis traders in developing countries (Hall *et al.*, 2010, pp. 1517). Further, as shown in Table 7, developed countries have deeper, broader and stable financial institutions and markets. These differences between developed and developing countries contribute to the lesser effect of exchange rate

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[15] Though γ_4 and γ_9 are insignificant, their t-statistic is greater than one.

volatility on trade of developed countries. Thus, the presence of capital account restrictions and absence of developed financial forward markets in India and its developing trading partners strengthen the impact of exchange rate risk on exports.

It is noteworthy that the results of panel for India vis-a-vis twelve major export destinations conceal the important differences between the developed and developing economies in their response to volatility of real exchange rate. The results of India vis-a-vis twelve major export destinations panel indicate negative and insignificant impact of exchange rate volatility on India's export growth. However, our findings indicate that this may be due to the insensitivity of developed countries vis-à-vis developing countries to shocks in exchange rate market. Further, the estimates of India vis-a-vis twelve major export destinations panel obscure the significance of ASEAN-India trade agreement in explaining India's export growth. The results of panel for India vis-a-vis developing countries suggest that India-ASEAN agreement positively and significantly affected India's export growth in contrast to positive and insignificant effect found in results of the panel for India versus its twelve major trading partners. This may be attributed to the non-inclusion of developed countries in the ASEAN.

Our results also bring to the fore evidence regarding the importance of demand-side supply-side factors in India's export growth. We find that for India, growth in foreign demand as well as export supply capacity are pivotal for growth in India's exports to both developed and developing countries. Further, our findings on adverse and significant impact of exchange rate volatility on India's export growth and positive and significant impact of growth in real exchange rate, domestic GDP and foreign GDP on India's export growth are similar to the findings of Srinivasan and Kalaivani (2012). However, we differ from their study in two main aspects. First, we consider the role of domestic demand, FDI and infrastructure in India's export behavior. Second, our analysis reveal the differences between determinants of India's export growth with developed and developing countries.

6. Conclusion

There is no consensus in the existing empirical literature on the relative importance of demand-side and supply-side factors in determining India's export growth. It stands to reason that ceteris paribus, a country that has strong infrastructure, high FDI, high income and low domestic

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demand has higher capacity to export. The present study attempts to incorporate these aspects into the analysis. Furthermore, given the diversification of India's exports in terms of destination during the last decade, we attempt to identify the differences in India's export behavior vis-à-vis it's developed and developing export destinations.

The export model used in this study relates India's export growth to output gap, growth in exporting partner's real GDP weighted by their share in India's exports, bi-lateral real exchange rate, India's GDP, FDI and infrastructure. The results indicate while exchange rate volatility adversely affects growth in India's exports to developing countries, growth in India's exports to developed countries is not sensitive to exchange rate shocks. We find that growth in bi-lateral real exchange rate, domestic income, FDI and infrastructure positively affects India's export growth with developed as well as developing economies. Furthermore, domestic demand is found to adversely affect India's export growth. Finally, we find significant and positive impact of ASEAN-India FTA and Japan-India comprehensive economic partnership agreement on India's export growth during 2004Q3-2016Q1.

The policy implications of this study are interesting. The results of our study illustrate that in a developing economy like India, growth in foreign demand as well as growth in export supply capacity are pivotal for export growth. Further, in case of India, we find support for the conventional view that exchange rate volatility hinders export growth. However, our study reveals that in terms of India's export destinations, only exports to developing countries are adversely affected by exchange rate volatility.

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Table 1: Descriptive Statistics for Real Exchange Rate Volatility

	Mean V_{it}	Standard deviation V_{it}
Developed Countries	**24.212**	**18.526**
Euro	27.671	37.049
U.S	20.404	11.642
U.K	21.558	12.382
Singapore	18.155	6.777
Japan	34.373	15.117
Hongkong	25.764	10.441
Developing Countries	**36.080**	**60.699**
Indonesia	29.436	20.759
Malaysia	13.473	5.715
China	35.454	22.260
Thailand	10.690	5.926
South Africa	37.216	12.622
Brazil	90.214	130.888

Table 2: Pesaran CD Test

Variable	CD statistic (P-Value)		
	Developed Countries	Developing countries	Total Panel
$\dot{X}_{it}$	5.40 (0.00)	4.07 (0.00)	10.93 (0.00)
$\dot{Y}_{it}$	0.60 (0.54)	0.90 (0.36)	1.96 (0.05)
$R\dot{E}X_{it}$	18.63 (0.00)	9.22 (0.00)	26.67 (0.00)
V_{it}	6.51 (0.00)	3.09 (0.00)	4.66 (0.00)

Table 3: Total Exports to Developed Countries: Panel GMM-IV Results

$$Dependent\ Variable : \dot{X}_{it}$$

Variable	Coefficient	GMM-IV	GMM-IV-FE
Constant	ω	-10.901* (2.296)	
$\dot{X}_{it-1}$	α_1	-0.130* (0.02)	-0.129* (0.017)
$\dot{X}_{it-3}$	α_3	0.078* (0.024)	0.078* (0.026)
$\dot{X}_{it-4}$	α_4	0.112* (0.017)	0.111* (0.018)
$R\dot{E}X_{it}$	β_0	0.348 (0.342)	0.473 (0.322)
V_{it}	γ_0	0.076 (0.081)	0.088 (0.084)
$\dot{Y}_t$	δ_0	1.747* (0.449)	1.840* (0.464)
$F\dot{D}I_t$	θ_0	0.025 (0.020)	0.020** (0.019)
$\dot{Y}_{it}$	φ_0	0.803* (0.024)	0.804* (0.016)
GAP_{t-4}	ϑ_4	-0.055 (0.033)	-0.059*** (0.034)
$IN\dot{F}R_t$	∂_0	1.005* (0.254)	1.073* (0.253)
$IN\dot{F}R_{t-1}$	∂_1	2.173* (0.770)	2.395* (0.722)
D_{it}	τ	-4.423*** (2.539)	-4.040* (2.810)

		(0.015)	(0.016)
$\dot{X}_{it-4}$	α_4	0.027** (0.013)	0.008 (0.018)
$\dot{REX}_{it}$	β_0	0.584 (0.550)	0.636 (0.447)
V_{it}	γ_0	-0.036*** (0.021)	-0.028 (0.027)
$\dot{Y}_t$	δ_0	1.058** (0.510)	0.916*** (0.525)
$\dot{FDI}_t$	θ_0	0.022 (0.018)	0.005 (0.027)
$\dot{Y}_{it}$	φ_0	0.630* (0.028)	0.637* (0.026)
$\dot{Y}_{it-1}$	φ_1	0.152* (0.030)	0.190* (0.036)
GAP_t	ϑ_0	-0.031 (0.039)	-0.015 (0.071)
$\dot{INFR}_t$	∂_0	1.599* (0.534)	1.482* (0.417)
$\dot{INFR}_{t-1}$	∂_1	1.764* (0.557)	1.727* (0.541)
$\dot{INFR}_{t-2}$	∂_2	0.960* (0.359)	0.927* (0.378)
D_{it}	τ	-29.709* (3.025)	-31.222* (2.021)
ASEAN		2.626* (1.114)	1.282** (3.091)
R^2		0.825	0.844
Heteroscedasticity Test		11.80 (0.92)	
Serial Correlation Test(at lags=5)		4.60 (0.46)	
Hansen's J Test*		2.45 ($p = 0.78$)	0.60 ($p = 0.96$)
Hausman Endogeneity Test		0.22 ($p = 0.99$)	3.62 ($p = 0.45$)
Rank/Underidentification test		$\dot{REX}_{it}$: 40.22 ($p = 0.00$) V_{it} : 32.98 ($p = 0.00$) $\dot{Y}_t$: 68.59 ($p = 0.00$) $\dot{FDI}_t$: 412.03 ($p = 0.00$)	$\dot{REX}_{it}$: 28.79 ($p = 0.00$) V_{it} : 42.97 ($p = 0.00$) $\dot{Y}_t$: 18.04 ($p = 0.00$) $\dot{FDI}_t$: 52.95 ($p = 0.00$)
Wald Test Null Hypothesis: Foreign demand do not significantly affects India's Export growth		537.27 ($p = 0.00$)	690.99 ($p = 0.00$)

Wald Test Null Hypothesis: Export Supply capacity and domestic demand do not significantly affects India's Export growth	33.88 ($p = 0.00$)	51.47 ($p = 0.00$)

*** indicate significance at 1% ** indicate significance at 5% * indicate significance at 10%

Table 5: Total Exports of India vis-à-vis 12 major importer Partners: Panel GMM-IV Results

$Dependent\ Variable : \dot{X}_{it}$

Variable	Coefficient	GMM-IV	GMM-IV-FE
Constant	ω	-10.348* (1.739)	
$\dot{X}_{it-1}$	α_1	-0.179* (0.043)	-0.207* (0.052)
$\dot{X}_{it-2}$	α_2	-0.046** (0.024)	-0.017 (0.035)
$\dot{X}_{it-3}$	α_3	-0.016* (0.013)	-0.005 (0.017)
$R\dot{E}X_{it}$	β_0	0.634 (0.593)	0.878* (0.536)
V_{it}	γ_0	-0.021 (0.032)	-0.011 (0.034)
$\dot{Y}_t$	δ_0	1.210* (0.451)	1.068** (0.396)
$F\dot{D}I_t$	θ_0	0.014 (0.043)	-0.02 (0.049)
$\dot{Y}_{it}$	φ_0	0.655* (0.046)	0.682* (0.037)
$\dot{Y}_{it-1}$	φ_1	0.040 (0.032)	0.102** (0.029)
GAP_{t-4}	ϑ_4	-0.028 (0.038)	-0.052* (0.049)
$IN\dot{F}R_t$	∂_0	2.252* (0.472)	2.073* (0.429)
$IN\dot{F}R_{t-1}$	∂_1	2.144* (0.825)	2.276* (0.521)
$IN\dot{F}R_{t-2}$	∂_2	1.120* (0.397)	1.182* (0.447)
D_{it}	τ	-18.043* (1.885)	-18.726* (1.429)
ASEAN	γ_{15}	1.368 (1.213)	3.22* (1.842)
Japan	γ_{16}	4.266*	3.097

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		(1.437)	(2.870)
R^2		0.773	0.792
Heteroscedasticity Test		223.07 ($p = 0.42$)	-
Serial Correlation Test(at lags=5)		3.78 ($p = 0.58$)	-
Hansen's J Test*		2.487 ($p = 0.477$)	0.807 ($p = 0.847$)
Hausman Endogeneity Test		1.823 ($p = 0.768$)	3.473 ($p = 0.482$)
Rank/Underidentification test		$\dot{REX}_{it}$:40.96 ($p = 0.00$) V_{it}:54.72 ($p = 0.00$) $\dot{Y}_t$:19.98 ($p = 0.00$) $\dot{FDI}_t$:31.87 ($p = 0.00$)	$\dot{REX}_{it}$ 56.72 ($p = 0.00$) V_{it}:60.01 ($p = 0.00$) $\dot{Y}_t$:15.02 ($p = 0.00$) $\dot{FDI}_t$:78.34 ($p = 0.00$)
Wald Test Null Hypothesis: Foreign demand do not significantly affects India's Export growth		243.22 ($p = 0.00$)	324.75 ($p = 0.00$)
Wald Test Null Hypothesis: Export Supply capacity and domestic demand do not significantly affects India's Export growth		35.67 ($p = 0.00$)	44.19 ($p = 0.00$)

*** indicate significance at 1% ** indicate significance at 5% * indicate significance at 10%

Table 6: Financial Openness Measure: Chin and Ito Index

Developed Countries		
	2005	2014
EU (average)	1.7935	1.776
US	2.389	2.389
UK	2.389	2.389
Japan	2.389	2.389

Singapore	2.389	2.389
HongKong	2.389	2.389
Developing Countries		
Indonesia	1.091	-0.126
Malaysia	-0.126	-0.126
Thailand	-0.126	-0.126
China	-1.188	-1.188
South Africa	-1.188	-1.188
Brazil	0.133	-0.126

Source: Graduate institute of international and development studies

Table 7: Financial Development Measures

Panel A: Financial Institutions

|	Financial depth		Access		Efficiency		Stability	
	2008-10	2011-13	2008-10	2011-13	2008-10	2011-13	2008-10	2011-13
Developed countries	113.3	96.1	2004.3	86.9	3.8	4.2	21.6	17.5
Developing countries	34.5	35.8	580.2	30.3	8.8	7.5	18.1	14.6

Source: Global Financial Development Report 2015/16, 2013

Note: Financial depth - Private credit by deposit money banks to GDP (%), Access - Account at a formal financial institution (%, age 15+), Efficiency - Bank lending-deposit spread (%), Stability - Bank Z-score.

Panel B: Financial Markets

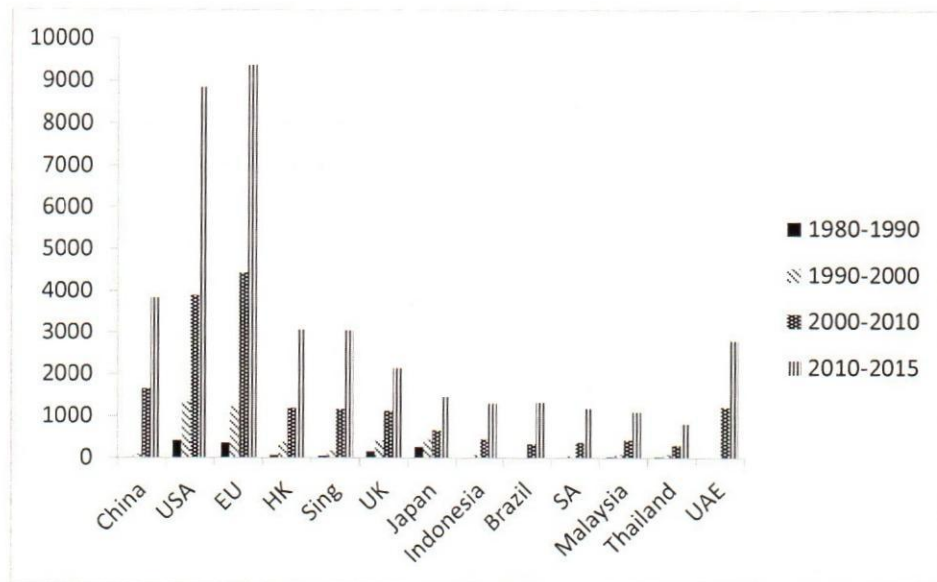|	Financial depth		Access		Efficiency		Stability	
	2008-10	2011-13	2008-10	2011-13	2008-10	2011-13	2008-10	2011-13
Developed countries	111.1	92.4	42.4	42.1	84.4	54.7	34.1	18.3
Developing countries	42.5	39.1	47.6	47.9	37.2	20.1	33.2	16.2

Figures

Figure 1
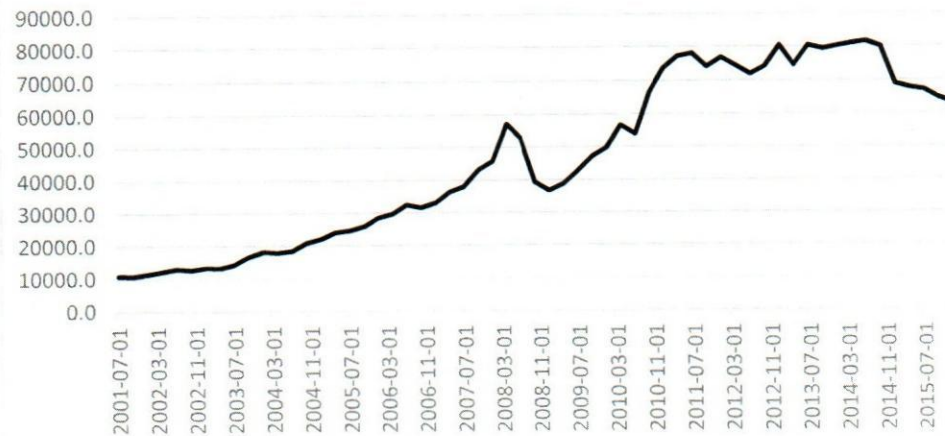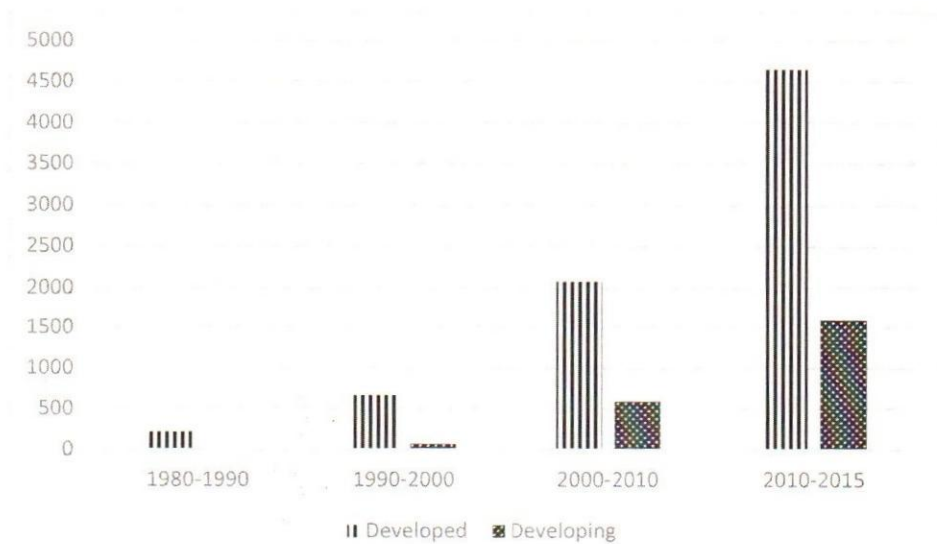

Source: CEIC database

Figure 2

Source: Author's own calculations based on CEIC database

Figure 3

Source: Author's own calculations based on CEIC database

Figure 4

Source: Author's own calculations based on CEIC database