CHAPTER 15

An Analysis of Dynamic Spillover in India's Forex Derivatives Markets

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15.1 Introduction

The continuous depreciation of Indian currency has sparked an intense interest in examining not only the degree of financial market integration along with the flow of foreign capital in the country, but also investigating the potential role of domestic currency trading platforms in the process of informational spillover. In the continuation of its aggressive economic liberalization measures, India set-up its own currency derivatives exchange on 29 August 2008 with the introduction of currency futures in US dollar paired with Indian rupee (USD/INR). The main objective was set out to minimize the currency risk in the event of awkward exchange rate fluctuation and to increase the international outreach of Indian rupee. Since then, the currency derivatives trading has been expanded by introducing futures trading in three more currency pairs viz. Euro (EURO/INR), British Pound (GBP/INR) and Japanese Yen (JPY/INR). At present, there are

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S.K. Mathur et al. (eds.), *Theorizing International Trade*,
https://doi.org/10.1007/978-981-10-1759-9_15

four major trading platforms i.e. Bombay Stock Exchange (BSE), Multi-Commodity Exchange-Stock Exchange (MCX-SX), National Stock Exchange (NSE) and United Stock Exchange (USE). Analyzing the trading figures, as on April 2013, India's forex trading platform accounted for about 0.5% of global foreign exchange market turnover, which is higher compared to 0.1% in 1998 (see BIS 2013). The market size is about 31 billion US dollars, which is low compared to 38 billion US dollars in 2007. This reveals the fact that India's forex market is indeed under pressure. More interestingly, the USD/INR pair has about 0.9% (50 billion US dollars) share in all the currencies paired with US dollar, which is lower than most of the emerging markets except Brazil. Analyzing the trading figure domestically, as of December 2013, NSE had the traded value of 30,107 million dollars followed by MCX-SX (14,181 million dollars) and USE (3077 million dollars) (see SEBI 2013 for details).[1] Since September 2010, when the currency derivatives trading was started even on USE, the trading figures still suggest that NSE is the largest player with the trading share of more than 52% followed by MCX-SX (39%) and USE only (9%).[2] The exchange rate trend indicates that since November 2011, the Rupee has continuously depreciated against US dollar and subsequently the other major currencies traded on India's currency derivatives platforms.[3] The consistent decline in the value of the Indian rupee has been one of the leading cause of concerns for not only policy makers, but also for hedgers who are involved in import/export of commodity. The possible reason for this decline appears to be the large outflow of capital from debt market that further led to the increase in bond yield and consequently a sharp depreciation of major emerging markets currencies in May 2013 (see Miyajima and Shim 2014). Considering the enormous implication of foreign exchange market upheavals on the economy, an insufficient number of studies have tried to study the phenomenon of currency market interdependence in the light of directional information spillover especially at the time when the rupee is passing through a difficult phase of decline. The objective of this study is twofold. First, to examine the level and direction of return and volatility spillover in India's two currency derivatives trading platforms to shed some light on the interdependence between futures and spot and between futures markets interactions. Second, we then explore whether the interactions between futures and spot and between futures series are inter-currency or intra-currency in nature. This is mainly because it has a lot of policy implications from cross-market hedging and speculation. To state it more intuitively, this chapter aims to provide answers to questions such as: First, what is the level and direction of information transmission in India's foreign exchange market? As this will address the issue of market efficiency in the currency market. Second, is the direction of informational spillover inter-currency or intra-currency? Third, has currency futures market started playing an important role in information transmission process? Fourth, which trading platform is dominant or satellite with respect to returns and volatility-based informational spillover? The answers to these questions are expected to provide important direction in undertaking policy measures and also for traders and investors concerned. As studies have noted, one of the salient features of the currency derivatives market is to provide a hedging platform for the exporters and traders in the event of strong currency market upheavals. Particularly, in the case of India, the research mentioned above questions appear to be relevant as for a quite long time, the introduction of forex derivatives has been one of the hotly debated topics among academics, researchers, traders, and regulators with regards to its constructive role in price discovery and the volatility spillover process in India. This is mainly because of the predatory pricing and market-dominant strategies adopted by large players in the currency derivatives markets (see MCX-SX 2014). The examination of informational spillover also plays a significant role in the formulation of a trading strategy for investors and traders and containing the risk of currency market speculation for policy makers. In the context of India's currency derivatives market, this is the first study that examines the directional spillover in returns and volatility of two prominent trading exchanges viz., National Stock Exchange (NSE) and Multi-Commodity Stock Exchange (MCX-SX). The study considers the four prominent exchange rates viz., United States Dollar (USD/INR), Euro (EURO/INR), British Pound (GBP/INR) and Japanese Yen (JPY/INR). This study is based on the daily data for the sample period of 01 February 2010 to 25 November 2014.

Focusing on the research concerning spillover analysis in case of derivatives markets, a close appraisal of existing literature reveals that two issues that have been widely investigated are price discovery and volatility spillovers between futures and spot and between futures prices of various commodities ranging from agriculture to currencies (see Harvey and Huang 1991; Abhyankar 1995; Lin et al. 1994; Tse 1999; Fung et al. 2001; Hong 2001; Han and Ozocak 2002; Roope and Zurbruegg 2002; Xu and Fung 2005; Hua and Chen 2007; Inagaki 2007; Karmakar 2009; Mahalik et al. 2010; McMillan and Speight 2010; Antonakakis 2012). Regarding volatility spillover, according to Chan et al. (1991) volatility spillover helps in investigating the process through which volatility in one market affects that of another market. In the words of Hong (2001), the identification of volatility spillover across assets or markets is important because it helps describing how one large shock increases the volatility not only in its asset or market but also in other assets or markets as well. Hence, there is general agreement that volatility spillovers correspond to information transmission between different assets or markets (Tse 1999; Gagnon and Karolyi 2006; Rittler 2012). Further, the examination of shock spillover across currency markets has grave implications for the formulation of currency trading strategies, currency risk diversification and exchange rate management policies usually formulated by the central bank. As mentioned, the examination of the currency derivatives market volatility in India is important because it is inextricably linked with trade policy of the country and liberalization measures undertaken in the recent past. As the experiences of many economies clearly suggest that due to globalization related free flow of capital and continuous innovation in the financial system, many economies have observed abnormal behaviour in their exchange rates. A volatile foreign exchange market not only affects the price and returns volatility of other assets in the system, but also it disturbs the trade flow and balance of payment of countries (See Claessens et al. 2001).The study of magnitude and direction of spillover between currencies and markets in which they are traded, that is, spot and futures, are important for the reason that it enables a researcher to gauge the level of informational efficiencies between markets. Volatility spillover between currencies and markets lead to the characterization of whether a particular market is dominant or satellite, where fluctuation in the value of one currency causes substantial changes in the relative prices of other currencies and assets in response to the first shock originated in a different market. This further leads to increased volatility following the cause and effect process found in the feedback systems. Sometimes these spillover effects are too large to ignore and for a country like India that is already struggling with the unfavourable balance of payment position and exchange rate volatility complicates the issue further. Diebold and Yilmaz (2009, 2012) define spillover regarding the share of the forecast error variance decomposition (FEVD) in a market that is caused by shocks mainly originated from other markets. The rate of flow of information between assets and markets has often been linked to volatility. It is argued that in case of the clustered flow of information, asset prices or returns may display volatility even if the market's reaction and correction mechanism is perfect and instantaneous. And an absence of spillover provides support to the proposition that the main factors responsible for changes in volatility are asset or market-specific fundamentals. And if this is the case, then a large shock will only disturb the volatility of a particular related asset or market. But in the presence of spillover effect, one large shock originated in a market will disturb volatilities in other assets and markets as well (see Hong 2001). Therefore, an explicit knowledge of volatility spillover across assets and markets is crucial in understanding the mechanism through which information and shocks are transmitted or spilled over to other markets and sectors of the economy.

15.2 Review of Literature

A large number of studies have examined the process of information transmission covering equity and commodities markets (see Engle et al. 1990; Harvey and Huang 1991; Lin et al. 1994; Tse 1999; Fung et al. 2001; Hong 2001; Han and Ozocak 2002; Roope and Zurbruegg 2002; Xu and Fung 2005; Hua and Chen 2007; Inagaki 2007; Karmakar 2009; Mahalik et al. 2010; Kumar 2011; Antonakakis 2012; Sehgal et al. 2015). The main thrust of most of these studies has been on examining spillover phenomenon on either well-developed markets or the equity component of financial market linkages. Although the research issue of informational spillover in case of currency derivatives market is not a new phenomenon, there is an insufficient number of studies that have examined the shock spillover by exploring the different dimensions in case of emerging markets like India. Fung and Patterson (1999) study the dynamic relationship in terms of return volatilities, volume and market depth for five currency futures markets viz., Canadian dollar, German mark, Japanese yen, Pound sterling and Swiss franc for the period 1977–1994. Using VAR methodology, the study concludes that there is a substantial evidence of reversal effects from trading volume and market depth and volatilities have predictive power on volume but not in the market depth. Asimakopoulos et al. (2000) investigate return spillovers across currency futures markets and detect some support for nonlinear causality, although they argue that the causality disappears when the series are controlled for common ARCH effects. Chan and Lien (2006) examine the impact of the introduction of options on the underlying asset's price formation by taking the futures and spot prices of Deutsche mark, British pound, Swiss franc, Japanese yen and Canadian dollar for the period 1982–1988. The study also examines the impact before and after the introduction of option in currency markets. Using the measure of linear dependence, the study concludes that there is significant and instantaneous feedback between futures and spot markets post introduction of options. Regarding volatility spillovers, in recent work, Nikkinen et al. (2006) analyze the linkages between the markets using implied volatilities from currency option prices, focusing on European currencies, and detect significant influence from the euro to the pound and Swiss franc. Inagaki (2007) examines volatility spillover between the euro and the British pound and show unidirectional causality from the euro to the pound. Elyasiani et al. (2007) examine the information transmission and spillover in currency markets using generalized variance decomposition analysis for the period 1985–2005. Considering the case of the British pound, Deutsche mark, Swiss franc and Japanese yen, the study supports the hypothesis of interdependency against the segregation model with a greater degree of shock spillover varying across countries. They further report that internal forces are more dominant for British pound and Japanese yen, whereas Deutsche mark and Swiss franc are vulnerable to external shocks. Kitamura (2010) examines the intra-day interdependence and volatility spillover among the euro, the pound and the Swiss franc markets for the period 2008–2009. Using varying-correlation (VC) model of multivariate generalized autoregressive conditional heteroskedasticity (MV-GARCH), the study concludes that return volatility in the euro spills over to the pound and Swiss franc. Bubak et al. (2011) in their study find out the volatility transmission in emerging European markets by taking the intra-day data of Central European currencies and EUR/USD foreign exchange. Their study uses the spillover index method developed by Diebold and Yilmaz (2009, 2012). Based on the empirical results, the study concludes that there is intra-regional volatility spillover among emerging foreign exchange rates. Finally, the study reports that volatility spillovers tend to increase in periods characterized by market uncertainty. Antonakakis (2012) investigates the exchange rate co-movements and volatility spillovers by taking the case of before and after the introduction of the euro. The study uses four major internationally traded currencies, namely the euro, the British pound, the Japanese yen and the Swiss franc against the US dollar. Using directional spillover measure suggested by Diebold and Yilmaz (2012) and Dynamic Conditional Correlation (Engle 2002; hencforth DCC), the study finds high bi-directional spillover rather than unidirectional spillover. Tamakoshi and Hamori (2014) study the cross-currency transmissions between the US dollar and euro LIBOR-OIS spreads by using the causality-in-variance and causality-in-mean tests of Hong (2001) for the period 2005–2011. Considering the case during the global financial crisis period, the study finds a bi-directional causal relationship between the two spreads. Particularly during Eurozone crisis (2009), the study finds no significant causality-in-mean and causality-in-variance between the spreads. Ciner (2011) examines the information transmission across futures markets by taking the case of euro, yen, British pound and Swiss franc currency futures markets for the period 1999–2009. Based on the empirical findings, the study reports significant international informational linkages.

As far as the examination of volatility spillovers in foreign exchange market is concerned, the published evidence on Indian economy is very scarce. Some relevant studies in this strand are Behera (2011), Kumar (2011, 2014), Sharma (2011), Patnaik (2013), and Sehgal et al. (2015). Behera (2011) examined the onshore and offshore markets of Indian rupee for volatility and shock spillover. The study found the evidence of mean spillover impact of onshore spot on non-deliverable forward (NDF), but the inverse was not true. Sharma (2011) examined the relationship between currency futures and exchange rate volatility in India. Using Granger causality, the study exhibited bilateral causality between the volatility in the spot exchange rate and trading activity in the currency futures market. It may be noted that though these two studies have strong policy implications for the Indian currency market, the objectives of these studies were different from the present work as this study not only provides the evidence of price discovery and volatility spillovers in spot and futures markets, but also examines the cross market informational linkages with the use of recent data. Sharma (2011) examines the return and volatility spillover among US dollar, euro and British pound using Diebold and Yilmaz (2009). The study finds that there is a significant contemporaneous relationship among the three exchange rate returns and volatility spillover indices. The empirical results of spillover suggest that the euro exchange rate contributes to pound rates, in terms of both return and volatility spillovers. US dollar exchange rates are largely unaffected by innovations in other exchange rates. Patnaik (2013) applies dynamic conditional correlation on spot series of four exchange rates. The study reports high volatility in individual spot series, while cross-volatility spillovers are very limited. In line with the previous study, Kumar (2014) applies the multivariate GARCH model on the nominal exchange rate of four currency pairs. The study finds substantial inter-currency volatility spillover between currency pairs and reports high volatility during the financial crisis period. Sehgal et al. (2015) investigate the price discovery and volatility spillover in India's foreign exchange market by examining the futures and spot prices of four currencies viz.

USD/INR, EUR/INR, GBP/INR and JPY/INR for the period 2010–2012. Using a different set of methodology, including the Diebold and Yilmaz (2009, 2012) spillover index measure, the study suggests that the volatility spillovers are stronger from futures to spot in the short run while the inverse is the case in the long run. Based on the empirical results, the study suggests that in India's foreign exchange market, it is the futures price that assimilates new market information more quickly in its price than spot, while, the inverse is found in the long run.

It is apparent from the preceding studies that there are not many studies that have examined the spillover in an emerging market setting. In case of India, this is the first study that examines the currency market spillover by considering four important traded currencies on NSE and MCX-SX platforms. Unlike the study of Kumar (2011, 2014) and Sehgal et al. (2015), the present study attempts to examine not only return and volatility spillover between futures and spot market of currencies, but also attempts to confirm whether the spillover is inter-currency or intra-currency only. The study of Sehgal et al. (2015) is closest to our study. Further, the study updates the literature by covering recent data that captures the important phases of recent and persistent depreciations of Indian currency.

The present study is organized as follows. In Sect. 15.3, we elaborate the methodology of directional spillover and dynamic conditional correlation. Section 15.4 explains the data and formula of calculating range based volatility. Section 15.5 discusses empirical results, followed by Sect. 15.6, which deals with conclusion and policy implications of this study.

15.3 Methodology

15.3.1 Directional Spillover and Spillover Index

In this section, we discuss the directional spillover measure proposed by Diebold and Yilmaz (2009, 2012) in brief. The study models currency market return and volatility as N market vector autoregression (VAR). According to Diebold and Yilmaz (2012, also as DY) a spillover index is calculated using forecast error variance decomposition under VARframework. The forecast error variance decomposition shows the portion of the variance to variable i that is the result of innovations (shocks) to variable j represented as a percentage. We apply generalized VAR framework of Koop et al. (1996) and Pesaran and Shin (1998) to compute the variance decompositions, which is insensitive to the order of variables. It further helps in calculating the net spillover between variables. The model is specified as follows: Let volatility of futures and spot series of sample currencies is modeled as a vector autoregressive process. A VAR (p) model of N variables (in generalized form) can be written as

$$x_t = \sum_{t=1}^{n} \psi_i x_{t-i} + \varepsilon_t \tag{15.1}$$

where ε error vector which is i.i.d and Σ is the variance-covariance matrix. The moving average representation of VAR (p) model can be written as $x_t = \sum_{t=1}^{\infty} A_i \varepsilon_{t-i}$, where the $N \times N$ coefficient matrices observe the recursion $A_i = \psi_1 A_{i-1} + \psi_2 A_{i-2} + \ldots\ldots\ldots\ldots + \psi_p A_{i-p}$ with A_0 an $N \times N$ matrix and $A_i = 0$ for $i < 0$. The variance decompositions further allow the fraction of the H-step-ahead residual variance in forecasting y_i to shocks to x_j, $\forall j \neq i$, for each i to be measured. Under Koop et al. (1996) and Pesaran and Shin (1998) frameworks, the formula to calculate the H-step-ahead generalized forecast error decompositions is given by

$$\theta_{ij}(H) = \frac{\sigma_{ii}{}^{-1} \sum_{h=0}^{H-1} \left(\mathrm{e}_i' h_h \sum e_j\right)^2}{\sum_{h=0}^{H-1} \left(\mathrm{e}_i' h_h \sum e_j\right)} \tag{15.2}$$

Where σ_{ii} is the i element on the principle diagonal of Σ. Since each row of $\theta_{ij}(H)$ does not sum to one, therefore, we normalize each element of the matrix by the summing the row as $\widetilde{\theta}_{ij}(H) = \frac{\theta_{ij}(H)}{\sum_{j=1}^{N} \left(\theta_{ij}(H)\right)}$ so that decomposition including shocks in each market sums to 1, i.e., $\sum_{j=1}^{N} \left(\theta_{ij}(H)\right) = 1$ and total decomposition over all markets sums to N i.e., $\sum_{j=1}^{N} \left(\theta_{ij}(H)\right) = N$ Following Diebold and Yilmaz (2012), the total spillover index is calculated as

$$S(H) = \frac{\sum_{\substack{j=1 \\ i \neq j}}^{N} \widetilde{\theta}_{ij}(H)}{N} \times 100 \tag{15.3}$$

In this study, we measure the directional spillover between futures and spot of sample currencies. It is the sum of the proportions of the forecast error variance of i series due to shocks to $j \forall\, i \neq j$. The directional spillover from futures to spot is calculated as

$$S_{i^o}(H) = \frac{\sum_{\substack{j=1 \\ i \neq j}}^{N} \widetilde{\theta}_{ij}(H)}{\sum_{j=1}^{N} \widetilde{\theta}_{ij}(H)} \times 100 \tag{15.4}$$

It is noteworthy that directional spillover measures are not ordering sensitive. In similar vein, directional spillover received from spot to futures is obtained as

$$S_{{}^o i}(H) = \frac{\sum_{\substack{j=1 \\ i \neq j}}^{N} \widetilde{\theta}_{ij}(H)}{\sum_{j=1}^{N} \widetilde{\theta}_{ij}(H)} \times 100 \tag{15.5}$$

Lastly, we calculate the net spillovers from futures to spot in the cases of all sample currencies by offsetting the (15.4) and (15.5) as

$$S_i(H) = S_{i^o}(H) - S_{{}^o i}(H) \tag{15.6}$$

The net spillover shows whether the futures market is a net transmitter or net receiver in a system of volatility spillovers (see Awartani and Maghyereh 2013).

15.3.2 Dynamic Conditional Correlation Analysis

To further distill the directional spillover analysis, this study moves a step ahead to estimate the dynamic conditional correlation model of multivariate generalized autoregressive conditional heteroskedasticity (henceforth, DCC). The Engle (2002) dynamic conditional correlation (DCC) model is estimated in two steps. In the first step, GARCH parameters are estimated followed by correlations in the second step

$$H_t = D_t R_t D_t \tag{15.7}$$

In Eq. (15.7), H_t is the $n \times n$ conditional covariance matrix, R_t is the conditional correlation matrix and D_t is a diagonal matrix with time-varying standard deviations on the diagonal.

$$D_t = \text{diag}\left(h_{11_t}{}^{1/2} \ldots h_{33_t}{}^{1/2}\right)$$

$$R_t = \text{diag}\left(q_{11_t}{}^{-1/2} \ldots\ldots q_{33_t}{}^{-1/2}\right) Q_t \text{diag}\left(q_{11_t}{}^{-1/2} \ldots\ldots q_{33_t}{}^{-1/2}\right)$$

Where Q_t is a symmetric positive definite matrix:

$$Q_t = (1 - \theta_1 - \theta_2)\bar{Q} + \theta_1 \varepsilon_{t-1} \varepsilon'_{t-1} + \theta_2 Q_{t-1} \tag{15.8}$$

$\bar{Q}$ is the $n \times n$ unconditional correlation matrix of the standardized residuals ε_{it}. The parameters θ_1 and θ_2 are non-negative with a sum of less than unity. Under the DCC specification, the time-varying correlations are defined as:

$$\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t} q_{jj,t}}} \tag{15.9}$$

The MGARCH models estimated by Quasi-Maximum Likelihood Estimation (QMLE) using the Broyden-Fletcher-Goldfarb-Shanno (BFGS) algorithm. T-statistics are calculated using a robust estimate of the covariance matrix.

15.4 Data

The sample data of the daily futures prices of four currencies viz., USD/INR (US Dollar/INR), EURO/INR (Euro/INR), GBP/INR (British Pound/INR) and JPY/INR (Japanese Yen/INR) are retrieved from the two Indian stock exchanges, MCX-SX and NSE (www.mcx-sxindia.com, www.nseindia.com). The spot prices are collected from Reserve Bank of India (RBI). All closing prices of futures series from both platforms are taken to the nearest contract to maturity. The sample period of the study is from 1 February 2010 to 25 November 2014 (894 observations). While estimating the model, we have converted the sample series in logarithmic returns. To calculate the volatility, we have calculated the range-based volatility by using the following formula suggested by Garman and Klass (1980).

$$\sigma_{it}^2 = 0.511(H_{it} - L_t)^2 \\ - 0.019[(C_{it} - O_{it})(H_{it} + L_{it} - 2O_{it}) - 2(H_{it} - O_{it})(L_{it} - O_{it})] \\ - 0.383(C_{it} - O_{it})^2$$

where *H*, *L*, *O* and *C* are the open, high, low and close, respectively. Since, there is no high, open and low in case of spot prices, we have calculated 20 days moving variance from return series for estimation purpose.

15.5 Empirical Results

The study provides time-series plots of spot prices of sample currencies (see Fig. 15.1), also a variety of summary statistics in Table 15.1. The plots shown in Fig. 15.1 show the depreciating trend of Indian currency post-2012 and continuing till 2014. The biggest jump seems to be during 2012 and towards middle and end of 2013, indicating that during these periods foreign exchange market has passed through high phases of volatility. Seeing the Table 15.1 (panel A) of summary statistics, it appears that the daily mean returns of all the sample currencies are positive with the highest return found in case of GBPMCX (0.028%) followed by USDNSE (0.024%), SUSD (0.024%), GBPNSE (0.023%) and SGBP (0.022%). The lowest daily mean return is observed in case of SJPY (0.0004%). The standard deviation as a measure of volatility is highest for SJPY and JPYMCX (0.008) and lowest in cases of USDMCX and USDNSE (0.005). Analyzing range-based volatility (see Table 15.1, panel B), it appears that all the sample currencies exhibit negative average daily return volatility. The maximum return volatility is observed in spot market of all four currencies ranging between 0.008% (SJPY) to 0.003% (SUSD). However, it is noteworthy that the least volatile futures currency market are JPY and most volatility futures contracts are EURO, GBP and USD. The calculated statistics of skewness and kurtosis along with Jarque–Bera statistics support the non-normality characteristics of sample currencies. All returns and volatility series of sample currencies exhibit volatility clustering and persistence as reported by the significant values of Ljung-Box (Q) and ARCH statistics. Hence, an application of volatility based empirical models appears to be the appropriate case.

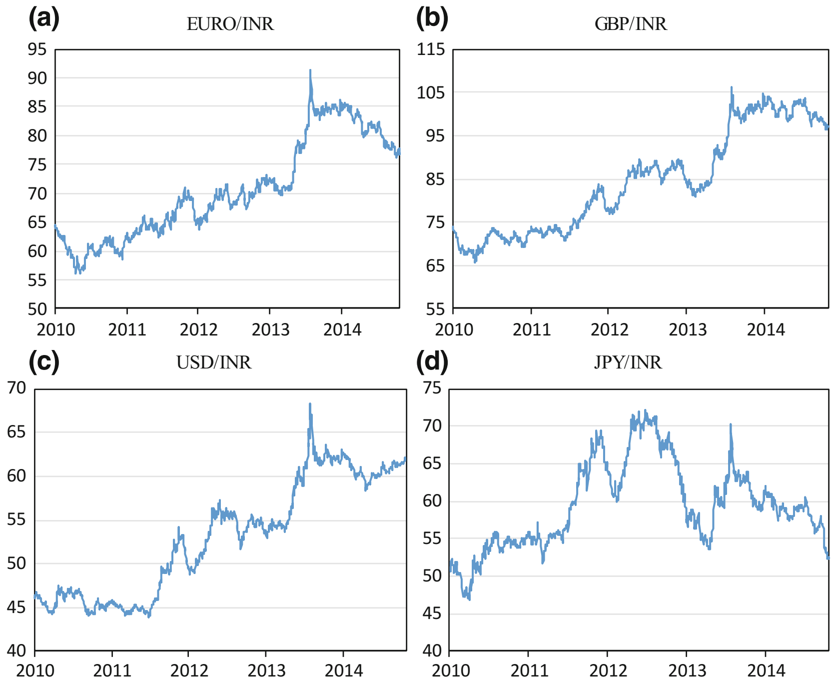

Fig. 15.1 Time-series plots of spot prices of sample currencies

15.5.1 Return Spillovers

The spillover index matrix of return and volatilities of sample currencies are depicted in Table 15.2 (panels A & B). The results are estimated using VAR model of order 2 and generalized variance decompositions of 10 days ahead of forecast errors.[4] The (i, j) entry in each panel is the estimated contribution to the forecast error variance of market i coming from innovations to market j. To All indicates the directional spillovers from one market to all other sample markets. From All shows the directional spillovers from all markets to a particular market. The total spillover index as in Eq. (15.7) is reported in the lower right corner of each panel. Panel A shows the static return spillover matrix. Following results from Table 15.2 (Panel A), the total spillover index indicates average contribution (77.4%) of unexpected changes to returns in the dependent variables (futures and spot prices of four sample currencies) in the 10-steps-ahead FEVD of all variables in the

Table 15.1 Descriptive statistics

Panel A

Summary statistics of return series

	EURMCX	*EURNSE*	*GBPMCX*	*GBPNSE*	*USDMCX*	*USDNSE*	*JPYMCX*	*JPYNSE*	*SEURO*	*SGBP*	*SUSD*	*SJPY*
Mean	0.0002	0.0001	0.0003	0.0002	0.0002	0.0002	0.0000	0.0000	0.0002	0.0002	0.0002	0.0000
Mean (%)	0.0184	0.0128	0.0285	0.0238	0.0195	0.0246	0.0022	0.0019	0.0156	0.0226	0.0241	0.0004
Max	0.0256	0.0356	0.0344	0.0333	0.0342	0.0326	0.0385	0.0384	0.0415	0.0368	0.0402	0.0481
Min.	−0.0212	−0.0263	−0.0362	−0.0218	−0.0231	−0.0228	−0.0431	−0.0384	−0.0237	−0.0278	−0.0268	−0.0453
Std. Dev.	0.0058	0.0060	0.0060	0.0058	0.0056	0.0056	0.0086	0.0084	0.0065	0.0062	0.0059	0.0086
Skewness	0.2116	0.2914	0.1810	0.2239	0.3390	0.3192	0.1060	0.1333	0.3243	0.1643	0.3265	−0.0160
Kurtosis	4.5890	5.2429	6.7115	4.9572	6.4457	6.3072	6.0737	5.3434	5.4925	5.1397	6.9466	5.3014
Jarque-Bera	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**
Q(10)	[0.0000]**	[0.0002]**	[0.0020]**	[0.0006]**	[0.0079]**	[0.0032]**	[0.4511]	[0.1813]	[0.0976]	[0.0293]**	[0.0066]**	[0.3335]
$Q^2(10)$	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0170]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**
ARCH(10)	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0181]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**

Panel B

Summary statistics of volatilities

	EURMCX	*EURNSE*	*GBPMCX*	*GBPNSE*	*USDMCX*	*USDNSE*	*JPYMCX*	*JPYNSE*	*SEURO*	*SGBP*	*SUSD*	*SJPY*
Mean	−7.51E-06	−8.06E-06	−8.74E-06	−7.85E-06	−8.45E-06	−1.00E-05	−1.65E-05	−1.36E-05	4.16E-05	3.89E-05	3.45E-05	7.53E-05
Mean (%)	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.002	−0.001	0.004	0.004	0.003	0.008
Max.	0.0003	0.0003	0.0002	0.0002	0.0003	0.0001	0.0003	0.0004	0.0003	0.0002	0.0003	0.0004
Min.	−0.0006	−0.0008	−0.0009	−0.0008	−0.0011	−0.0009	−0.0012	−0.0010	0.0000	0.0000	0.0000	0.0000
Std. dev.	3.10E-05	4.45E-05	4.21E-05	3.93E-05	5.33E-05	3.69E-05	6.42E-05	6.62E-05	3.30E-05	3.00E-05	3.85E-05	5.73E-05
Skewness	−4.892	−8.653	−9.163	−7.690	−11.946	−13.619	−7.067	−4.522	4.080	3.879	3.883	2.105
Kurtosis	114.170	162.840	160.267	130.768	236.982	301.370	106.025	68.810	24.693	23.087	22.919	8.910
Jarque-Bera	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**
Q(10)	[0.0001]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**
$Q^2(10)$	[0.7379]	[0.0000]**	[0.0002]**	[0.0000]**	[0.9083]	[0.8068]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**
ARCH(10)	[0.8006]	[0.0000]**	[0.0006]**	[0.0000]**	[0.0000]**	[0.8308]	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**	[0.0000]**

Note: Values in parentheses [] are p-values. ** shows the level of significance at 5% and better. EURMCX, GBPMCX, USDMCX, JPYMCX and EURNSE, GBPNSE, USDNSE and JPYNSE represent the futures contracts of EURO/INR, GBP/INR, USD/INR and JPY/INR traded on MCX-SX and NSE, respectively. While, SEURO, SGBP, SUSD and SJPY denote the spot prices of EURO/INR, GBP/INR, USD/INR and JPY/INR retrieved from RBI website

Table 15.2 Returns and volatility spillover results

Panel A: Return spillovers

	EURMCX	*EURNSE*	*GBPMCX*	*GBPNSE*	*USDMCX*	*USDNSE*	*JPYMCX*	*JPYNSE*	*SEURO*	*SGBP*	*SUSD*	*SJPY*	*From all*	*Net spillover*
EURMCX	26.8	19.3	12	9.1	3.8	4.1	4.5	3.2	10.6	4.3	1.2	1.2	73	−2
EURNSE	16.5	23.4	7.3	11.6	5.6	5.6	2.7	4.4	13.2	5.8	2.1	1.8	77	14
GBPNSE	11.2	8.4	24.7	17.7	5.9	6.3	6.1	4.1	3.6	8.3	2.1	1.5	75	3
GBPMCX	7.1	10.6	14.8	21.5	8.2	8.4	3	5.4	4.9	10.5	3.6	2.1	79	24
USDMCX	3	5.2	5	8.4	21.3	20.8	6.2	10	1.5	3.2	11.1	4.3	79	23
USDNSE	3.1	5.1	5.2	8.5	20.6	21.1	6.3	10	1.5	3.2	11.1	4.2	79	24
JPYMCX	4.1	3.2	6.5	4	8.4	8.6	26.9	19.7	0.9	1.6	3.8	12.3	73	−6
JPYNSE	2.3	4.2	3.4	5.8	10.8	10.9	16.2	22.9	1.4	2.5	5.2	14.5	77	14
SEURO	13.3	18.3	5.6	9	5.4	5.4	2.5	4	21.5	9	3.5	2.4	79	−29
SGBP	5.8	8.6	11.1	16.7	7.2	7.2	2.4	4.4	7.8	19	6.1	3.6	81	−22
SUSD	3	4.5	4.3	7.3	16.3	16.4	4.8	7.7	2.8	6.1	19.4	7.4	81	−23
SJPY	1.8	3.4	2.6	4.9	9.3	9.2	12.5	18.2	2.2	4.6	8.9	22.6	77	−22
To all	71	91	78	103	102	103	67	91	50	59	58	55	929	
All	98	114	103	125	123	124	94	114	72	78	78	78		
	Total spillover index = 77.4%													

Panel B: Volatility spillovers

	EURMCX	*EURNSE*	*GBPMCX*	*GBPNSE*	*USDMCX*	*USDNSE*	*JPYMCX*	*JPYNSE*	*SEURO*	*SGBP*	*SUSD*	*SJPY*	*From all*	*Net spillover*
EURMCX	33.1	10.1	7.4	8.6	4.9	9.3	5.5	6.8	3.7	6.7	3.2	0.8	67	−27
EURNSE	6.7	25.6	9.3	10.7	4.8	12.1	7.2	7	4.5	7.5	3.8	0.9	74	2
GBPNSE	3.5	8	22.2	13.3	5.9	13.8	9.7	6	4.9	7.9	3.9	1	78	1
GBPMCX	4.9	8.9	11.9	26.6	5.3	13.8	7.1	6.1	4	6.7	3.7	1	73	21
USDMCX	5.1	7.2	7.3	8.7	32.7	12.9	5.6	5.8	3.6	5.7	4.4	1.1	67	−21
USDNSE	4.9	8.9	9.7	12.1	6.9	22.4	7.7	8.2	4.7	7.9	5.3	1.4	78	30
JPYMCX	2.9	7.1	11.4	9.2	4.7	12.7	25.6	11	4.1	6.5	3.5	1.4	74	−2
JPYNSE	2.9	6.9	5.1	6.1	4.1	10.3	12.3	38.9	3.2	5.3	3.2	1.7	61	8
SEURO	2.4	5	4.4	6.7	2.2	5.1	3.4	4	26.3	23.2	10.5	6.9	74	2
SGBP	2	5.4	5.2	8.7	2.9	6.9	3.9	4.3	16.6	28.1	9.6	6.5	72	36
SUSD	2.3	4.5	4.9	6	2.5	7.6	4.5	5.7	15.2	17.2	20.5	9.1	80	−19
SJPY	1.9	4.2	2.9	4	2.1	3.5	5.2	4.4	11.2	13.1	10.2	37.2	63	−31
To all	40	76	79	94	46	108	72	69	76	108	61	32	861	
All	73	102	101	121	79	130	98	108	102	136	82	69		
	Total spillover index = 71.7%													

VAR system. About currencies, it appears that the futures of USD/INR (USDNSE and USDMCX) and GBP (GBPMCX) are the largest contributors to the FEVD of the other variables in the VAR. These variables contribute to the FEVD of the other variables on average by 103% (USDNSE and GBPMCX) and 102% (USDMCX), while these futures contracts receive from other currencies by 79% (each). Hence, in net terms, USDNSE and GBPMCX contribute 24% points more to the forecasting of other variables than they receive from other sample currencies. The second largest contributor to the FEVD of all other currencies is USDMCX with a net contribution of 23%. EURNSE and JPYNSE are also net transmitters, with the contribution standing at 14%. The smallest net contributor is GBPNSE, with net contributions of 3%. Important to note that all spot series of all four currencies contribute less than they receive from all other currencies. Overall, the findings suggest that the return spillover index divides the sample currencies into two groups based on whether they are net transmitters or net receivers of spillovers. The former comprises futures contracts, while the latter comprises spot series of sample currencies. The observed pattern in return spillovers indicates evidence of strong market interdependence between prices of futures and spot series of sample currencies, wherein the futures contracts of all four currencies are identified as the net transmitters of return spillovers with a particular emphasis on USD/INR, GBP/INR, and EURO/INR. The reason could be because these three currency pairs are highly liquid and traded in the large volume on MCX-SX and NSE. Further, according to recent forex trading figures, as on April 2013, the US dollar dominated the Indian currency trading platforms with a share in total trades with 43.5% followed by euro (16.5%), Japanese yen (11.5%) and British pound (about 6%) (see BIS 2013). In the context of Indian currency derivatives markets, it is apparent that futures market has started playing an important role in not only spillover but also regarding assimilation of new information. More importantly, the nature of information transmission is not only intra-currency but also inter-currency. As can be observed in Table 15.2 (Panel A) that futures of GBP/INR (GBPMCX and GBPNSE) not only explain the FEVD of its spot (SGBP) but also the futures of EURO/INR and USD/INR. Like for example, GBPMCX describes the FEVD of EURNSE and USDMCX and USDNSE by more than 11% and 8%, respectively. The strongest inter-currency spillover is seen between USD/INR and JPY/INR followed by GBP/INR and EURO/INR. These findings are in line with Kumar (2011) and Sehgal et al. (2015) who also report the dominance of

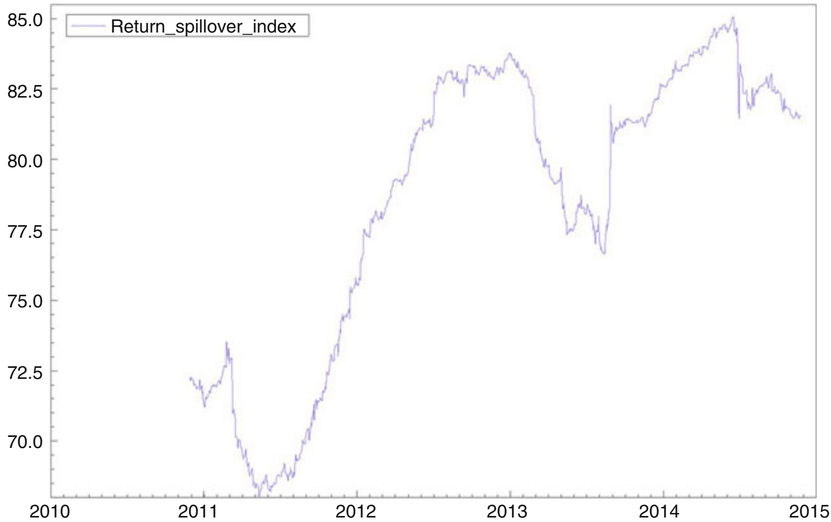

Fig. 15.2 Returns spillovers, 200-day rolling windows

USD/INR and GBP/INR concerning return spillover over other currencies traded on Indian currency derivatives trading platform.

After discussing the static return spillover index which is time-invariant and constant across time, we now examine these results under the dynamic framework. This is mainly because by adding the time-dimension in spillover analysis may help in examining the impacts of various economic and financial fluctuations that have taken place during the sample period. For example, the dynamic return spillover index exhibited Fig. 15.2 suggests that the magnitude as well as direction of return spillovers, can significantly deviate from the average total return spillover index (77.4%) reported in Table 15.2. Indeed, the time-varying return spillover index has varied from 68% in mid-2011 to 85% in mid-2014. Specifically, it has undergone periods of gradual decline (2012–2013), steep decline (mid-2011), and accelerated growth (2012). The identification of these turning points reveals to the fact that the time-varying spillover index can capture the significant events related to the weakening of Indian currency including the visible impact of the announcement of the US Federal Reserve decision to withdraw quantitative easing in May 2013 (see Economic Survey 2014–2015). Consequently, during August 2013, the spillover index graph shows a steep

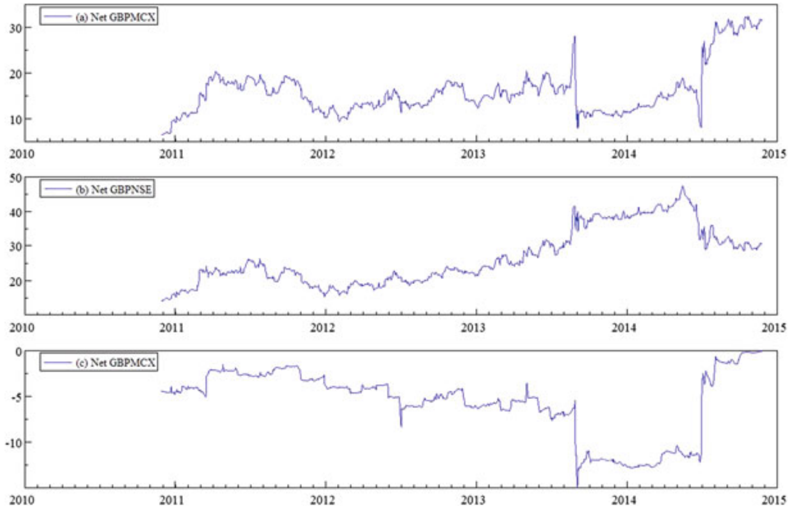

Fig. 15.3 Directional return spillovers of EURO/INR currency traded on MCX-SX and NSE. Directional net return spillovers of EURMCX SEURO and EURNSE. Net spillovers are calculated by subtracting directional 'To' spillovers from directional 'From' spillovers. Positive (negative) values (*above zero line*) indicate that variables are net transmitters (receivers) of spillovers. Net spillovers are estimated using 200-days rolling windows. (**a**) Shows the net spillover from EURMCX to SEURO. (**b**) Shows the net spillover between EURNSE and SEURO and (**c**) Exhibits net spillovers between EURMCX and EURNSE

jump in volatility. Although, Table 15.2 sufficiently sheds light on the level and direction of net volatility spillovers, there are periods in which net return spillovers are above or below average levels. Figs. 15.3, 15.4, 15.5, and 15.6 reports bar charts of dynamic net return spillovers, which also complements the static spillover results reported in Table 15.2. We estimate rolling windows and compute the time-varying net return spillovers. Focusing on net spillovers, we can infer whether one of the variables of interest is either a net transmitter or a net receiver of spillover effects. A variable is considered to be a net transmitter of spillover effects when the bar charts lie within the positive upper part of each figure. The plots of net spillovers are shown in Fig. 15.3, 15.4, 15.5, and 15.6. Though the findings summarized

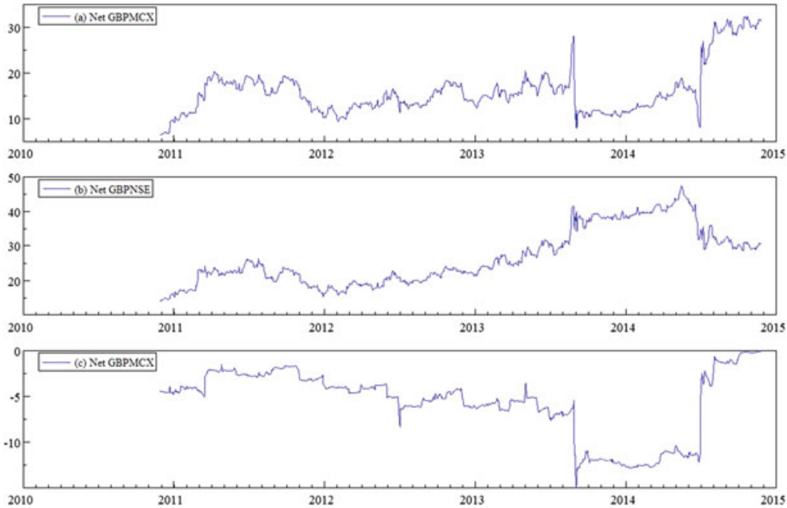

Fig. 15.4 Directional return spillovers of GBP/INR currency traded on MCX-SX and NSE. Directional net return spillovers of GBPMCX SGBP and GBPNSE. (**a**) Shows the net spillover from GBPMCX to SGBP. (**b**) Shows the net spillover between GBPNSE and SGBP and (**c**) Exhibits net spillovers between GBPMCX and GBPNSE

in Table 15.2 (panel A) are generally supported by the dynamic net return spillovers. Spot receives return spillovers from futures throughout the sample period in case of all sample currencies except JPYMCX. In case of between futures returns of MCX-SX and NSE, it is the MCX-SX that receives the return spillovers from NSE in the case of all currencies. It implies that the futures contracts of sample currencies traded on NSE assimilate new information more quickly than MCX-SX. It further means that NSE leads MCX-SX concerning return based information spillover.

15.5.2 Volatility Spillovers

In this section, we analyze the total static spillover index among sample currencies and decompose it by emitters and receivers of spillover. It also measures the extent to which variables under consideration are net volatility receivers or net transmitters. The results reported in Table 15.2 (panel B)

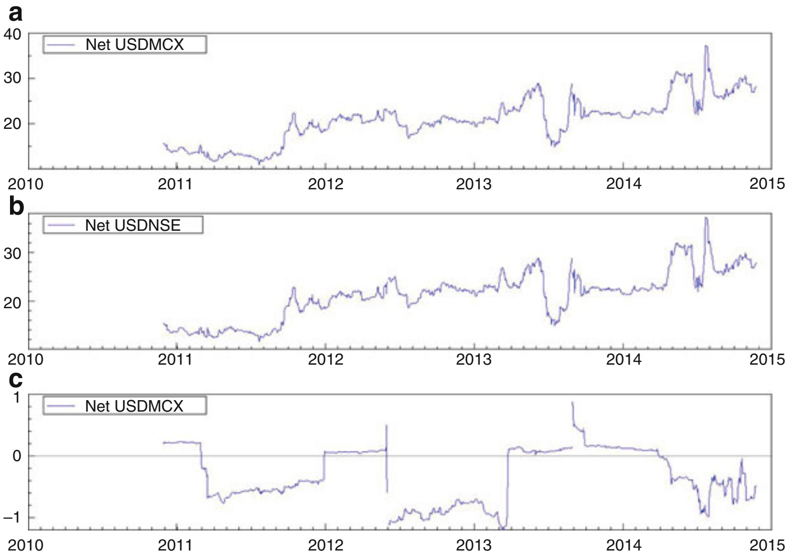

Fig. 15.5 Directional return spillovers of USD/INR currency traded on MCX-SX and NSE. Directional net return spillovers of USDMCX SUSD and USDNSE. Net spillovers are calculated by subtracting directional 'To' spillovers from directional 'From' spillovers. Positive (negative) values (*above zero line*) indicate that variables are net transmitters (receivers) of spillovers. Net spillovers are estimated using 200-days rolling windows. (**a**) Shows the net spillover from USDMCX to SUSD. (**b**) Shows the net spillover between USDNSE and SUSD and (**c**) Exhibits net spillovers between USDMCX and USDNSE

indicate that the average contribution of unexpected shocks to sample currencies in the 10-step-ahead forecast error variance decomposition is of all other variables in the VAR is 71.7%. Within sample currencies, futures of USD/INR and a spot of GBP/INR are identified as the largest average contributors of volatility spillovers to the other variables in the VAR (108%) each, followed by futures of GBP/INR, that is, GBPNSE and GBPMCX by 94% and 79%, respectively. It may be noted that the average contributions of futures contracts traded on MCX-SX are relatively lesser than the futures of NSE. This implies that NSE leads MCX-SX concerning volatility spillover. Regarding net volatility spillovers, a similar pattern as for the directional return spillovers is observed. Within futures contracts, USDNSE and GBPMCX are identified as net transmitters, while, EURMCX and

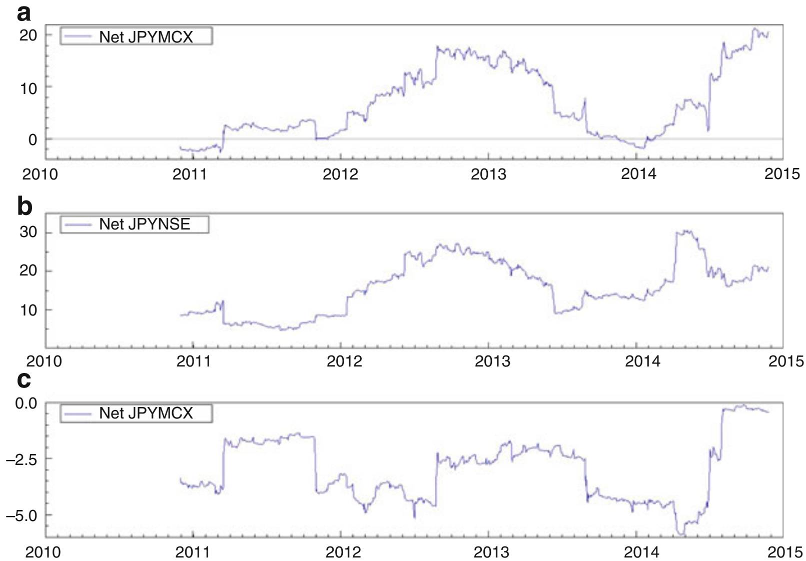

Fig. 15.6 Directional return spillovers of JPY/INR currency traded on MCX-SX and NSE. Directional net return spillovers of JPYMCX SJPY and JPYNSE. Net spillovers are calculated by subtracting directional 'To' spillovers from directional 'From' spillovers. Positive (negative) values (*above zero line*) indicate that variables are net transmitters (receivers) of spillovers. Net spillovers are estimated using 200-days rolling windows. (**a**) Shows the net spillover from JPYMCX to SJPY. (**b**) Shows the net spillover between JPYNSE and SJPY and (**c**) Exhibits net spillovers between JPYMCX and JPYNSE

USDMCX are identified as the net receivers of volatility spillovers. Within spot markets, SGBP is the largest net emitter of volatility spillover followed by SEURO, while SUSD and SJPY are net receivers of volatility spillovers. USD/INR is again the largest net transmitter of volatility spillovers with its net contribution of 30%. The possible explanation of USD/INR could be because of its largest share in total trade as mentioned earlier. The results are broadly in agreement with Kumar (2011, 2014) who also report strong information spillover from USD/INR to other currency pairs. Focusing on the direction of volatility spillovers, it appears that the direction of volatility spillover is not only intra-currency but also inter-currency. Like for example, futures contracts of USD/INR traded on NSE (USDNSE) explains the

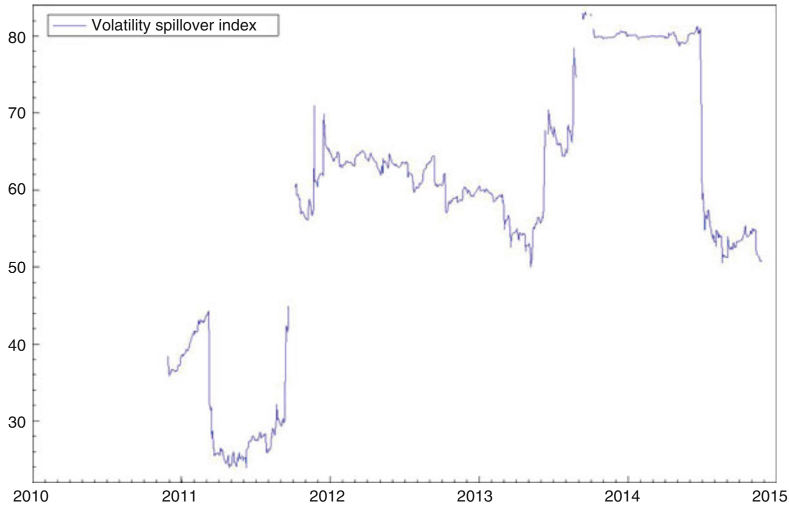

Fig. 15.7 Volatility spillovers, range based estimator (200 days rolling windows)

FEVD of not only its own spot market volatility but also the volatility of other currencies such as EURO/INR and GBP/INR. Seemingly is the case of GBPNSE. These findings receive support from return spillover results as USD/INR and GBP/INR appear to be stronger currencies with respect to intra-currency spillover compared to other currency pairs. The findings are also in agreement with Kumar (2011, 2014) and Sehgal et al. (2015) in case of India's foreign exchange market.

As mentioned, one key drawback of static volatility spillover matrix is that the intensity of interdependence among sample variables are constant over time. Therefore, we now analyze the time-varying total spillover index presented in Fig. 15.7. The salient features of the total volatility spillover are in order. First, the spillover index varies between 25% and 85% and it remained stable during 2011. Second, the spillover index remained stable during 2012 and started to increase during mid-2013, and it experienced as the notable jump from mid-2013 to the beginning of 2014. Hence, dynamic spillover resonates well with the time-varying return spillover. Indeed, the time-variation in the total volatility spillover has endured four phases, (i) steep jump (mid-2011), (ii) relative stability (2012), (iii) accelerated growth (2013–2014) and (iv) steep decline (2014). Although, Table 15.2 (panel B) sheds light on the level and direction of net volatility

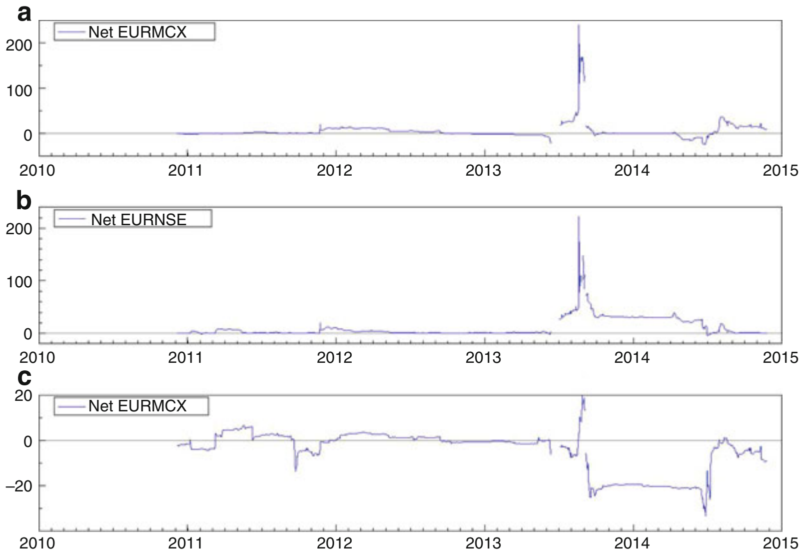

Fig. 15.8 Directional volatility spillovers of EURO/INR currency traded on MCX-SX and NSE. See notes of Fig. 15.3 for details about pair-wise net directional spillovers

spillover, there are periods in which actual dynamic volatility spillovers are above or below the average level. Fig. 15.8, 15.9, 15.10, and 15.11 reports time-varying net volatility spillovers which also extend and complement spillover matrix reported in Table 15.2 (panel B). Although, futures contracts of all sample currencies are net transmitters to their respective spot markets except the case of GBPNSE which appears as the net recipient of net volatility spillovers from the spot market, in certain periods futures contracts also act as the net recipient. Like for example, in case of EURO/INR, EURMCX becomes a net recipient of volatility spillover for some periods in 2014. GBPMCX receives volatility spillovers in mid-2013 and beginning of 2014. It is important to note that almost all the net spillover plots exhibit steep jump in volatility spillover during mid-2013. Like for example, in case of EURO/INR, USD/INR and JPY/INR, net spillover plots show a sudden jump in mid-2013 and afterward. Analyzing the actual exchange rates figures shown in Fig. 15.1, it can be found that during mid-2013, the rupee depreciated sharply in May–August 2013. The possible explanation could be because of the rise in uncertainty due to the

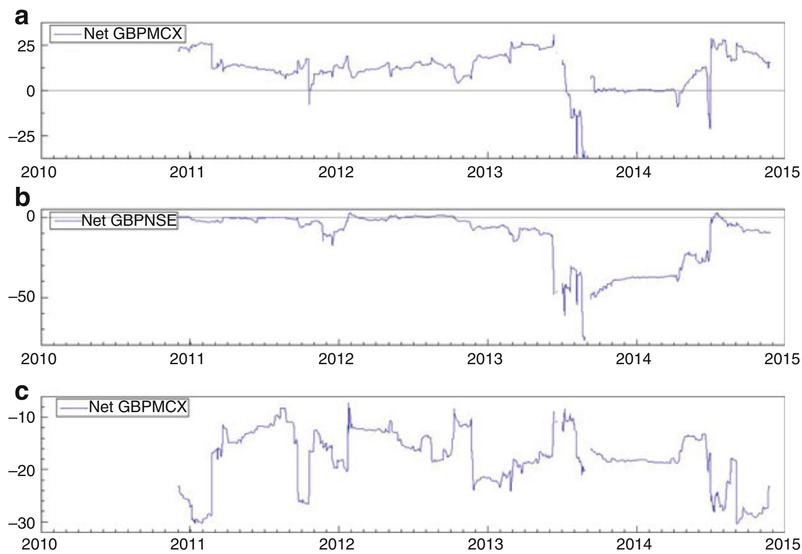

Fig. 15.9 Directional volatility spillovers of GBP/INR currency traded on MCX-SX and NSE. See notes of Fig. 15.4 for details about pair-wise net directional spillovers

US Federal Reserve's decision to withdraw quantitative easing in May 2013 (see World Bank 2013). As reported by Ray (2014), during June 2013 and August 2013, the rupee depreciated against US dollar by 16%. Considering the case of between futures contracts traded on both platforms, it appears that NSE is net transmitter of volatility spillovers to MCX-SX. This further complements the findings of net return spillover. Therefore, it can be concluded that NSE is a dominant trading platform compared to MCX-SX with respect to return and volatility spillovers. This particular finding is in agreement with Sehgal et al. (2015) who also arrive at the same conclusion. There is a surprising result that needs attention that in case of return spillover, the forecast error variance of futures explains the forecast error variance of spot, but in case of volatility spillover it is quite opposite. Like, for example, for volatility spillover, the FEVD of spot explain insufficient amount of the forecast error variance of futures. It suggests that for the futures market, the market makers are not bothered about the impact of new information in spot market. Rather, they are more interested in evaluating the cross-currency spillover. Further, spot market seems to be

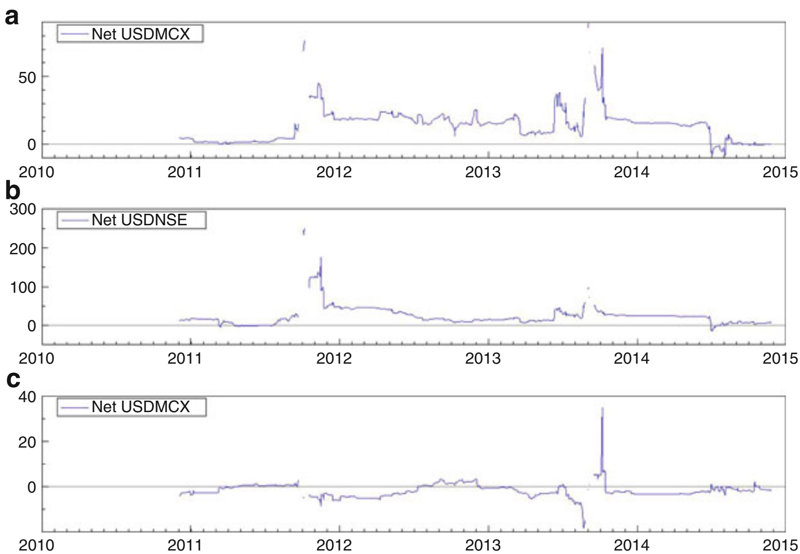

Fig. 15.10 Directional volatility spillovers of USD/INR currency traded on MCX-SX and NSE. See notes of Fig. 14.5 for details about pair-wise net directional spillovers

an independent market as shocks emanating from futures market spot do not appear to impact market volatility. In this regard, Najand et al. (1992) provide two explanations: first, this often happens when a lot of currency traders specialize in one market only. Second, this could be due to lack of sufficient information and expertise, especially traders (exporters and importers), who do not able to assimilate new information in their investment strategy. This appears to be highly appropriate in case of India.

15.5.3 Robustness Checks

In order to check the robustness of DY methodology, we undertake various robustness checks. First, we try to find it out whether the use of alternative H-step-ahead FEVDs and alternative rolling windows affects the estimated results of directional return and volatility spillovers. Specifically, we allow the forecast horizon H to range from 5 to 20 days, while holding constant the rolling windows of 200 days. The results remain qualitatively similar.

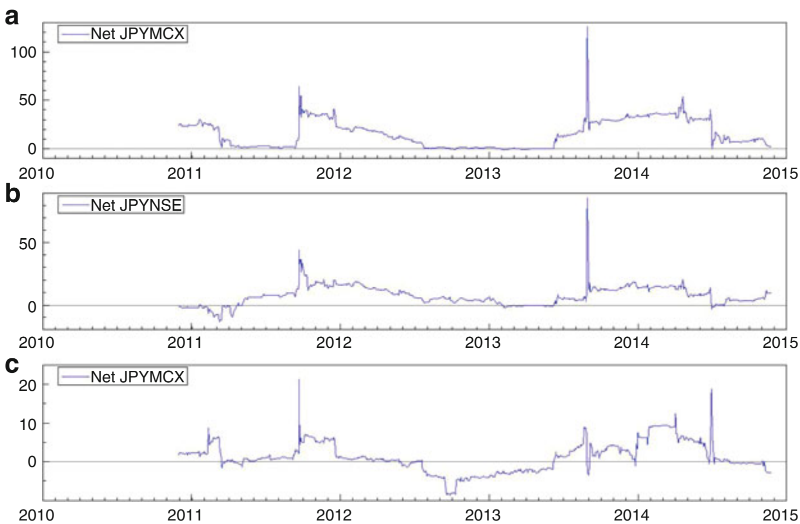

Fig. 15.11 Directional volatility spillovers of JPY/INR currency traded on MCX-SX and NSE. See notes of Fig. 15.6 for details about pair-wise net directional spillovers

Second, we choose alternative rolling windows from 100, 200 and 300 days, while holding the forecast period as 10 days. The reported results in this study obtained based on the rolling window of 200 days are again validated. Lastly, we apply the spillover approach of Diebold and Yilmaz (2009), which is based on the Cholesky decomposition and in which FEVDs are highly sensitive to the ordering of variables in the VAR. In particular, we analyze 200 random permutations (different variables orderings in the VAR) and calculate the corresponding spillover indices for each order.[5] The minimum and maximum values that the return and volatility spillovers receive based on Cholesky factorization are in agreement with those of our main results reported previously.

15.5.4 Dynamic Conditional Correlation Analysis

To re-confirm the directional spillover results, the study employs the dynamic conditional correlation popularly known as the DCC-GARCH model. Table 15.3 (panel A) shows the first step procedure of simple GARCH estimation. The results indicate that all the variance coefficients are significant. The results of the second step shown in panel B indicate that the estimated coefficients θ_1 and $\theta_2$for examined currencies are positive and sum to less than one, implying that dynamic conditional correlations of all currencies are mean reverting for sample currencies. Fig. 15.12 shows the plotted results of dynamic conditional correlations results between futures and spot of sample currencies. It can be found that the magnitude of the correlation is quite high and it is ranging between 0.60 and 0.80, implying that the magnitude of information transmission is in line with the estimated directional spillover results. Fig. 15.12 exhibits the dynamic conditional correlation between futures returns of MCX-SX and NSE. The plots exhibited in (a to d) clearly suggests that conditional correlations between futures are quite high (more than 0.90) can capture the ups and downs caused by external shocks such as Eurozone turmoil and its aftermath. Further, the dynamic conditional correlation clearly captures the recent upheavals in currency markets with regards to fear of outflow of capital owing to the apprehension of the Federal Reserve increasing the interest rate. The magnitude of conditional correlation appears to be very high and USD, in particular, shows strongest co-movement between MCX-SX and NSE than any other currency.

15.6 Conclusion and Discussion

In this chapter, we examine the return and volatility spillovers in India's currency derivatives markets. More precisely, based on daily data of futures and spot series of four exchange rates (EUR/INR, GBP/INR, USD/INR and JPY/INR) over the period from February 2010 to November 2014, we report the following empirical regularities. First, the analysis of static spillover effects in the sample exchange rates shows that USD/INR and GBP/INR are net transmitters of return and volatility spillovers during the sample period. Whereas EURO/INR and JPY/INR are net receivers. These results suggest that the information contents of USD/INR and GBP/INR can help improve forecast accuracy of returns and volatility on EURO/INR and JPY/INR return and volatilities. Second, USD/INR is the largest gross exchange rate transmitter of return and volatility spillovers to the remaining exchange rates in our study. Third, pairwise exchange rates

Table 15.3 DCC estimation results

	EUROMCX	EURONSE	GBPMCX	GBPNSE	USDMCX	USDNSE	JPYMCX	JPYNSE	SEURO	SGBP	SUSD	SJPY
Panel A: First-step, univariate GARCH estimation results												
1. Return equations												
Constant (μ)	1.6E-04	8.9E-05	2.0E-04	1.8E-04	1.7E-05	8.1E-05	−1.4E-04	−1.2E-04	8.7E-05	1.7E-04	5.0E-05	−2.0E-04
2. Volatility equations												
Constant	3.500	3.221*	2.355	1.509*	0.620*	0.560	4.840*	4.554*	3.970	1.747*	0.973*	2.530
α	0.057**	0.066**	0.051**	0.060**	0.084**	0.080**	0.074**	0.080**	0.094**	0.063**	0.137**	0.099**
β	0.839**	0.841**	0.878**	0.893**	0.897**	0.903**	0.859**	0.854**	0.810**	0.890**	0.836**	0.869**
Panel B: Second-step, correlation equation results												
θ_1			0.0273									
			[0.000]**									
θ_2			0.9457									
			[0.000]**									
Log Likelihood			60471.44									
Q(10)	17.727	12.601	19.961	22.767	27.781	32.085	26.248	16.011	14.924	16.632	23.586	26.749
	[0.191]	[0.280]	[0.089]	[0.071]*	[0.065]*	[0.042]**	[0.157]	[0.200]	[0.220]	[0.190]	[0.351]	[0.160]
Q2(10)	21.010	18.532	7.029	9.615	8.183	5.873	27.579	26.888	6.476	11.466	16.664	3.110
	[0.080]	[0.056]*	[0.564]	[0.474]	[0.640]	[0.825]	[0.060]	[0.082]	[0.773]	[0.322]	[0.082]*	[0.978]

Note: Q (10) and Q^2 (10) are the Ljung-Box statistics for serial correlation. The values in parentheses are p-values. ** and * indicate the level of significance at 1% and better, 5% and above, respectively

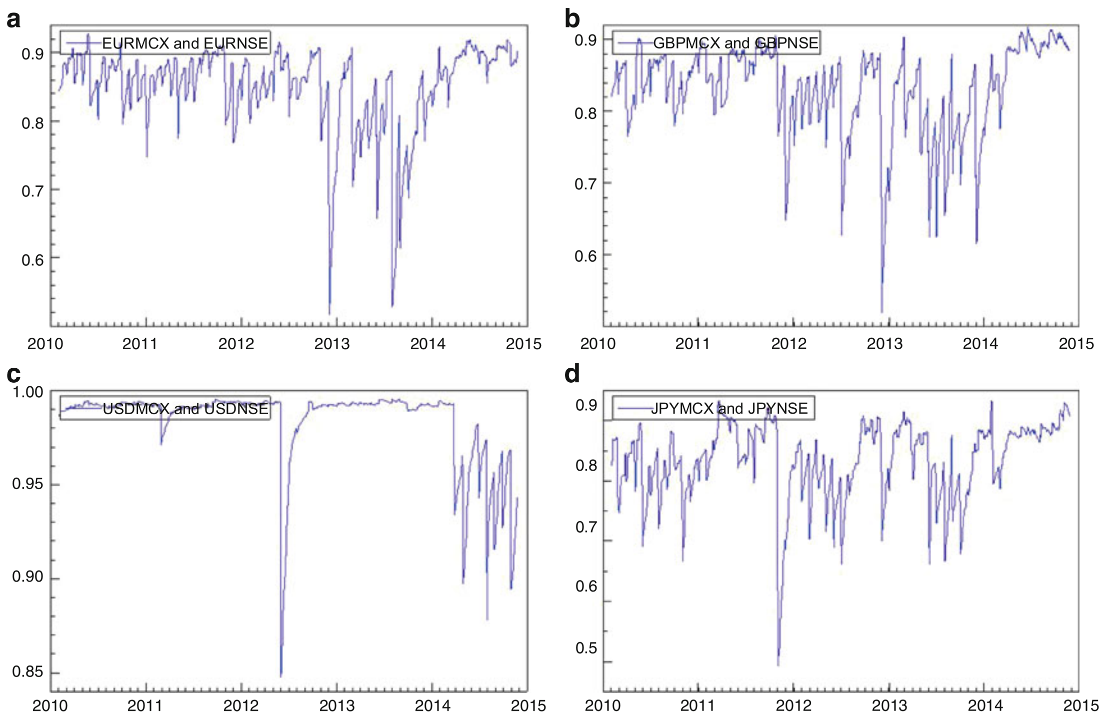

Fig. 15.12 Dynamic conditional correlation results between futures and spot of sample currencies

return and volatility spillovers reveal relatively stronger bilateral interdependencies between futures and spot and between futures contracts of sample currencies. Fourth, the analysis of time-varying spillovers shows time- and event-specific patterns. For example, for USD/INR, EURO/INR and JPY/INR return and volatilities, the transmission process intensified in the period marked by the fear of tapering of the stimulus package by Federal Reserve, the USA in May 2013 and ensuing worldwide economic slowdown. Fifth, the directions of return and volatility spillovers are not only intra-currency but also inter-currency in nature. For instance, EURO/INR and GBP/INR exhibit a high level of directional interdependence. Same is the case between USD/INR and JPY/INR. These findings substantiate some of the previous findings on the spillover analysis of Indian currency markets. Sehgal et al. (2015) also reports similar findings. Based on the spillover matrix, it appears that USD/INR, and GBP/INR are dominant currencies concerning return and volatility spillover. Within exchange rates, USD/INR appears as the largest transmitter of volatility spillover followed by GBP/INR and EURO/INR. These results are similar to the studies of Kumar (2011, 2014), who also report that there are significant volatility spillovers between USD/INR, GBP/INR and EURO/INR. Kumar (2011) also reports USD/INR as dominant currency. Sixth, in case of volatility spillovers, the role of spot market seems to be very limited, as spillovers are largely confined to inter-spot markets. Seventh, analyzing both trading platforms, NSE appears to be dominant trading platform and MCX-SX as a satellite. Eighth, the magnitude of directional spillover is quite high in both return (77%) and volatility (72%), implying that the market is quite efficient than the commodity derivatives market as reported by Sehgal et al. (2014). Ninth, the findings of Diebold and Yilmaz (2012) spillover measures are further substantiated by the results of DCC-GARCH model given by Engle (2002). Last, the results of DY-model are robust to several modelling specifications.

The findings of this study suggest that while the static spillover analysis clearly categorizes the sample exchange rates into net transmitters and net receivers, the dynamic spillover analysis shows periods wherein the roles of emitters and recipients of return and volatility spillovers can be interrupted or even reversed. Thus, even if some commonalities appear in each identified category of exchange rates, such commonalities are event specific and time dependent. These results are in agreement with Antonakakis and Kizys (2015) who also report similar empirical evidence in case of commodity and currency markets. These results are of substantial significance as they can be used to formulate the trading strategies and can also help investors to undertake superior investment decisions. Further, based on findings of this study it can be said that the introduction of futures contracts has yielded the India's foreign exchange market as it has started playing an important role in informational spillover. There is need to focus more on enhancing the knowledge base of not only traders but also small and large investors who can not only understand the dynamics of informational spillover but also benefit it by applying in their hedging strategies. However, future research may take up this issue as an academic exercise. Further studies in this direction may consider inter-currency spillover by using intra-day data across several markets to examine the phenomenon of 'meteor shower' or 'heat wave'.

Notes

1. The figures are converted in terms of dollars by taking the exchange rate of USD as on 28 February 2014.
2. The percentage is calculated by authors of the SEBI Handbook of Statistics by compiling the trading data of MCX-SX, NSE and USE.
3. Considering the standard average exchange rate mark of ₹ 48/USD, the rupee has depreciated by about 30% as on 28 February 2014.
4. VAR order is selected based on the Schwartz Bayesian criterion (SBC).
5. Figures are available with the authors upon request.

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