Article

Effect of Central Bank Intervention in Estimating Exchange Rate Exposure: Evidence from an Emerging Market

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Abstract

This study examines the relationship between the value of the firm and unanticipated changes in exchange rate. Using a sample of 651 Indian firms over the period from 2001 to 2013, this study finds that unanticipated changes in exchange rates are more appropriate than actual changes to discover statistically significant and economically important exchange rate exposure. Using a vector error correction model (VECM) to generate unanticipated exchange rate changes, this study provides new evidence that the intervention by central bank has a major impact on the level of Indian firms' exchange rate exposure.

Keywords

Central bank intervention, exchange rate exposure, India, emerging market, vector error correction model

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Introduction

Financial theory suggests that cash flows of a firm are sensitive to unanticipated changes in exchange rates (Hekman, 1983, 1985; Shapiro, 1975). The extent to which the value of a firm is affected by unexpected changes in exchange rates is known as exchange rate exposure (Adler & Dumas, 1984). Conventionally all firms, domestic and international, are exposed to exchange rate risk, but empirical studies have found mixed results. While some studies report strong evidence of exposure (Bacha, Mohamad, Raihan, & Mohd, 2013; Kiymaz, 2003; Parsley & Popper, 2006; Tsai, Chiang, Tsai, & Liou, 2014; Ye, Hutson, & Muckley, 2014), a large number of studies reveal that only a small number of firms are significantly affected by exchange rate changes (Chue & Cook, 2008; Jorion, 1990; Lin, 2011; Muller & Verschoor, 2007). The inability of empirical evidence to support the theoretical phenomenon gives rise to 'exchange rate exposure puzzle', a term mentioned by Bartram and Bodnar (2007). One of the explanations of the exposure puzzle provided by existing literature includes methodological weakness (Francis, Hasan, & Hunter, 2008; Priestley & Ødegaard, 2007), and measurement biases due to different return measurement horizon (Bodnar & Wong, 2003; Chow, Lee, & Solt, 1997; Dominguez & Tesar, 2006) and the choice of exchange rate (Fraser & Pantzalis, 2004; Rees & Unni, 2005).

There are a few measurement issues observed in the literature related to the estimation of exchange rate exposure. First, the extant literature has used actual changes in exchange rates to estimate the exposure, assuming that most of the changes in spot exchange rates are unanticipated (Dominguez & Tesar, 2006; He & Ng, 1998; Hutson & Laing, 2014; Hutson & Stevenson, 2010; Jorion, 1990). However, existing literature suggests that exchange rates do not always follow random walk (Dua & Ranjan, 2012; Li, Tsiakas, & Wang, 2014) and, therefore, actual exchange rate changes contain both expected and unexpected components. In this way, it becomes important to separate unexpected part from actual changes (Amihud, 1994; Bredin & Hyde, 2011; Choi, Elyasiani, & Kopecky, 1992; Gao, 2000; Jongen, Muller, & Verschoor, 2012).

Second, a very small part of literature has used unanticipated changes in exchange rates to estimate exposure. Existing studies that use macroeconomic models to capture unexpected exchange rate changes (Doukas, Hall, & Lang, 2001; Gao, 2000) have ignored the potential influence of country's exchange rate regime-related factors that possibly affect the level of exchange rates and the associated exchange rate exposure (Ye et al., 2014). There is a wide range of theoretical literature and mounting empirical evidence which suggest that intervention by central bank plays an important role in influencing the level of exchange rates (Dominguez & Frankel, 1993; Galati, Melick, & Micu, 2005; Goodhart & Hesse, 1993) and exchange rate volatility (Fatum & King, 2006; Hoshikawa, 2008; Kim, Minh, & Pham, 2006). The information on central bank intervention also improves the predictive power of the forecast model (Dua & Ranjan, 2012; Reitz, 2002) in countries that have managed floating exchange rate regime. Therefore, the macroeconomic models adopted for developed markets to capture unexpected exchange rate changes should not be replicated for countries that follow managed float exchange rate regime and need to be extended by incorporating the effects of central bank intervention.

In this study, a sample of 651 Indian firms is used to examine the relationship between unanticipated changes in exchange rate and the value of the firm. The unanticipated changes in exchange rate are captured by the proposed macroeconomic model that incorporates central bank intervention effects. This study argues that exposure puzzle can be attributed to the measurement biases due to the use of spot actual changes in exchange rate for estimating exposure by prior studies. The study explores an alternative explanation to the exposure puzzle by using a different approach to the majority of the extant literature of measuring the unanticipated exposure.

This article contributes to the existing literature in a number of ways. First, this study proposes an extended macroeconomic model with central bank intervention effects to estimate the unanticipated exchange rate changes and provides new evidence that the intervention by central bank has a major impact on the level of firms' exchange rate exposure. Second, this article employs a different econometric approach, a vector error correction model (VECM), to capture unanticipated exchange rate changes. Since there is a simultaneous relationship between exchange rates and macroeconomic variables, ordinary least square (OLS) method provides inaccurate estimates (Gujarati, 2002). The current study has used VECM for a system of seven macroeconomic variables that are supposed to affect exchange rates.

The findings have important theoretical and practical implications. In terms of theoretical significance, the results explain the existing exposure puzzle by providing evidence that intervention by central bank is a major factor which affects the exchange rate exposure of firms. In this way, this study contributes to the extant literature which attributes the insignificant empirical findings to exposure measurement biases. In terms of practical significance, the study suggests a new efficient approach for managers to measure the exposure of their firms which could further help them to plan their hedging policies.

The rest of this article is structured as follows. The next section contains theoretical framework and a brief review of the related literature on exchange rate exposure. The research methodologyis described in 'Methodology' section. The 'Data and Sample Selection' section contains some information on the data and sample selection. The empirical analysis is presented in 'Empirical Results and Discussion' section followed by robustness tests in the next section. The final section offers some concluding remarks.

Theoretical Background and Empirical Literature

Exchange rate exposure is defined as the sensitivity of the value of the firm to unexpected changes in exchange rates (Adler & Dumas, 1984). This specification assumes that the stock market operates efficiently and current market prices are assumed to have already incorporated the anticipated changes in exchange rates. Hence, only the unanticipated or innovated components should affect stock returns. The exchange rate exposure is theoretically classified into three broad categories (Eun & Resnick, 2014). The first is 'transaction exposure', which is defined as 'the sensitivity of realised domestic currency values of the firm's contractual cash flows denominated in foreign currencies to unexpected exchange rates'. The second is 'economic exposure', which is defined as 'the extent to which future cash flows are affected by unanticipated changes in exchange rates'. The third is 'translation exposure', which refers to 'the potential that the firm's consolidated financial statements can be affected by changes in exchange rates'. Theoretically, all firms, domestic and international, are exposed to exchange rate risk.

The empirical literature on exchange rate exposure provides mixed results. Most studies are focused on US multinational firms and report a small number of firms with significant exposure (Amihud, 1994; Bartov & Bodnar, 1994; Chaieb & Mazzotta, 2013; Chang, Hsin, & Shiah-Hou, 2013; Hutson & Laing, 2014; Jorion, 1990). Many non-US studies have also reported similar findings (He & Ng, 1998; Khoo, 1994; Loudon, 1993; Rees & Unni, 2005). Studies of emerging market firms find much higher rates of significant exposure than studies of developed market firms. The findings of these studies are also inconclusive. Some studies report a small number of firms with significant exposure. These are Lin (2011) for 6 Asian countries, Chue and Cook (2008) for 15 emerging markets, Rossi (2011) for Brazilian firms, Dominguez and Tesar (2006) for Thailand and Chile, Muller and Verschoor (2007) for East Asian countries, and Aysun and Guldi (2011) for 6 emerging markets. On the other hand, few studies find a substantial number of firms with significant exchange rate exposure. These are Parsley and Popper (2006) for East Asian countries, Kiymaz (2003) for Turkish firms, Bacha et al. (2013) for Malaysian firms and Tsai et al. (2014) for Taiwanese industries. Ye et al. (2014) find that about half of the emerging market firms from 20 countries are significantly exposed to exchange rate changes.

Several explanations are documented in literature to explain the insignificant findings on exchange rate exposure. In relation to measurement bias, it is worth noticing that the existing literature has consensus on the seminal definition of exposure, which relates unexpected changes in exchange rates to firm value. In spite of this definition, most previous literature has used actual or realised changes in exchange rates as a proxy for unanticipated currency movements in estimating the exposure (Dominguez & Tesar, 2006; He & Ng, 1998; Hutson & Laing, 2014; Hutson & Stevenson, 2010; Jorion, 1990). This could be a cause for insignificant empirical findings of prior studies.

However, unlike aforesaid studies, some other studies have recognised the inappropriate use of actual exchange rate changes as a proxy for unexpected changes to estimate the exposure and have made a significant effort to generate unanticipated changes (Amihud, 1994; Bredin & Hyde, 2011; Choi et al., 1992; Gao, 2000; Jongen et al., 2012). These studies assume that exchange rate movements are not a random walk (Dua & Ranjan, 2012; Li et al., 2014) and, therefore, actual exchange rate changes contain both expected and unexpected components. Choi et al. (1992) estimate the exposure of 48 largest US commercial banking institutions over the period January 1975 to December 1987 and conclude that actual rates are not able to detect the true exposure as stock prices have already responded to the anticipated changes at some point in the past. A recent study by Jongen et al. (2012) examines the effect of unexpected exchange rate changes on firm value for a sample of 634 US multinational firms. Using survey data to measure unanticipated changes in exchange rate, their study concludes that prior models assuming that changes in actual exchange rates are unanticipated are basically misspecified and, thus, are not able to correctly estimate the exchange rate exposure.

This literature suggests the appropriateness of unanticipated rates to estimate the exposure and brings out an important new and researchable avenue. It is important to notice that the existing studies that use macroeconomic models to capture unexpected exchange rate changes (Doukas et al., 2001; Gao, 2000) have largely ignored the potential influence of country's exchange rate regime-related factors which could possibly affect the level of exchange rates and firms' exchange rate exposure (Ye et al., 2014). These macroeconomic models adopted for developed markets should not be used in a similar form for countries that follow managed float exchange rate regime. This is because the exchange rate in emerging markets that follow managed float exchange rate regime is also influenced by the intervention of regulatory authorities in the foreign exchange market along with other macroeconomic factors.

There are several economic theories which postulate that the intervention by central bank affects exchange rates through various channels, namely, monetary channel, portfolio channel, signalling channel and noise-trading channel. Non-sterilised intervention affects exchange rates through the monetary channel in which foreign exchange transactions affect the money supply and interest rates. The portfolio channel works when investors consider foreign and domestic assets as imperfect substitutes. The purchase of foreign currency by a central bank creates excess demand for foreign currency assets and, therefore, the investors holding domestic currency assets should be compensated by higher return. This might affect the level of exchange rates. According to the signalling channel, sterilised intervention is expected to convey a signal to market participants about the inside information of future fundamentals and brings about a change in the exchange rate. The noise-trading channel hypothesis proposed by Hung (1997) says that sterilised intervention may be intended to increase or decrease exchange rate volatility to manage the exchange rate level. Empirical evidence is also available to support these theories (Dominguez & Frankel, 1993; Galati et al., 2005; Goodhart & Hesse, 1993).

The moral hazard hypothesis suggests another explanation for the impact of central bank intervention on exchange rate exposure. The efforts of the central bank to stabilise the exchange rates through foreign exchange market interventions provide an implicit government guarantee which may encourage firms to remain unhedged and may expose firms to higher exchange rate risk (Eichengreen & Huasmann, 1999).

There are some studies (Parsley & Popper, 2006; Patnaik & Shah, 2010; Ye et al., 2014) which provide some general evidence on the relationship between the exchange rate regime and firms' exposure, but they did not, specifically, examine the influence of central bank intervention on exchange rate exposure for emerging market firms that have managed float exchange rate regime. There is a study by Lin (2011) which provides some clue to the relationship between central bank intervention and exchange rate exposure, and concludes that central bank intervention does not play any role in reducing firms' exposure to exchange risks. This study did not, however, capture the influence of central bank intervention, through exchange rates, on individual firm's exposure. Also, Lin (2011) did not include indirect interventions in the form of policy changes in defining central bank interventions and used volatility of foreign exchange reserves as a measure of intervention. This article goes ahead by capturing the effect of direct and indirect intervention on unanticipated exchange rate changes and thus on individual exposure of firms.

Methodology

Model for Estimating Exchange Rate Exposure

Exchange rate exposure is theoretically defined as the sensitivity of firm value to changes in exchange rate. The empirical model to measure exchange rate exposure was first proposed by Adler and Dumas (1984) in which exposure is measured by the slope coefficient from a regression of stock returns on exchange rate changes. A shortcoming of this model was that it does not account for other market factors that affect stock returns. Later, value-weighted market index to control for market movements was included in the model by Jorion (1990) which has been extensively used throughout literature. According to Jorion's (1990) model, foreign exchange exposure can be determined by calculating the coefficient β_{si} in the time series regression of returns on a given stock, R_{it}, with respect to the market returns, R_{mt}, and the fluctuations of foreign exchange rate R_{st}.

In other words,

$$R_{it} = \beta_{0i} + \beta_{mi}.R_{mt} + \beta_{si}.R_{st} + \varepsilon_{it}, \tag{1}$$

where R_{it} is the monthly stock return of firm i in period t; R_{mt} is the monthly return on the market portfolio in period t; R_{st} is the monthly percentage change in the trade-weighted exchange rate index, measured in units of foreign currency per one Indian rupee in period t. The increase in the value of R_{st} indicates an appreciation of Indian rupee against a basket of foreign currencies. The coefficients β_{mi} and β_{si} represent a measure of sensitivity of stock return i to market risk and exchange risk; ε_{it} is the disturbance term. The value obtained for β_{si} for different firms can be interpreted as the level of exposure to exchange rates, indicating the extent to which the stock return responds to 1 per cent change in the exchange rate. The aforementioned regression model is used to examine the levels of exposure to exchange rate changes that should be reflected in the statistical significance of the coefficient β_{si}, (two-tailed test) and the direction of such exposure, which is indicated by the sign that accompanies the coefficient. A positive coefficient means that the firm's stock return increases when Indian rupee appreciates against the basket of other currencies.

In the aforementioned model, β_{si} cannot be interpreted as 'total exposure', but rather the exposure of stock over and above that of the market portfolio, that is, residual exposure. In order to eliminate the effect of exchange rates from the market portfolio, studies have suggested orthogonalisation procedure (Kiymaz, 2003; Priestley & Ødegaard, 2007) by the following regression:

$$R_{mt} = \alpha_0 + \beta_1 R_{st} + \vartheta_{mt}, \tag{2}$$

where ϑ_{mt} is the error term which is defined as the orthogonal market return, that is, that part of the return on the market portfolio that is uncorrelated with changes in the exchange rates. ϑ_{mt} should be used in equation (1) instead of R_{mt} to estimate the 'total exposure' of stocks to exchange rates.

The potential measurement bias with Jorion (1990) model may be that it assumes most of the changes in spot exchange rates to be unanticipated, and therefore uses actual changes in exchange rates as a proxy for unanticipated changes to calculate the exposure. However, exchange rates do not always follow random walk (Dua & Ranjan, 2012; Li et al., 2014) and, therefore, actual exchange rate changes contain both expected and unexpected components. Hence, it is essential to separate the unexpected and expected components of exchange rate changes and use the unanticipated part to measure exposure.

Anticipated changes in exchange rate can be predicted by forecasting methods and can be subtracted from the actual changes to estimate the unexpected part of exchange rate changes. A study by Gao (2000) was the first to use a macroeconomic model of forecasting exchange rates to extract the unexpected changes in exchange rates for estimating exposure. His study provides a model in the form of a general specification of macroeconomic exchange rate dynamics which includes essential elements of various macro or monetary models.

This model is as follows:

$$R_{it} = \beta_{0i} + \beta_{mi} . R_{mt} + \beta_{ui} . UR_{st} + \omega_{it}, \tag{3}$$

where the unanticipated change in exchange rate UR_{st} is captured by taking as a residual of regression of the actual exchange rate changes on the macroeconomic variables by the following equation:

$$UR_{st} = R_{st} - \begin{pmatrix} \alpha + \sum_{j=1}^{n1} \beta_{rj} r_{t-j} + \sum_{j=1}^{n2} \beta_{mj} m_{t-j} + \sum_{j=1}^{n3} \beta_{yj} y_{t-j} \\ + \sum_{j=1}^{n4} \beta_{\pi j} \pi_{t-j} + \sum_{j=1}^{n5} \beta_{TBj} TB_{t-j} \end{pmatrix}, \tag{4}$$

where r_t is the interest rate, m_t is the money supply, y_t is industrial production, π_t is the rate of inflation and TB_t is the trade balance. The selection of macroeconomic variables in this model is based on economic theories or monetary models. However, model of Gao (2000) is not appropriate for countries that follow managed float exchange rate regime and needs to be extended. As discussed earlier, the information on central bank intervention has a significant influence on exchange rates, and it should be added to the forecast model to generate unexpected exchange rate changes. Therefore, in this study the unanticipated changes are estimated by introducing a variable, which captures central bank's intervention, into the forecast model along with other macroeconomic variables as follows:

$$UR_{st} = R_{st} - \begin{pmatrix} \alpha + \sum_{j=1}^{n1} \beta_{rj} r_{t-j} + \sum_{j=1}^{n2} \beta_{mj} m_{t-j} + \sum_{j=1}^{n3} \beta_{yj} y_{t-j} \\ + \sum_{j=1}^{n4} \beta_{\pi j} \pi_{t-j} + \sum_{j=1}^{n5} \beta_{TBj} TB_{t-j} + \sum_{j=1}^{n6} \beta_{FIj} FI_{t-j} \\ + \sum_{j=1}^{n7} \beta_{NFIj} NFI_{t-j} \end{pmatrix}, \tag{5}$$

where FIt is the intervention by central bank directly into the foreign exchange transactions and NFIt is the intervention by central bank in the form of non-foreign exchange transactions or by indirect policy changes. All these are domestic variables. The rationale to measure central bank intervention by these variables is based on the theoretical definition of intervention.

'Foreign exchange market intervention is defined as any transaction, announcement or other policy changes by an official agent of a government that is intended to influence the value of an exchange rate' (Dominguez, 1998; Neely, 2000). The intervention in the form of direct foreign exchange transactions such as sale and purchase of foreign currency in the foreign exchange market is termed as direct intervention. However, as mentioned by Neely (2000), intervention also refers to other policies designed to influence exchange rates indirectly. These policies include '*capital controls*—taxes or restrictions on international transactions in assets like stocks or bonds—or exchange controls—the restriction of trade in currencies' (Dooley, Mathieson, & Rojas-Suarez, 1997; Evrensel, 2013; Neely, 1999).

Since there is a simultaneous relationship between exchange rates and macroeconomic variables, it is better to combine a set of variables that can be determined simultaneously by the remaining set of variables (Gujarati, 2002). In the simultaneous equation models, the parameters of a single equation cannot be estimated without taking into account the information provided by other equations in the system. If the parameters of each equation are estimated by using OLS method ignoring other equations, the least-squares estimators are biased and inconsistent because the basic assumption of the method of OLS—that the independent variables that are either non-stochastic or, if stochastic (random)—are distributed independently of the stochastic disturbance term, is violated (Gujarati, 2002).

Therefore, equation (5) is estimated in the framework of vector autoregression (VAR). Tests for non-stationarity are first conducted followed by tests for cointegration. All macroeconomic variables, except intervention by central bank, were found to be integrated of order one. The significant cointegrating relationships are developed by Johansen cointegration approach. Finally, a VECM at lag length of 3 is selected on the basis of Akaike information criterion (AIC) and other diagnostic tests. The detailed explanation of econometric methodology for modelling exchange rate is presented in 'Results of VECM Analysis' section.

The individual vector error correction equation with dependent variable as actual exchange rate is used to predict the changes in exchange rate and the residuals UR_{st} are extracted. The market portfolio return that is orthogonal to the unanticipated exchange rate changes UR_{st} was obtained by the following regression:

$$R_{mt} = \alpha_0 + \gamma_1 UR_{st} + \nu_{mt}. \tag{6}$$

Now UR_{st} estimated from equation (5) and v_{mt} from equation (6) can be used to estimate the 'total unanticipated exposure' of firms as follows:

$$R_{it} = \beta_{0i} + \beta_{omi} . \nu_{mt} + \beta_{ui} . UR_{st} + \omega_{it}, \tag{7}$$

where β_{ui} denotes the unanticipated exchange rate exposure coefficients and β_{omi} represents the coefficients of orthogonal market portfolio returns for different firms. Equation (7) is estimated by OLS method for all sample firms separately after checking for main econometric problems of stationarity, multicollinearity, autocorrelation and heteroskedasticity. When all equations have the same regressors, single equation-by-equation OLSs is the efficient estimator (Greene, 2002).

The stock returns of all firms, exchange rate changes and market portfolio returns are checked by augmented Dickey–Fuller (ADF) unit root test and are found to be stationary. The multicollinearity problem is resolved by orthogonalisation procedure. Autocorrelation and heteroskedasticity are eliminated by correcting the OLS standard errors using Newey and West (1987) method. The estimation through OLS and using adjusted robust errors is cited as a common practice in finance studies for time series models (Chow et al., 1997; Petersen, 2009).

Data and Sample Selection

The sample of firms for the study is primarily sourced from Centre for Monitoring the Indian Economy (CMIE) database, Prowess. There were 27,445 firms on the database. Elimination of financial firms from total firms reduced the sample to 20,704 firms. The decision to examine only non-financial firms was based on the complexity of foreign exchange rate exposure and risk management techniques used by financial firms. Since the exposure is measured based on the market value of firms' stock returns, only listed firms are considered for analysis. The non-financial firms which are listed either on Bombay Stock Exchange (BSE) or National Stock Exchange (NSE) were 4,308. The non-financial listed firms with international transactions (exports or imports) in each of the years of the sample period were 1,255, out of which 651 firms had no instances of missing stock return data. Therefore, the final sample consists of 651 firms. Out of 651 firms, 16 firms are pure importers and 2 firms are pure exporters. Firms with net import and net export transactions are 307 and 326, respectively. The average value of imports (₹6,823.37 million) for sample firms is almost twice of the average value of exports (₹3,891.31 million). Also, the average net value of international trade of firms that are net importers (₹8,692.66 million) is almost three times of that of firms which are net exporters (₹2,328.52 million). Overall, it can be observed that sample firms are import oriented. The industrial classification and international trade pattern of sample firms collected from Prowess database is presented in Table 1.

Monthly data is obtained for estimating firms' exposure coefficients at the first stage. Month-end closing prices of firm's stock are extracted from Prowess database and are used to calculate the stock returns of firms. Market portfolio monthly returns were calculated from BSE Sensitive

Table 1. Industry Classification and International Trade Pattern of Sample Firms

Industry Group	Industry Subgroup	No. of Firms	Percentage of Total Firms	Average Exports (₹ million)	Average Imports (₹ million)	Average Exports/Total Sales (%)	Average Import Ratio (%)
Manufacturing	Food- and agro-based products	45	6.90	1,710.58	1,523.96	23.12	11.63
	Textiles	46	7.06	1,823.37	1,069.80	33.22	19.03
	Chemical, plastic and petroleum products	152	23.31	8,532.98	21,622.46	21.66	25.17
	Consumer goods	35	5.37	1,581.90	1,982.52	30.22	22.80
	Construction materials	37	5.67	642.65	1,120.90	11.34	19.03
	Metal and metal products	44	6.75	5,144.79	8,457.01	17.19	26.54
	Machinery	75	11.50	1,172.73	1,766.38	14.30	24.00
	Transport equipment	51	7.82	1,688.38	2,081.97	10.37	17.43
	Miscellaneous manufacturing	23	3.53	305.68	595.06	13.18	22.51
	Diversified	16	2.45	1,863.32	2,608.80	11.81	26.66
Mining		6	0.92	9,095.01	12,004.03	37.63	21.50
electricity		5	0.77	450.45	2,831.55	5.90	9.20
services	Hotel and tourism	12	1.84	1,170.08	96.91	42.00	7.00
	Wholesale and retail trading	20	3.07	1,907.50	3,342.72	13.00	30.10
	Transport services	7	1.07	2,423.43	4,083.13	14.50	18.65
	Communication services	4	0.61	4,796.88	2,726.13	13.98	17.29
	IT	38	5.83	9,135.84	386.47	71.50	7.76
	Miscellaneous services	16	2.45	322.36	330.66	7.30	26.23
Construction and real estate		19	2.91	3,379.69	2,733.86	12.80	10.71
	Total	651	100	3,891.31	6,823.37	22.20	24.77

Source: Authors' compilation from CMIE prowess.

Index (Sensex) of 30 firms. The index value is available on the website of BSE. The monthly averages of 36 countries' nominal effective exchange rate index (36 NEER; Base: 1985 = 100) published in Reserve Bank of India (RBI) monthly bulletin is used for the purpose of calculating monthly exchange rate changes. Data is collected at monthly frequency instead of daily or weekly, since daily and weekly exchange rate indices are noisier and usually suffer from non-synchroneity problem which is the nonalignment of stock-return and exchange-rate series (Allayannis & Ofek, 2001). Examining exposure to the trade-weighted exchange rate index is a standard practice followed in literature (Bodnar & Gentry, 1993; Choi & Prasad, 1995; Dominguez & Tesar, 2006; Jorion, 1990).

The decision to select the nominal exchange rate index is based on prior studies (Allayannis & Ofek, 2001; Choi & Prasad, 1995) which mention that real and nominal exchange rates are highly correlated and produce similar results.

Table 2 summarises the descriptive statistics of monthly returns on BSE Sensex, and monthly changes in spot and unanticipated NEER index. For the purpose of forecasting exchange rates and estimating unanticipated changes, data for macroeconomic variables was obtained from RBI publications. Month-wise index numbers of Industrial Production General (base 1993–1994 = 100) are used for industrial output. Monthly

Table 2. Summary Statistics for Market Portfolio Returns and Exchange Rate Changes

	Changes in Market Portfolio	Actual Changes in Exchange Rate	Unanticipated Changes in Exchange Rate UR_{st}	
	R_{mt}	R_{st}	Gao (2000) Model	Proposed Model
Mean	0.0115	–0.0016	0.0004	–0.0001
Median	0.0114	–0.0016	–0.0003	–0.0004
Max	0.2489	0.0983	0.0939	0.0927
Min	–0.2730	–0.0464	–0.0436	–0.0400
S.D.	0.0736	0.0180	0.0167	0.0155
ADF	–10.7819***	–10.6259***	–12.4012***	–11.8768***

Source: Authors' calculations.

Notes: This table presents summary statistics including mean, median, maximum, minimum and standard deviation of monthly returns on BSE Sensex and changes in NEER index. ADF represents augmented Dickey–Fuller test statistics showing the stationarity of the series and *** indicates statistical significance at 1 per cent.

Consumer Price Index for Industrial Workers General Index (base: 1982 = 100) was collected to serve as a proxy for inflation rate. The data for money supply (M3), interest rates (91-days Treasury bill rate) and trade balance were collected from RBI monthly bulletin. The intervention into foreign exchange market by the central bank is measured by two variables. First is a net purchase of US dollar by RBI, which represents the intervention by central bank in foreign exchange transactions. The second is a dummy variable having value 1, if RBI indirectly intervenes in the foreign exchange market by non-foreign exchange transactions, zero otherwise. Policy-related announcements are available in the press release section of the website of RBI. In India, the 1997 report of the Committee on Capital Account Convertibility (Chairman: S. S. Tarapore) provided the initial framework for the liberalisation of capital account transactions in India. The Committee recommended a phased implementation of capital account convertibility to be completed by the year 1999–2000. Considering the fact that capital flows have substantial influence on exchange rate, the time period of this study is April 2001 to March 2013.

Empirical Results and Discussion

This section reports the results from estimating exchange rate exposure coefficients for a sample of Indian firms. At first, brief results from VECM analysis are presented to explain how unanticipated changes in exchange rates are captured based on Gao's (2000) model (equation (4)) and the proposed model with intervention effects (equation (5)). Subsequently, the exposure coefficients estimated from the three models are presented.

Results of VECM Analysis

Equations (4) and (5) are estimated in the VECM framework over a period from March 2000 to March 2013. All the macroeconomic variables are collected at monthly frequency. The definition of variables is presented in Table 3.

The first step in the estimation of econometric model is to test for non-stationarity. Table 4 reports the KPSS test with constant and trend for variables at level and at first difference. KPSS test assumes the null hypothesis that the series is stationary. The value of test statistic and critical values are presented. The inference at the 5 per cent significance level is given in the last column which shows that apart from central

Table 3. Definition of Macroeconomic Variables

Variables	Definition
e_t	Log of Nominal Effective Exchange Rate Index (36 country, base: 1985 = 100)
π_t	Log of Consumer Price Index for Industrial Workers General Index (base: 1982 = 100)
y_t	Log of Index number of Industrial Production General (base: 1993–1994 = 100)
m_t	Log of Money Supply (M3)
r_t	Yield of SGL transactions in Treasury Bills of 91 days maturity
TB_t	Trade Balance
FI_t	Net Purchases of USD by RBI
NFI_t	A dummy variable having value 1, if RBI indirectly intervenes into the market or, 0 otherwise

Source: Authors' compilation.

Table 4. Unit Root Test Results (Intercept and Trend)

	KPSS Test		
Variable	Levels	First Difference	Inference
e_t	0.2650	0.0328	I(1)
π_t	0.3857	0.0463	I(1)
y_t	0.1904	0.1319	I(1)
m_t	0.2430	0.1550	I(1)
r_t	0.1652	0.0562	I(1)
TB_t	0.2635	0.0580	I(1)
FI_t	0.1217	0.0273	I(0)
	Critical Values		
1% level	0.2160		
5% level	0.1460		
10% level	0.1190		

Source: Authors' calculation using Eviews 8.1.

Notes: This table reports results of KPSS test for variables at level and at first difference. e_t is the trade-weighted nominal exchange rate index, r_t is the interest rate, m_t is the M3, y_t is industrial production, π_t is the rate of inflation, TB_t is trade balance and FI_t is the intervention by central bank directly into the foreign exchange transactions.

bank intervention, all other variables are non-stationary. Testing for differences of each variable indicates that all the variables are integrated of order one.

Next step is to test for the cointegration. The significant cointegrating relationships are developed by Johansen cointegration approach. The variables should be integrated of the same order for cointegration. Therefore, all macroeconomic variables, except foreign exchange intervention, have been tested for cointegration at their level form. The cointegrating relationship equations and subsequently VECMs were constructed at the lag length of $k = 0$ to 12 for both models (Maysami & Koh, 2000). For monthly data, the lag length of 12 should be appropriate (Enders, 2009). The final model was selected based on the AIC and various diagnostic tests.

Table 5 presents the results of Trace Statistics and Max-Eigen Statistics for the two models. Trace Statistics indicates that the number of cointegrating equations is two and five for the Model 1 and the Model 2, respectively. While Max-Eigen Statistics indicates two cointegrating equations for both models. As a result, it is concluded that the number of cointegrating equations is two for both models. When there are more than one cointegrating vectors, the first eigenvector is considered as the most useful which is based on the largest eigenvalue (Maysami & Koh, 2000).

Table 5. Results for Trace Statistics and Eigen Value

Hypothesised No. of CE(s)	Eigenvalue	Trace Statistic	5 % Critical Value	Max-Eigen Statistic	5 % Critical Value
Model 1: $e_t = f(\pi_t, y_t, m_t, r_t, TB_t)$ at Lag Length $k = 1$					
None	0.305	150.455*	94.150	56.446*	39.370
At most 1	0.251	94.008*	68.520	44.756*	33.460
At most 2	0.138	49.251*	47.210	22.998	27.070
At most 3	0.107	26.254	29.680	17.560	20.970
Model 2: $e_t = f(\pi_t, y_t, m_t, r_t, TB_t, FI_t, NFI_t)$ at Lag Length $k = 3$					
None	0.363	176.180*	94.150	69.055*	39.370
At most 1	0.235	107.125*	68.520	41.039*	33.460
At most 2	0.155	66.086*	47.210	25.759	27.070
At most 3	0.133	40.327*	29.680	21.756	20.970
At most 4	0.112	18.571*	15.410	18.124	14.070
At most 5	0.003	0.448	3.760	0.448	3.760

Source: Authors' calculation using Eviews 8.1.
Note: * denotes rejection of the hypothesis at the 5 per cent level.

Since the intervention variable is stationary, its sign and significance can be determined from the framework of an error correction model. The cointegrating vectors for the two models are (1, –0.7492, –1.5634, 0.7601, –1.4750, –0.0008) and (1, 0.3380, –0.7514, 0.0709, –0.7340, –0.0004) respectively. The corresponding cointegrating equations are as follows:

Model 1: $e_t = (0.749258 * \pi_t + 1.5634 * y_t - 0.7601 * m_t + 1.475 * r_t + 0.000879 * TB_t)$

Model 2: $e_t = (-0.33809 * \pi_t + 0.75145 * y_t - 0.07096 * m_t + 0.73407 * r_t + 0.00046 * TB_t)$

The signs of the coefficients in the cointegrating equations are consistent with the theory except the sign of π_t in the Model 1. The relationship can be represented in the form of VECM, if the variables are cointegrated. After running VECM collectively for the system of variables, the individual vector error correction equations corresponding to two models, taking exchange rate as dependent variable, are estimated. The final VECM which best meets the selection criteria of minimising AIC and other diagnostic tests is selected at lag length of $k = 1$ for the Model 1 and $k = 3$ for the Model 2. Table 6 presents the coefficients of individual vector error correction equations taking dependent variable as Δe_t.

Table 6. Error Correction Models

Dependent Variable: Δe_t				
	Model 1		Model 2	
Variable	Coefficient	t-statistics	Coefficient	t-statistics
Constant	0.0016	0.6434	0.0003	0.0673
ECT1	–0.0386**	–2.5370	–0.0748**	–2.1252
ECT2	0.0576*	2.6001	–0.0449*	–1.8774
Δe_{t-1}	0.1162	1.4505	0.1500*	1.7206
Δe_{t-2}			–0.0594	–0.7090
Δe_{t-3}			–0.0591	–0.6949
Δr_{t-1}	0.0302	0.1402	–0.1881	–0.8215
Δr_{t-2}			–0.2066	–0.8788
Δr_{t-3}			0.1751	0.7486
Δm_{t-1}	–0.0880	–0.6211	–0.1024	–0.6817
Δm_{t-2}			–0.0890	–0.5726
Δm_{t-3}			0.1176	0.7927
Δy_{t-1}	–0.0219	–0.6626	0.0321	0.6065

(Table 6 continued)

(Table 6 continued)

	Dependent Variable: Δe_t			
	Model 1		Model 2	
Variable	Coefficient	t-statistics	Coefficient	t-statistics
Δy_{t-2}			0.0443	0.8530
Δy_{t-3}			0.0474	1.2829
$\Delta \pi_{t-1}$	–0.3074	–1.5871	–0.3296*	–1.6688
$\Delta \pi_{t-2}$			–0.4903**	–2.3160
$\Delta \pi_{t-3}$			0.3406	1.5701
ΔTB_{t-1}	0.0000	0.2374	0.0000	–1.0454
ΔTB_{t-2}			0.0000	–1.3405
ΔTB_{t-3}			–0.0003*	–2.0311
FI_t			0.00083*	1.7988
NFI_t			0.0001*	1.591
Overall AIC for system	–17.920		–17.929	
R-square	8.10%		12.58%	
F-statistic	2.700***		1.994***	
Akaike info criterion	–5.209		–5.239	
Serial correlation LM test	1.388		1.269	
Heteroskedasticity Test (ARCH)	0.340		0.021	
Jarque–Bera normality test	244.77***		424.89***	
Chow breakpoint test	0.956		1.260	

Source: Authors' calculation using Eviews 8.1.

Notes: This table reports error correction equation taking Δe_t as dependent variable. ECT1 and ECT2 are the error correction terms in the equations. e_t is the trade-weighted nominal exchange rate index, r_t is the interest rate, m_t is the money supply, y_t is industrial production, π_t is the rate of inflation, TB_t is trade balance, FI_t is the intervention by central bank directly into the foreign exchange transactions and NFI_t is the intervention by central bank in the form of non-foreign exchange transactions or by indirect policy changes. ***, ** and * indicate statistical significance at 1 per cent, 5 per cent and 10 per cent level, respectively.

Notice that the coefficients of error correction term of exchange rate in the error correction models has a correct sign (negative) and statistically significant in both models. Both chosen equations of the two models pass the various diagnostics tests. Model 2 has minimum AIC and better R-square, which indicates that the inclusion of central bank intervention in the macroeconomic model improves the predictive power of the model.

The residuals of these models are the unanticipated changes in exchange rate and are used further for estimating the exchange rate exposure coefficients.

Exposure Rate Exposure Using Jorion's (1990) Model

Table 7 reports a summary of the exposure coefficients estimated from Jorion's (1990) model. The results reveal that 66.6 per cent (434 of 651) of Indian firms are significantly exposed to exchange rate changes at 10 per cent level of significance. The significant exposure coefficients are positive in sign. The average value of exchange rate exposure coefficients is 1.317, indicating that a 1 per cent appreciation of Indian rupee causes almost 1.32 per cent gain in the firms' stock returns. These results are similar to those of previous studies on emerging markets which report more than half of their sample firms with significant exposure (Bacha et al., 2013; Kiymaz, 2003; Parsley & Popper, 2006; Tsai et al., 2014; Ye et al., 2014). The findings indicating that, on average, firms gain from the appreciation of domestic currency is also not surprising and consistent with the prior literature on emerging markets (Chue & Cook, 2008; Dominguez & Tesar, 2006; Muller & Verschoor, 2007; Tsai et al., 2014; Ye et al., 2014).

Table 7. Summary of Exchange Rate Exposure Coefficients from Jorion's (1990) Model

No. of firms with significant exposure	434
% of sample firms with significant exposure	66.6%
No. of firms with positive significant exposure (10% level)	434
No. of firms with negative significant exposure (10% level)	0
Average value of significant exposure coefficients	1.668
Average value of exposure coefficients of all firms	1.317
Minimum	–1.296
Maximum	4.491
Standard deviation	0.779

Source: Authors' calculation using Eviews 8.1.

Table 8. Summary of Exchange Rate Exposure Coefficients from Gao's (2000) Model

No. of firms with significant exposure	447
% of sample firms with significant exposure	68.6%
No. of firms with positive significant exposure (10% level)	447
No. of firms with negative significant exposure (10% level)	0
Average value of significant exposure coefficients	1.863
Average value of exposure coefficients of all firms	1.489
Minimum	–1.514
Maximum	4.875
Standard deviation	0.874

Source: Authors' calculation using Eviews 8.1.

Exchange Rate Exposure Using Gao's (2000) Model

Table 8 presents the results when unanticipated changes of exchange rates are used in the time series regression model to estimate exposure (see equation (3)). The unanticipated part is captured by the residual of the regression of actual exchange rate changes on macroeconomic variables as suggested by Gao (2000) (see equation (4)). The results reveal that 68.6 per cent (447 of 651) of Indian firms are significantly exposed to exchange rate changes at 10 per cent level of significance and exposure coefficients of all of these firms are positive. The average value of exchange rate exposure coefficients is 1.489, indicating that a 1 per cent unanticipated appreciation of Indian rupee causes almost 1.5 per cent gain in the firms' stock returns. It is, therefore, evident that the use of unanticipated changes in exchange rates is able to discover more statistically and economically significant exchange exposure which is consistent with prior studies (Choi et al., 1992; Jongen et al., 2012).

Exchange Rate Exposure Taking into Account the Effects of Central Bank Intervention

Table 9 displays the results of exchange exposure after taking into account the effects of central bank intervention. That is, first the unanticipated part of exchange rate changes is captured by allowing for the effects of central bank's intervention in the macroeconomic model of Gao (2000). Then, those unanticipated changes are used to compute the exposure coefficients in the time series regression model. Strikingly, as soon as the effects of interventions are taken into account, 72 per cent of firms

Table 9. Summary of Exchange Rate Exposure Coefficients from Proposed Model

No. of firms with significant exposure	465
% of sample firms with significant exposure	72%
No. of firms with positive significant exposure (10% level)	465
No. of firms with negative significant exposure (10% level)	0
Average value of significant exposure coefficients	2.009
Average value of exposure coefficients of all firms	1.645
Minimum	–1.713
Maximum	4.834
Standard deviation	0.942

Source: Authors' calculation using Eviews 8.1.

exhibit significant exchange rate exposure. Also, the average value of exposure coefficients is 2.009, indicating that a 1 per cent unanticipated appreciation of Indian rupee against foreign currencies leads to almost 2 per cent increase in stock returns. Again the sign of all significant exposure coefficients is positive. Therefore, relative to the results from Jorion's (1990) and Gao's (2000) models, it is found that there are more firms significantly exposed when the effects of central bank interventions are taken into account. Also, the incorporation of the effects of central bank intervention is able to detect higher magnitude of average exposure coefficients.

Comparing Alternative Models

This section presents the comparison of the results obtained from various models. The extant literature suggests that a model is considered better, if it is able to generate results which are statistically significant and economically important (Aysun & Guldi, 2011; Bartram, 2004; Bodnar & Wong, 2003; Doidge, Griffin, & Williamson, 2006; Dominguez & Tesar, 2006; Priestley & Ødegaard, 2007; Rossi, 2012). The statistical significance of exposure coefficients is examined by the traditional *t*-ratio on the exposure estimates. The proposed model is better, if it is able to detect a higher number of firms significantly exposed to exchange rate changes. The economic significance of the exposure coefficients is examined by the size or the average value of coefficients and the average of adjusted R-square values obtained for the regression models of all firms in the sample and for firms with significant exposure. The model is supposed to be better in terms of economic significance, if it is able to produce higher average value of exposure coefficients and a positive change in the average value of adjusted R-square.

Tables 10 and 11 display the statistical and economic significance of the estimated exposure coefficients from the three models. It is evident, by comparing the results that Gao's (2000) model detects larger number of firms with significant exposure and higher magnitude of exposure in comparison to Jorion's (1990) model. This clearly suggests that the use of unanticipated changes in exchange rates provides more accurate results in terms of identifying higher exposure. The proposed model which takes into account the effects of central bank intervention is able to discover 72 per cent of firms with significant exposure which is almost a 7 per cent increase in the number of firms with significant exposure coefficients obtained from Jorion's (1990) model. In terms of the size of the exposure coefficients, on an average, a 1 per cent unanticipated appreciation of Indian rupee causes 1.65 per cent rise in stock returns (almost 25 per cent increase in the average exposure from Jorion's model) when the effects of central bank intervention are considered. Firms with significant exposure also show higher magnitude of exposure as we move from Jorion's model to the model that incorporates the intervention by central bank (see Panel A of Table 11).

Table 10. Comparing Alternative Models: Statistical Significance of Exchange Rate Exposure Coefficients

	No. of Firms with Significant Exposure Coefficients			% of Sample Firms with Significant Exposure			No. of Firms with Positive Significant Exposure (10% Level)	No. of Firms with Negative Significant Exposure (10% Level)
Models	10% Sig. Level	5% Sig. Level	1% Sig. Level	10% Sig. Level	5% Sig. Level	1% Sig. Level		
Jorion's (1990) model	434	365	238	66.6	56.0	36.5	434	0
Gao's (2000) model	447	384	245	68.6	58.9	37.6	447	0
Model with central bank intervention effects	465	393	259	71.5	60.3	39.7	465	0

Source: Authors' calculation using Eviews 8.1.

Panel B of Table 11 shows the average value of adjusted R-square obtained from the time series regressions of sample firms. For the model with intervention effects, the average adjusted R-square is 20.93 per cent for all firms' regressions which is higher than the other models.

Panel B of Table 11 also discloses the change in the value of adjusted R-square, when moving from the regression of stock return on the market portfolio alone, that is, CAPM model to a regression also including exchange rate as explanatory variable. The average value of adjusted R-square from the regressions of stock returns on market portfolio returns (i.e., CAPM specification) is 20.23 per cent. The average value of adjusted R-square increases by 0.52 per cent, when actual changes in exchange rates are added to the CAPM model. This value increases by 0.55 per cent, when unanticipated changes in exchange rates estimated from Gao (2000) model are added to the CAPM model and increases by 0.70 per cent for the model which uses intervention effects to capture unexpected changes in exchange rates.

Thus, central bank interventions appear to be important for uncovering exposure, both significantly and economically. In summary, the results reveal that intervention by central bank along with other macroeconomic factors captures the unanticipated part of exchange rate changes more accurately, and therefore uncovers significant exposure coefficients.

Table 10 also displays information about the signs of the exchange rate exposure coefficients. Concerning the direction of exchange rate exposure, the study finds that overall, an appreciation of Indian rupee is associated with positive stock returns. These findings are in contrast to the theoretical expectation, but, surprisingly, supported by previous studies on emerging markets (Chue & Cook, 2008; Dominguez & Tesar, 2006; Muller & Verschoor, 2007; Tsai et al., 2014; Ye et al., 2014). These findings can be attributed to the reliance of Indian firms on imports for the production and exports to the other markets. Additionally, the heavy short-term capital inflow and outflow to India in recent years may be the other possible reason behind this phenomenon. Tsai et al. (2014) bring out the role of hot money, that is, short-term entry and exit of international capital, in influencing the stock market. Since the inflow of speculative foreign capital increases stock prices (Zhang & Fung, 2006), it might be possible that this foreign investment or speculation effect swamped the underlying 'standard' market reaction to exchange rate movements and led to positive stock returns in Indian market. This finding is important for decision-makers and participants in the area of international finance, trade and policymaking. Following the literature (Aggarwal & Harper, 2010; Aysun & Guldi, 2011; Bartram, 2004; Choi & Prasad, 1995;

Table 11. Comparing Alternative Models: Economic Significance of Exchange Rate Exposure Coefficients

Penal A

Models	Size or Average Value of Exchange Rate Exposure Coefficients		Minimum	Maximum	Standard Deviation	Minimum	Maximum	Standard Deviation
	Across All Firms	Across Firms with Significant Exposure	Across All Firms			Across Firms with Significant Exposure		
Jorion's (1990) model	1.317	1.668	−1.296	4.491	0.779	0.562	4.491	0.623
Gao's (2000) model	1.489	1.863	−1.514	4.875	0.874	0.549	4.875	0.699
Model with central bank intervention effects	1.645	2.009	−1.713	4.834	0.942	0.645	4.834	0.758

Penal B

Models	Average Value of Adjusted R-Square (%)	Change in Adjusted R-Square After Adding Exchange Rate to the CAPM Model (%)
	Across All Firms	Across All Firms
Jorion's (1990) model	20.75	0.52
Gao's (2000) model	20.78	0.55
Model with central bank intervention effects	20.93	0.70

Source: Authors' calculation using Eviews 8.1.

Doukas et al., 2001; Faff & Marshall, 2005), this study is not particularly concerned about the direction of exchange rate changes on stock returns, but rather the extent of exposure in an absolute sense.

Exposure During Sub-periods of Varying Levels of Central Bank's Intervention

This section presents firms' exchange rate exposure during the sub-periods with varying levels of central bank interventions. The sample period is separated into two equal sized sub-periods following previous studies (Choi & Prasad, 1995; Doidge, Griffin, & Williamson, 2002; Dominguez & Tesar, 2006; Hutson & Stevenson, 2010) and consequently, the exchange rate exposure coefficients are examined for each period. If moral hazard hypothesis is correct, firms should face higher exchange rate exposure during the sub-periods of higher level of interventions. The absolute value of average and total foreign exchange intervention by RBI during two sub-periods is presented in Table 12. The following two periods are identified:

Period 1 (April 2001–March 2007): This is an appreciation period. The average absolute value of net purchases of US dollar by RBI is 1809.61 USD million during this period.

Period 2 (April 2007–March 2013): This is the depreciation period. The average absolute value of net purchases of US dollar by RBI increased by 20 per cent from the previous sub-period.

Table 13 presents the average value of exchange rate exposure coefficients over two sub-periods estimated from the three models. The results reveal that the average value of exposure rate coefficients is higher in sub-period 2 than the sub-period 1. These results are similar for all models and

Table 12. Intervention by Central Bank During Sub-periods

Periods	Total |FI| (USD Million)	Average |FI| (USD Million)	Median NFI	Average Monthly NEER Changes
April 2001–March 2007	130,292.37	1,809.61	0	0.000064
April 2007–March 2013	156,415.00	2,172.73	1	–0.003178

Source: Authors' calculation using Eviews 8.1.

Notes: This table reports intervention by central bank in terms of foreign exchange transactions (FI) and policy announcements (NFI). NEER denotes nominal effective exchange rate index.

Table 13. Average of Significant Exposure Coefficients During Sub-periods

Models	Period 1: April 2001–March 2007	Period 2: April 2007–March 2013
Jorion's (1990) model	0.964	1.521
Gao's (2000) model	1.081	1.785
Model with central bank intervention effects	1.474	1.726

Source: Authors' calculation using Eviews 8.1.

support moral hazard hypothesis as larger interventions in terms of net sale/purchase of US dollar are associated with higher exposure. Moreover, comparative statistics of the three models reveal that the model, which incorporates the information of central bank intervention, is superior to the other models and is able to detect higher mean value of exposure coefficients. The results reveal that, as compared to the whole sample period, the mean exposure is much higher in various sub-periods. Thus, sub-periods based on the intervention level are economically important to uncover the exposure of firms. The sub-period analysis also provides robustness of the results in terms of consistency in the signs of the beta coefficients. These findings support the existing theoretical literature of moral hazard hypothesis which says that the implicit government guarantee in the form of central bank intervention in foreign exchange market induces firms to remain unhedged, and therefore firms face higher exposure during the period of larger intervention. This implies that firms should be careful about their hedging policies and should use the information on intervention to explore the accurate currency exposure of their firms.

The findings suggest that intervention by central bank, through its effects on exchange rates, has a major impact on the level of Indian firms' exchange rate exposure. The generality of these findings can be extended to other emerging markets that have managed floating exchange rate regime. This is consistent with the recent findings of Ye et al. (2014) which suggest that the exchange rate regime of a country is a significant determinant of firms' exchange rate exposure.

The findings of this article have important theoretical and practical implications. In terms of theoretical significance, the results explain the existing exposure puzzle by providing evidence that intervention by central bank is a major factor which affects the exchange rate exposure of firms. In this way, this study contributes to the extant literature which attributes the insignificant empirical findings to exposure measurement biases. The findings also extend the existing theoretical literature of the moral hazard hypothesis.

The findings have important practical implications for corporate managers to anticipate the exchange rates and the associated unanticipated exposure of their firms to exchange rate risk. The firms of emerging countries that follow managed float exchange rate regime should take into account the effect of central bank intervention while gauging the future exchange rates and exposure. The accurate estimation of unanticipated exposure can further help managers to frame their hedging policies. In this way, this study suggests a new efficient approach for managers to accurately measure the currency exposure of their firms by using information on central bank intervention. The findings are also important for investors to assess the currency exposure of the firms which could help them to construct their portfolio.

Robustness Tests

This section presents robustness of the results to the industry-level evidence, to alternate market index returns and during sub-periods.

Industry-level Evidence

This sub-section presents robustness of exchange rate exposure coefficients by providing industry-level evidence. Panels A and B of Table 14 show the number of firms that are significantly exposed to the exchange rate risk and average exposure for each industry estimated from the three models. Consistent with the firm-level evidence, the model which captures the effects of central bank intervention is able to reveal much higher exposure in terms of larger number of firms with significant exposure coefficients and higher average value of exposure coefficients for each industry. This indicates that the results are robust, and the exchange rate exposure is widely spread across industries and not concentrated in a few industries. Therefore, the proposed model of this study reveals statistically significant and economically important exposure for various industries.

Table 14. Industry-wise Number of Firms with Significant Exposure Coefficients

Penal A			
Industry	Jorion's (1990) Model	Gao's (2000) Model	Model with Central Bank Intervention Effects
Food and agro-based products	22	25	24
Textiles	33	32	36
Chemical, plastic and petroleum products	93	99	106
Consumer goods	17	22	25
Construction materials	23	24	24
Metal and metal products	33	36	35
Machinery	62	60	64
Transport equipment	34	31	33
Miscellaneous manufacturing	13	13	16
Diversified	10	12	8
Mining	4	5	4
Electricity	3	4	4
Hotel and tourism	4	4	7
Wholesale and retail trading	15	15	14
Transport services	6	5	5
Communication services	3	2	2
IT	31	32	30
Miscellaneous services	13	13	12
Construction and real estate	15	13	16
Total firms with significant exposure	434	447	465

Source: Authors' calculation using Eviews 8.1.

Evidence with Alternate Market Portfolio

Market index returns are used to control for other variables that affect stock prices besides exchange rates. In this study, the returns of the market index of BSE Sensex are used. Bodnar and Wong (2003) suggest that currency exposure estimates are sensitive to the selection of the market portfolio. Therefore, to provide robustness of results, it is verified whether the choice of an alternate market index affects the extent of exposure. Table 15 (Column 2) shows that the number of firms with significant exposure, signs of the coefficients and the mean value of exposure are similar to the previous results, when the returns on S&P 500 BSE index are used

Table 14. Average Value of Significant Exposure Coefficients for Each Industry

Penal B			
Industry	Jorion's (1990) Model	Gao's (2000) Model	Model with Central Bank Intervention Effects
Food and agro-based products	1.696	1.758	1.775
Textiles	1.386	1.694	1.797
Chemical, plastic and petroleum products	1.536	1.729	1.993
Consumer goods	1.686	1.997	2.188
Construction materials	1.399	1.692	1.806
Metal and metal products	1.709	1.870	2.136
Machinery	1.675	1.861	1.976
Transport equipment	1.524	1.702	1.723
Miscellaneous manufacturing	1.731	1.938	2.138
Diversified	1.650	1.630	1.871
Mining	1.571	1.948	2.193
Electricity	2.045	1.684	1.613
Hotel and tourism	1.595	1.763	1.620
Wholesale and retail trading	1.726	1.952	2.182
Transport services	1.464	1.579	1.748
Communication services	2.117	2.795	3.109
IT	2.146	2.409	2.560
Miscellaneous services	2.135	2.262	2.390
Construction and real estate	2.129	2.251	2.060
Average of exposure coefficients of all firms	1.668	1.8626	2.009

Source: Authors' calculation using Eviews 8.1.

in regression equation (7). This indicates that the results are robust to the choice of the market portfolio.

Sub-period Analysis

One of the major challenges that emerging market firms faced in the last decade was the financial crisis of 2008/2009. Because financial crisis must have influenced the extent of emerging market firms' exchange rate exposure, and also for the purpose of examining the robustness of exposure coefficients, firm-level exposure is examined during two sub-periods. The first sub-period is from April 2001 to December 2007, the pre-crisis period, and the second is from January 2008 to March 2013, the post-crisis period. Table 15 (Columns 3 and 4) presents the proportion of firms exposed significantly in each period. Consistent with full period results, high levels of exposure are found across two sub-periods, though the percentage of significantly exposed firms is different among periods. Specifically, the proportion of firms with significant exposure increased from pre-crisis period (43%) to post-crisis period (63%).

The mean exposure for the significantly exposed firms indicates that the recent financial crisis leads to an increase in the size of exchange rate exposure, with the average rising to 2.44 during post-crisis period from 2.29 during pre-crisis period. These results are consistent with prior studies (Lin, 2011; Ye et al., 2014) which report that the financial crisis caused higher exchange rate exposure for emerging market firms including in India. Overall, it is found that exchange rate exposure is persistent for sample firms across the sub-periods.

Table 15. Robustness Analyses

	Exposure Coefficients Using Alternate Market Portfolio	Sub-period Analysis	
		Pre-crisis Period (April 2001–December 2007)	Crisis and Post-crisis Period (January 2008–March 2013)
No. of firms with significant exposure	466	281	410
% of sample firms with significant exposure	71.5	43.1	63.0
No. of firms with positive significant exposure (10% level)	466	277	410
No. of firms with negative significant exposure (10% level)	0	4	0
Average value of exposure coefficients of all firms	1.645	1.361	1.799
Average value of significant exposure coefficients	2.005	2.290	2.440
Minimum	–1.713	–4.396	–4.540
Maximum	4.834	5.726	7.489
Standard deviation	0.760	1.321	1.270

Source: Authors' calculation using Eviews 8.1.

Conclusion

The inconclusiveness of empirical findings about the relationship between exchange rate changes and the value of the firm gives rise to the 'exposure puzzle' (Bartram & Bodnar, 2007). Measurement biases and methodological weaknesses are possible explanations mentioned by prior literature (Bodnar & Wong, 2003; Priestley & Ødegaard, 2007). This study contributes to this area of the extant literature by arguing that exposure puzzle can be attributed to the measurement biases due to the use of spot actual changes in exchange rate for estimating the exposure by prior studies.

Using a sample of 652 Indian firms, this study explores the relationship between unanticipated exchange rate changes and stock returns by using a different approach to the majority of the extant literature. The study incorporates central bank intervention effects in the macroeconomic model of Gao (2000) to capture unanticipated changes in exchange rate. The analysis finds that the use of unanticipated exchange rate changes generated from proposed macroeconomic model reveals 72 per cent of firms with significant exposure, while actual exchange rate changes detect only 66 per cent of firms with significant exposure. Also, the average size of exposure across sample firms increases to 2.009 from 1.67, once the unanticipated changes are considered. The estimates of exposure coefficients are further uncovered during the sub-periods of varying degree of central bank intervention. The findings also support the moral hazard hypothesis by revealing the higher exposure of firms during the period of larger intervention. Therefore, this study provides new evidence that the intervention by central bank, through its effects on exchange rates, has a major impact on the level of firms' exchange rate exposure.

The findings have important theoretical and practical implications. In terms of theoretical significance, the results explain the exposure puzzle by providing evidence that the central bank intervention is an important variable that affect exposure estimates of firms in the emerging countries that have managed float regime. Also the findings extend the existing theoretical literature supporting the moral hazard hypothesis. In terms of practical significance, the study suggests a new approach for managers to measure the exposure of their firms which could further help them to formulate their hedging policies.

Future research may focus on the exposure of unlisted firms taking their earnings and cash flows as a proxy for firm value. The standard market model of Jorion (1990) used in this study to estimate the exposure does not include firm-specific controls which might be a possible alternative for future research.

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