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Working Paper

How to intervene in foreign exchange market without buying/selling dollars?

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Abstract

The Emerging Market Economies are vulnerable to adverse external shocks. Such shocks cause excessive volatility in foreign exchange markets. Faced with high volatility, the central banks in EMEs often end up, in futility, depleting their foreign exchange reserves by selling dollars to restore stability. Few central banks use currency-options based intervention to contain volatility and anchor market expectations. In the Indian context, this paper demonstrates that such options-based intervention policies can be considered to contain excessive volatility and anchoring market expectations. Using the risk-neutral densities extracted from currency options data, it is demonstrated that certain options-trading strategy can be effective in stabilizing markets. Therefore, options-based intervention may be a viable policy alternative, which is more cost-effective than the conventional spot-market intervention.

Keyword: Fx interventions; risk-neutral density; currency options

Introduction

On May 22, 2013, the US Fed contemplated 'whether a recalibration of the pace of (its) asset purchases is warranted' (*sic*). The markets apprehended a probable exit from quantitative easing in the US and its consequences. The US dollar-Indian Rupee (USD-INR) exchange rates were volatile in a disorderly manner. During this turbulent period, Reserve bank of India (RBI) tried to stabilize the currency market using liquidity tightening measures. As a result, money market interest rates jumped by 300 basis points. Yet, the pace of depreciation and turbulence went unabated. RBI intervened in the spot-market to tame exchange rate volatility. India drained her

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foreign exchange reserves (~ $14 billion). Still, the calm in the foreign exchange market could not be restored. The futility of conventional policies in taming the turbulence is the prime motivation for taking up this study to find a policy-alternative.

The Scope of the Study

For policy analysis, a working definition of foreign exchange intervention is required. To be treated as *intervention* it must be sterilized, such that it intervention remains distinct from monetary policy, and must be intended for influencing either level or volatility of exchange rates (Moreno, 2005). Thus, not any operation of central bank in foreign exchange market may qualify as intervention. Such narrower definition refines the broader definition of intervention that used to accommodate any transaction by a central bank undertaken in foreign exchange market (Jurgensen, 1983). Conventionally, in the literature, this narrower definition of intervention captures high-frequency foreign exchange transactions in spot market aimed at influencing the exchange rate. A sub-class can be carved out from the narrower definition of intervention as a central bank might choose derivatives-market and not spot-market as its venue for intervention. Further, a smaller subset of intervention in derivatives-market may involve a central bank exercising its choice between exchange-traded and over-the-counter markets, or, onshore and offshore markets. This study delves into the analysis and policy implications of the narrowest class – interventions in onshore, exchange-traded, European-style currency options market which are cash-settled in domestic currency in emerging market economies in a managed-float regime. Specifically, this research analyzes the possibility of designing an intervention mechanism using exchange-traded, European-style currency options (which has fixed expiry near the end of a calendar month), on USD-INR, traded on National Stock Exchange in Mumbai (onshore) and settled in Indian rupees.

Stance of Central Banks: Before and After the 2008 Crisis

Central banks' beliefs, motives, choice of instruments, choice of markets and time-zones of transactions are some of the critical dimensions that qualify as an *intervention* (Neely, 2001). Most of such dimensions have undergone a change from before and after periods of 2008 crisis (Mohanty & Berger, 2013). In 2004 and 2013, Bank of International Settlements (BIS) surveyed central banks' intents and opinions on their foreign exchange interventions. The 2004 survey identified three broad macroeconomic objectives behind their intervention, namely: (a) inflation control and internal balance (b) external balance and growth, (c) maintenance of financial stability and thus, prevention of disorderly markets or crises. Three specific intervention objectives found in the 2004 survey were: (a) to influence the exchange rate level (b) to dampen volatility under floating and (c) to influence the amount of foreign reserves (BIS, 2005). Consistent with the 2004 survey, the findings of the 2013 survey affirm that central banks continue to prioritize maintenance of monetary and financial stability. However, in the post-crisis period, the central banks attach greater priorities in preventing speculative attacks on currency, containing inflation risk, curbing speculative capital flows, and reducing excessive exchange rate volatility. Interventions in foreign exchange markets were carried out by some central banks, including India, when negative external shocks impact markets' expectations in a way such that currencies experience sharp depreciation far beyond their perceived fundamental values. Enhancing and augmenting foreign currency liquidity in the foreign exchange market has emerged as an important policy objective of central banks in the post-crisis period (Mohanty & Berger, 2013). The 2013 survey indicates that the preference towards

containing excessive volatility took precedence over influencing levels of exchange rate. Therefore, in the post-crisis period, policy priorities of central banks have clearly shifted towards curbing excessive exchange market speculation and anchoring markets' expectations towards restoration of financial stability.

Interventions in Developed Markets

In developed markets, central banks, in the past, had chosen to intervene in coordination with other central banks. There were two major agreements to foster coordination among central banks. The Plaza agreement in September 1985 attempted to induce cooperation targeted to depreciate US dollars. On the other hand, Louvre agreement of February 1987 tried to smoothen exchange rate volatility by way of cooperation among central banks around the world. The coordination and support mechanism was granted through two or more central banks simultaneously intervening in the same currency pair market on the same day in the same direction. Coordination mechanism can reinforce effectiveness of intervention via signaling channel by stabilizing speculation and reducing misalignment of expectations among fundamental-based traders (For Yen-US-dollar illustration, see (Stefan & Taylor, 2012). Fewer instances exist when two or more central banks intervene simultaneously on the same currency pair in opposite direction. However, central banks in developed countries do not actively intervene any longer. The reasons for non-intervention, as expressed by central banks of developed countries in the 2004 survey, were that (a) intervention does not carry any durable impact on real exchange rate (b) it affect interest rates and other policy instruments, and thus undermine monetary policy stance and that (c) private financial markets have developed capacity to hedge and absorb shocks (BIS, 2005).

Interventions in Emerging Market Economies

The central banks of emerging market economies (EMEs), however, continue to accumulate foreign exchange reserves and conduct large-scale intervention with a belief in effectiveness of intervention (Gadanecz, Mehrotra, & Mohanty, 2014). In EMEs, central banks monitor foreign exchange market activities, primarily using indicators, including, cross-border bank lending, cross-border securities purchases/sales, equity/corporate bond market, developments in the US, Europe and Japan and risk indicators in industrial countries, such as, volatility index (VIX) and sovereign spreads. The timing of intervention is based on observed developments in foreign exchange markets and reactive intervention is carried out in response to other news, such as, US Fed's intention of tapering or exit from unconventional monetary policy or quantitative easing (QE)) (Mohanty & Berger, 2013). A comparison of priorities, based on responses of 19 central banks in the 2004 and the 2013 surveys, are presented in (Mohanty & Berger, 2013). One of the prime objectives of central banks that remains unaltered over the past two decades is curbing excessive speculation in exchange market. The other policy objectives of central banks of EMEs are to maintain monetary stability, discourage sharp capital inflows or outflows, build or reduce foreign exchange reserves, smoothen the impact of commodity price fluctuations, maintain or enhance competitiveness and alleviate foreign exchange funding shortages of banks and corporations.

Composition of Reserve Assets of Central Banks

The Special Data dissemination Standard (SDDS) of International Monetary Fund (IMF, n.d.) is subscribed by 78 countries. Each subscribing national authorities disseminate standardized information on their international reserves and foreign currency liquidity using a reserves template.

The reserves template covers official reserve assets and other foreign currency assets with predetermined short-term net drains on foreign currency assets and contingent short-term net drains on foreign currency assets. Among the 78 reporting countries, 34 monetary authorities[2]hold derivatives (forwards, futures, swaps and options) as their foreign currency assets. Seven of them hold derivatives that have residual maturity greater than one year. Swaps is most popular derivatives held by 24 central banks; followed by forwards (18 out of 34) and futures (10 out of 34). Seven[3] central banks disclose their hedging instruments, which includes, in-the-money options. A small minority of central banks disclose financial derivative assets with their estimated net, marked to market valuation with specified choice of instruments, including, forwards, futures, swaps, options. According to the BIS 2013 survey, 17 of 21 central banks from EMEs preferred reactive intervention in response to market developments. On choice of instruments, the survey found, most (19 out of 21) central banks used (direct or indirect) intervention in spot markets. The next prominent choice (11 out of 21) is intervention using derivatives (futures, swaps, volatility and options). Thus, options-based intervention has possibly emerged as a more preferred choice than intervention in spot markets for central banks in EMEs in the post-crisis period.

Literature Review

Options-based Foreign Exchange Intervention

The global recovery from the 2008 crisis is still uneven. An eventual monetary tightening in advanced economies can propagate adverse shocks. To cope with the consequent turbulence, it is important to consider options-based intervention as a policy-alternative for the central banks of emerging-market economies. However, until recently, only a few[4] central banks have considered options-based intervention to mitigate the exchange rate volatility. Market expectations can be anchored by deploying market-friendly instruments, such as, currency options (Archer, 2005;Arizmendi, 2013). During the Asian financial crisis (1997-98), the Reserve Bank of Australia (RBA) purchased call options on the Australian dollar. Banco de México deployed options-based intervention strategy to accumulate foreign-exchange reserves (Breuer, 1999) which resulted in stabilizing the markets, as well. In November 1999, Banco Central de Colombia also used options-based intervention to contain volatility in currency markets (Mandeng, 2003;Uribe & Toro, 2005). Arizmendi (2013) advocated options-based intervention as a policy-alternative and showed how to integrate inflation targeting rules in currency-options pricing equations (à la Garman & Kohlhagen, 1983).

Australian Experience

Australia operates in a floating exchange rate regime. RBA allows exchange rates to move over a wide range. In extreme cases, RBA intervenes infrequently to moderate 'overshooting' relative to changes in economic and financial conditions. During Asian crisis, Australian dollar (AUD) fell by 15 percent against US dollar, calling for small and occasional support from RBA.

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[2] Albania, Armenia, Australia, Austria, Belarus, Belgium, Brazil, Canada, China, Colombia, Costa Rica, Denmark, Estonia, Finland, Hungary, Iceland, Indonesia, Japan, Kazakhstan, Latvia, Lithuania, Malta, Morocco, Netherlands, New Zealand, Norway, Portugal, Slovak Republic, Slovenia, South Africa, Spain, Sweden, Switzerland, United Kingdom.

[3] Australia, China PR, Estonia, Hungary, Norway, Sweden, Switzerland.

[4] Australia, Colombia, Mexico

Once large-scale speculative selling of AUD started in June, 1998, RBA bought $A2.6 billion in spot market. After a short-lived recovery, in August, AUD came under severe speculative selling and attending 'herd' behavior. The AUD-USD exchange rate fell by 25 per cent following Russian crisis. This time RBA instead of buying in spot market, started buying call options on AUD. That it, RBA had right to buy AUD at a predetermined prices. Even with a limited outlay, it helped RBA, in reducing the volatility. As a result, the US dollar-Australian dollar exchange rate was stabilized. The RBA later resold the options, with a profit, after the period of instability was over (Reserve Bank of Australia, 1999). The RBA reported that option-based intervention techniques increase the flexibility at a minimal risk. Besides there is no obligation to exercise the options, the effect on currency market is the same as spot-market intervention. The cost of options-based intervention carried out during August/September 1998 was $665 million, roughly 1/3rd of spot-market intervention.

Colombian Experience

The goals of Banco Central de Colombia were to contain excessive exchange rate volatility and reserve accumulation. The options-based intervention program was started in 1999 after adopting a free-float and inflation-targeting regime (Uribe & Toro, 2005). To curb excessive volatility Banco Central de Colombia resorted to writing of foreign exchange options. The rule was to exercise options when exchange rate appreciate or depreciate beyond a 20-day moving average. The volatility options with 30-days' time to expiry were issued whenever exchange rate moved more than 4 per cent of the 20-day moving average (Keefe & Rengifo, 2014). The success of volatility options were moderate (Mandeng, 2003). The issuance of put options were effective for reserve accumulation during 1999-2002 (Uribe & Toro, 2005). The call option writing program was largely successful during 2000-2005 in containing exchange rate volatility and levels (Keefe & Rengifo, 2014).

Mexican Experience

Since peso crisis in 1994, Banco de México follows a free-float. The need for building up of foreign exchange reserves received priorities in 1996. In August 1996, the Foreign Exchange Commission announced implementation of US dollar buying program by writing put options. Since 1996, Banco de México sold US dollar put options/ peso call options with a notional amount equivalent to US$300 million a month (Breuer, 1999). The writing of put options gave commercial banks to sell US dollar to Banco de México. The put options program enabled the monetary authority to increase foreign exchange reserves without interfering with free-float regime. The options-based strategy was carried out when there were ample supply of US dollar, barring when there were tighter supply, to avoid depreciating pressures. This mechanism enabled Banco de México to accumulate US$ 12.2 billion of foreign exchange reserves (Aug/1996- Jun/2001) (Sidaoui, 2005). In order to limit exchange rate volatility, the Foreign Exchange Commission authorized Banco de México to sell US$ 0.2 billion daily since February 1997. In May, 2003, Banco de México slowed down the pace of reserve accumulation. Banco de México repeated the program during Feb/2010- Oct/2011, in volatile market condition.

Monitoring and Anchoring Market Expectations

The market expectations can be extracted from order-book information of exchange-traded currency options in the form of a probability density function (pdf) (BIS,1999). These *pdf*s are an

important forward-looking indicators that measures market expectations, and therefore, useful for policy-makers.

Methodology

A Framework

We adopt the foreign currency options valuation model from (Garman & Kohlhagen, 1983). The valuation of call options is represented as:

$$\mathrm{C(S,T)} = e^{-r_F T} S\, N(x + \sigma\sqrt{\mathrm{T}}) - e^{-r_D T} K N(x)$$

$$\mathrm{P(S,T)} = e^{-r_F T} S\, N[(x + \sigma\sqrt{\mathrm{T}}) - 1] - e^{-r_D T} K[N(x) - 1]$$

Where,

$$x \equiv \frac{\ln\left(\frac{S}{K}\right) + \left\{\mathrm{r}_D - \mathrm{r}_F - \frac{\sigma^2}{2}\right\} T}{\sigma\sqrt{T}}$$

Where,

C(S,T)= price of call options
P(S,T)= price of put options
S= the spot exchange rate (domestic currency per unit of foreign currency
F= Forward exchange rate at options maturity
K= exercise (strike)price for exchange rate
T= time to maturity of options
r_D = domestic risk-free interest rate
r_F =foreign risk-free interest rate
σ = volatility of spot exchange rate
N(.)= cumulative normal distribution function

I. Among the usual partial derivatives, the *vega* is of special interest in this study. This is because, *vega* gives us responsiveness of options prices with respect to changes in volatility.

$$\frac{\partial C}{\partial \sigma} = e^{-r_D T} K n(x) > 0; \ldots \quad \ldots \quad \ldots \quad (1)$$

Where, *n(x)* is normal density function

Utilizing inverse function theorem, as *n(x)* is continuously differentiable:

$$\frac{\partial \sigma}{\partial \mathrm{C}} = \frac{1}{[e^{-r_D T} K n(x)]} > 0; \ldots \quad \ldots \quad \ldots \quad (2)$$

II. Breeden & Litzenberger (1978) originally attempted to derive a risk-neutral density from options prices. Differentiating the call option equation with respect to the exercise price K will give the discounted cumulative density function (*cdf*):

$$\frac{\partial \mathrm{C(S,T)}}{\partial \mathrm{K}} = -e^{-r_D T} \int_K^{\infty} N(x)dx \ldots \quad \ldots \quad \ldots \quad (3)$$

If differentiated twice with respect to K, it yields the discounted probability density function (*pdf*):

$$\frac{\partial^2 C(S,T)}{\partial K^2} = e^{r_D T} n(x) \ldots \quad \ldots \qquad \ldots \qquad (4)$$

Numerical Analysis

Through hedging argument, it is possible to show that the future terminal price distribution of an underlying asset is independent of preference parameters and growth rate of the underlying asset (Jondeau, Poon, & Rockinger, 2007). This is known as risk-neutral approach to option pricing. Such terminal price distribution, for the purpose of pricing options, is known as risk-neutral density. The models for extracting pdfs from options-prices are structural and non-structural. The structural approach fully describes the underlying price dynamics and volatility process. The non-structural are of three types, namely, parametric, semi-parametric and non-parametric. The parametric models utilize a direct expression for the pdf, without referring to price dynamics. The semi-parametric approach uses some approximation of true pdf. The non-parametric models do not presume an explicit specification of a pdf and let the data speak for itself.

In this study such risk-neutral densities are extracted from order-book information of exchange-traded currency options in the form of a pdf as illustrated in [Fusai Roncoroni, 2008]. The implied volatility is the essential parameter for estimating the risk-neutral density. There exist a comprehensive literature on how to extract implied volatilities (σ) and to recover risk-neutral densities. The risk-neutral densities (RND) can be a useful monitoring mechanism to assess market expectations. The policymakers can employ this as a forward-looking indicator. All four prominent methods available in the literature are used to recover the risk-neutral density from order-book information of European style exchange traded currency options data. These methods are: (a) mixture of log-normal (Bahra, 1996; Soderlind & Svensson, 1997) (b) generalized beta (Bookstaber & McDonald, 1987) (c) Edgeworth-expansion (Jarrow & Rudd, 1982; Corrado & Su, 1996) and (d) Shimko (1993). The risk-neutral densities are extracted in R-program (Hamidieh, 2015) and its parameters are estimated. Certain scenarios are constructed with perturbed options prices and spot-prices, keeping everything else same. With small increment/decrements in options prices we demonstrate the effects on parameters of risk-neutral densities.

Data and Results

In India, the currency options (Appendix B) for the US dollar-Indian rupee (USD-INR) exchange rate have been trading since October 29, 2010. The National Stock Exchange provides daily reports containing order-book information and annualized volatility (σ). This volatility series can be segmented into four phases, exhibiting, low ($\sigma<5$), moderate ($5\leq\sigma<10$), high ($10\leq\sigma<15$), and excessive volatility ($\sigma\geq15$). The policy alternative is suitable for implementation during the episode of prolonged turbulence in USD-INR exchange rate (Jun-Oct, 2013), when volatility reached 30 (Figure 1). Following the procedures narrated in (Jondeau, Poon, & Rockinger, 2007), we extract risk-neutral densities (RND) for need to find an explanation for the phenomena of differing shapes of RNDs at different levels of volatility. At differing levels of volatility these RNDs behave differently.

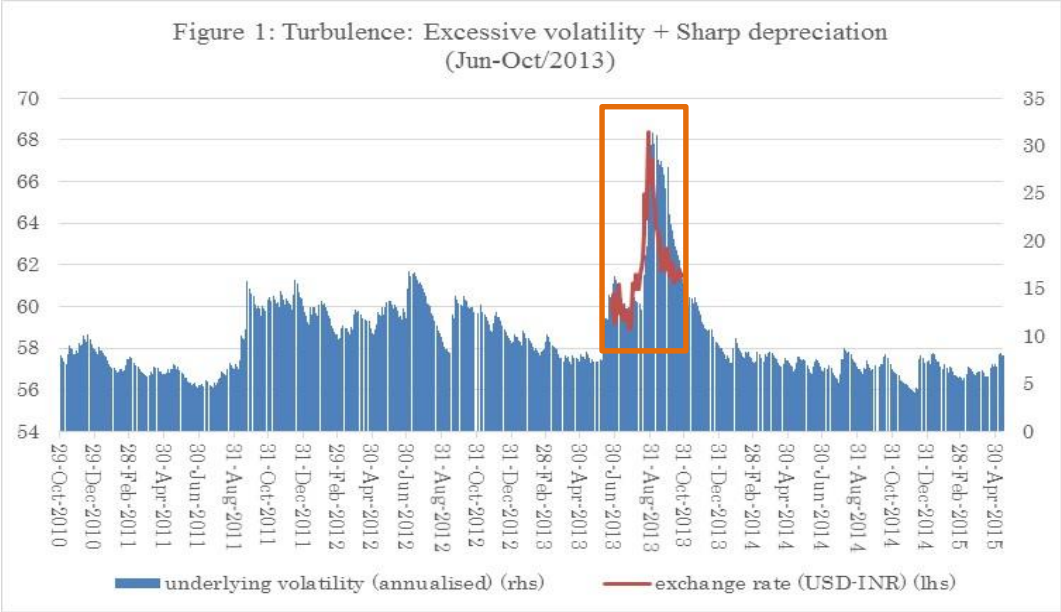
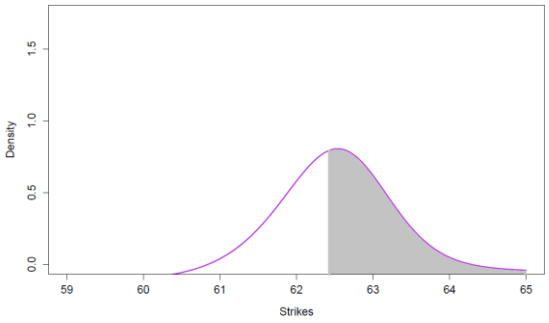
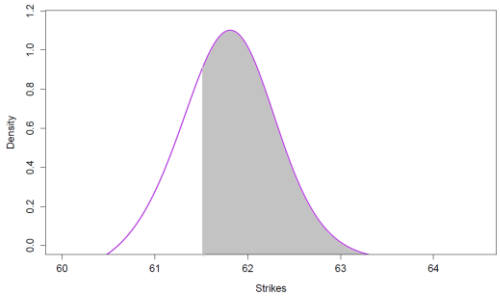


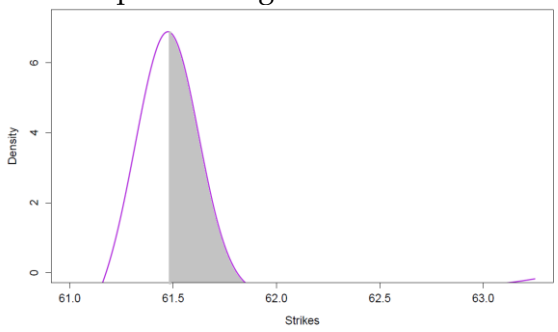
Figure 2: Probability density functions (*pdf*s) reflecting changes in market expectations



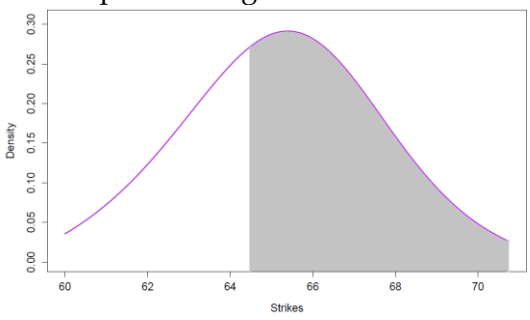
low volatility (σ<5), Dec/12/2014
spot exchange rate= 62.4422



moderate volatility (5≤σ<10), Nov/11/2014
spot exchange rate = 61.5500



high volatility (10≤σ<15), Jan/27/2015
spot exchange rate = 61.4640



excessive volatility (σ≥15), Sep/10/2013
spot exchange rate = 64.2162

The differences in peaks and thickness of tails are discernible from simple visual representation. The extent of expected depreciation is reflected in the extent of probability assigned to the different levels of exchange rates. Market typically assigns greater probability to deeper depreciation when volatility is higher (Figure 2).

The Choice of Models

We implement the (Breeden & Litzenberger, 1978) formula in R-program with the end-of-the-day options prices (Appendix C) over a finite range of strikes [58.50-67.25]. As per contract specification for European-style exchange-traded currency options, the strikes interval is exchange-determined at an increment of 0.25 Indian rupee. Trading taking place at those finite range of strikes implies traders are either buy or sell call or put options at those USD-INR exchange rate. We extract the risk-neutral densities under all possible models, such as, Black-Scholes, Mixed-Log-Normal, Generalized Beta, Edgeworth Expansion and Shimko methods. Each model generates estimated call and put options prices from the model. We compare the model-generated options prices and market-prices. In general, it is observed that, mixed-log-normal model generates options prices that are close to actual market prices. Therefore, we prefer mixed-log-normal density which can be specified as:

$$f(x)=\alpha.g(x)+(1-\alpha)h(x)$$

Where, g(x) and h(x) are two log-normal densities with parameters; α ($0<\alpha<1$) is proportion of the first lognormal; for the second lognormal it is (1- α); meanlog.1 and meanlog.2 are mean of the log of the first and the second lognormal, respectively; sdlog.1 and sdlog.2 are the standard deviation of the log of the first and the second lognormal.

It is possible to undertake multiple buy or sell positions using call and put options at various strikes. Under several such options trading strategies, we build scenarios with tiny increment/ decrements in options prices using order-book data. Then with the perturbed options-prices, we extract mixed-log-normal densities and compare their parameters. In addition, the densities are useful for illustration of effects of options-based intervention on market expectations.

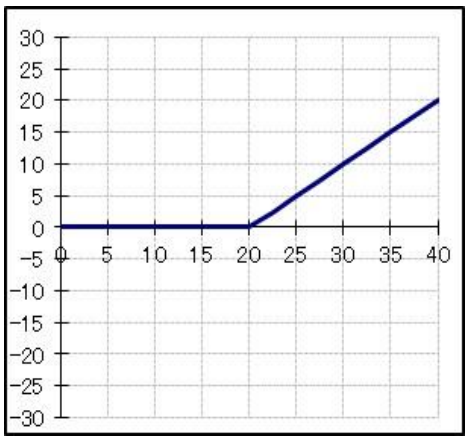
Options-trading Strategies

The underlying in the currency options traded on the exchange is USD-INR exchange rate. A single unit of call or put options is traded for a market lot-size of US$1000, as predetermined by the exchange. The spot-exchange rate is determined outside the options market. The RBI notifies the reference rate on each trading day at 12pm based on trading activities in inter-bank spot-market supervised by Federation of Exchange Dealers Association of India (FEDAI). The FEDAI is under regulatory oversight of RBI under Foreign Exchange Management Act, 1999. For the European-style exchange-traded currency options market, on predetermined expiry day of the contract cycle, each options contracts are cash-settled in Indian rupee. By definition, a call (put) options gives a trader right to buy (sell) the underlying asset with no obligation. The buyer of the options pays the premium as reflected in the traded options prices. At the expiry, depending on the RBI reference rate, the options ends up either in-the-money, near-the-money or out-of-the-money. The buyer of the options receives profit if the options expire in-the-money; otherwise they lose the options premium paid. In case a trades sells (writes) an option, he may face unlimited loss if the options

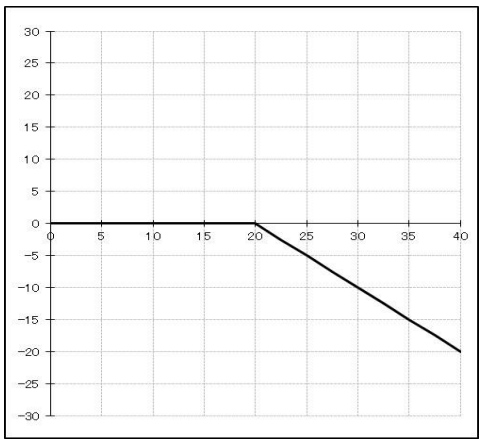
expire in-the-money. At market-wide settlement, mutual net payments are determined by the exchange playing the role of a central counterparty to every trader.

Figure 3: Payoff diagrams for Options-strategies

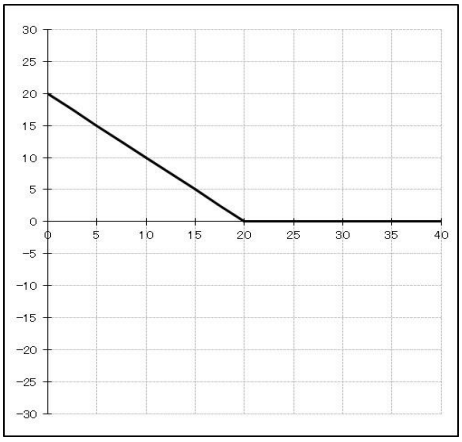
3a Buy Call



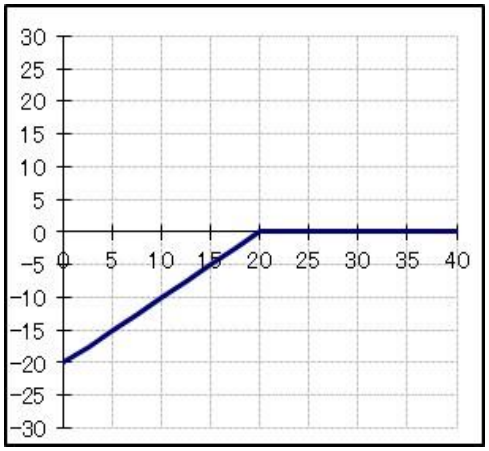
3b Sell Call



3c Buy Put

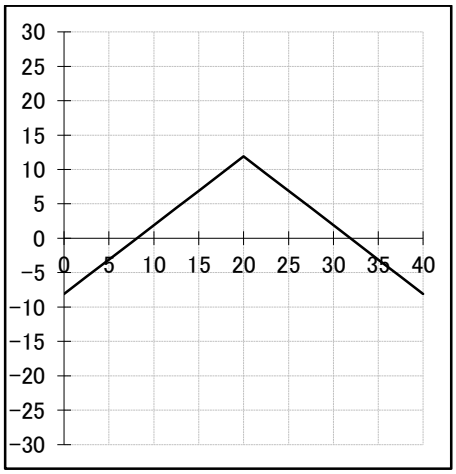


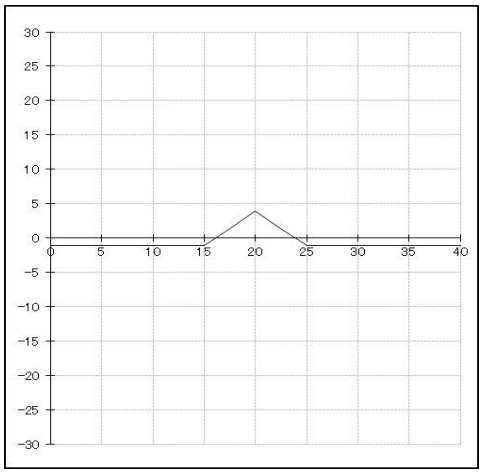
3d Sell Put



3e Short Straddle

3f Butterfly spread





The Vega and its Reciprocal

The *vega* is sensitivity of option price with respect to its implied volatility. The *vega*-reciprocal should be sensitivity of implied volatility with respect to option prices. The *vega* is strictly positive, therefore, its reciprocal must be positive as we can see from expression (1) and (2) above. Therefore, in order to contain volatility, one possible way is to reduce call option prices. Given a limit order-book, it is write at-the-money call and put options. The options-based intervention would mean to sell (offer/ask) options at the lowest buy (bid) prices. This intervention is similar to the practice in Mexico and Colombia. The anonymous order-matching will execute the trades and bring down the call and put option prices. The more such sell orders are placed, the more is the fall in options prices. With the volatility reduction properties of options prices, the volatility goes down with reduced options prices. The antecedent risk of writing options are unlimited and enormous. A risk-management tool, implementing a 'butterfly spread' trading strategy is examined subsequently, as advocated by (Keefe & Rengifo, 2014).

The Order-book

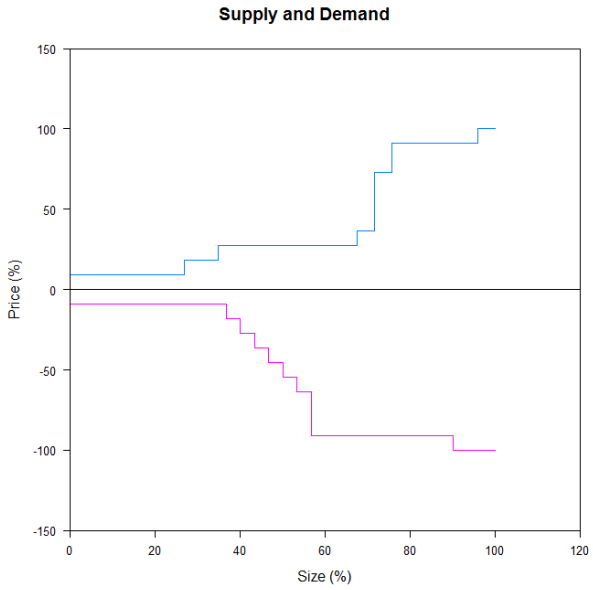
In an exchange-traded currency options market we are concerned with, an order-book is collection of limit orders yet to be traded or executed. For a call or put options, an order-book corresponding to a specific strike or exercise price reflects bid-size, bid-price, ask-size and ask-price. The orders on the bid side represents orders to that a trader might wish to buy a specific number of options contracts (bid-size) at the quoted prices (bid-price). The corresponding sell side is reflected in the ask side of the electronic order-book. A trader can add, cancel, replace, modify or remove an order. In case, a trader places a market order, it gets automatically executed, in full or in part, at the highest ask price. Each order is time-stamped and bears a unique identification. A trade gets executed as soon as a bid price matches its' ask price. This rule is called time-price priority, implying the earliest time-stamped order gets first priority in electronic automated order-matching. An order might get partly executed if bid-size is larger than the ask-size. Whenever, an order gets partly or fully executed, the traded price is determined. The cumulated traded quantity in a day is shown on both bid and ask side. Samples of order-books for a typical trading session for call and

put options at several near-the-money strikes are presented in Annexure A. We use the order-book data to build scenarios under several options trading strategies.

The Order-book Simulation

There are four basic types of orders that can be placed in an order-book, those are: buy call options, sell call options, buy put options and sell put options. A sell order if executed works on the ask-side (supply-side) of the order-book. A buy order works on the bid-side (demand-side) of the order-book and pushes up the option prices. This is a typical analog of supply-demand framework in microeconomics. In R-program, using *orderbook* package (Kane, Liu, & Nguyen, 2011) such supply-demand analysis of trades and simulation can be performed figure 4). As more and more options are sold the excess supply reduces its price and vice-versa. Using order-book data it is possible to place buy or sell orders and simulate the order-book with pre-specified probabilities for a cancel order, market order and limit order (Gilles, 2006).

Figure 4: Supply (ask) and Demand (bid) sides in a typical order-book



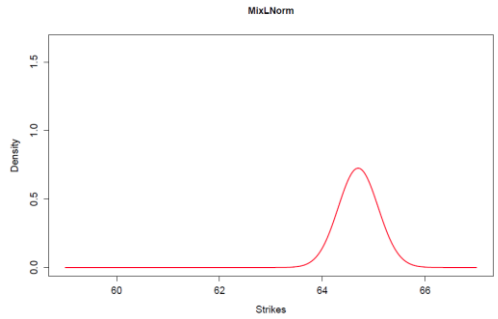
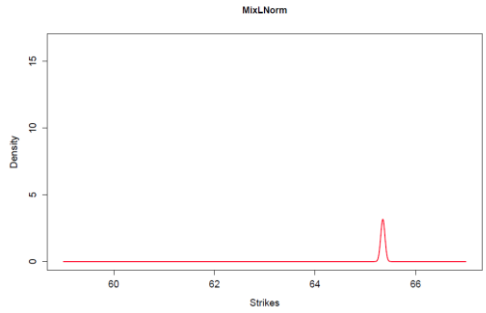
The Perturbed Order-books

In the present context, in the absence of day-long, contact-specific, order-book data, we use end-of-the-day snapshots of order-books for four near-the-money call and put options. On 15th June, 2015, we have captured snapshots of order-books for near-the-money call and put option pairs. The spot exchange rate as announced by RBI on 15th June, 2015 was 64.0868. Therefore, we chose call and put options at strike of 64.00, call options at strike of 64.25, and put options at strike of 63.75. Given the exchange determined strike interval, these would be the best possible near-the-money options pairs we could have chosen. The intervention, by way of mechanism described above, would result (C+ε), (P+ε) (bid-side intervention) (C-ε), (P-ε) (ask-side intervention). We denote C and P for call and put options; and ε is an arbitrarily small perturbation on traded price as a result of order-book intervention.

The Perturbed RNDs under a Butterfly Spread

The notion of risk-neutrality implies that expected return of an asset is the risk-free rate (Ross, 2015). In R-program, we extract the risk-neutral densities for original data and perturbed data under diffident scenarios as described above, using RND package (Hamidieh, 2015). The first scenario we build for a spot-market intervention. For illustration purpose, we consider that RBI intervenes in the market by selling dollars in the spot-market. We assume, as a result of spot-intervention, the spot-exchange rate changes by 0.0567 rupees, appreciates from 64.0868 INR/USD to 64.0301 INR/USD. In this counter-factual scenario, assuming everything else in the options market is unchanged, we extract the risk-neutral density. We can observe, the perturbed RND actually reflects changed market expectations towards a sharp depreciation. The standard deviation under mixed-log-normal density increases (Figure 5.a). The next scenario is built for an options-trading strategy alike a butterfly spread. To construct a butterfly spread, one call and one put options are sold at strike 64.00 and at the same time one call option is bought at 64.25 and one put option is bought at 63.75. A butterfly spread saves the intervening institution from unlimited loss potential. As we discussed above, the unlimited loss potential from writing call and put options (even though liabilities are net-settled in domestic currency), could be a concern. In butterfly spread, we incur a trade-off. Implied volatility decrease from writing at-the-money options and it increases from buying near-the-money options (Figure 3f). The net effect can be observed from the perturbed parameters of the two distributions (Figure 5.b). The means are primarily unchanged, with an opposing force working in the standard deviations. The weight parameter α does not get perturbed much. Comparing figure 5a and 5b, we can observe, a butterfly-spread carries more stabilizing effect on market expectations, as reflected in the perturbed risk-neutral densities.

Figure 5a: The Original and perturbed RNDs with spot-intervention

no intervention (spot xr= 64.0868)	spot-intervention (spot xr=64.0301)
	

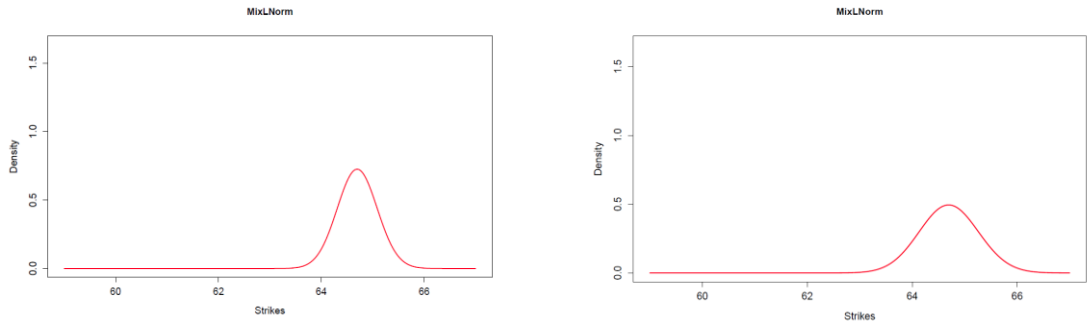
Parameters of implied mixed-log-normal density

mln.alpha.1=0.7051387	mln.alpha.1=0.3339312 (↓)
mln.meanlog.1=4.169755	mln.meanlog.1 =4.179737 (↑)
mln.meanlog.2 =4.15104	mln.meanlog.2 =4.156506 (↑)
mln.sdlog.1=0.005998237	mln.sdlog.1=0.000643967 (↑)

mln.sdlog.2=0.000000028	mln.sdlog.2= 0.0000000057 (↑)

Figure 5b: The Original and perturbed RNDs with butterfly-spread options-intervention

no intervention (spot xr= 64.0868)	butterfly-spread(spot xr=64.0301)



Parameters of implied mixed-log-normal density

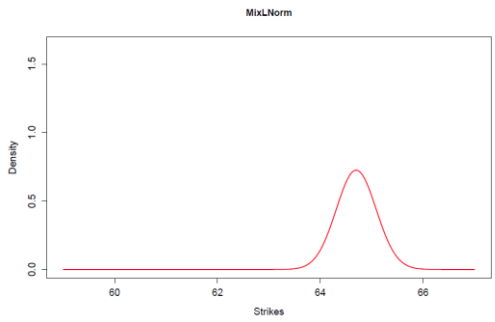
mln.alpha.1=0.7051387	mln.alpha.1=0.6992236(↓)
mln.meanlog.1=4.169755	mln.meanlog.1 =4.169741(↔)
mln.meanlog.2 =4.15104	mln.meanlog.2 =4.15104(↔)
mln.sdlog.1=0.005998237	mln.sdlog.1=0.008713116(↑)
mln.sdlog.2=0.000000028	mln.sdlog.2=0.0000000198(↓)

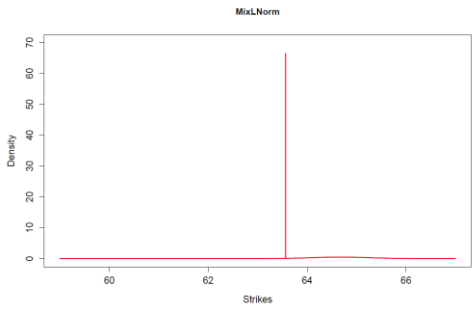
The Perturbed RNDs under a Short Straddle

Other more risky options strategies, such as naked writing of call and put options are comparatively more effective in reducing volatility and perturbing the risk-neutral densities and therefore, the market expectations. The impact of parameters of mixed-log-normal (mln) densities are larger if just options are written. For example, writing at-the-money call option at strike 64.00, degenerates the mln density with the entire mass nearly a point estimate much below the spot exchange rate (Figure 6a). Similarly, although less forceful, is the options strategies involving writing at-the-money put options at strike 64.00. The perturbed mln density help anchoring the market expectations (Figure 6b). In the scenario where both calls and put options are written at the same strike 64.00, the opposing forces counterbalance and stabilize the market expectations. A short straddle of writing both at-the-money call and put options (Figure 3e), generates a neutral effect as reflected in the perturbed mln density (Figure 6c). This strategy stabilizes distribution. Next, we proceed to analyze risk-management issues and concerns that the intervening institutions might face in arriving at a trade-off.

Figure 6a: The Original and perturbed RNDs with call options writing intervention

no intervention (spot xr= 64.0868)	A call option written at strike=64.00



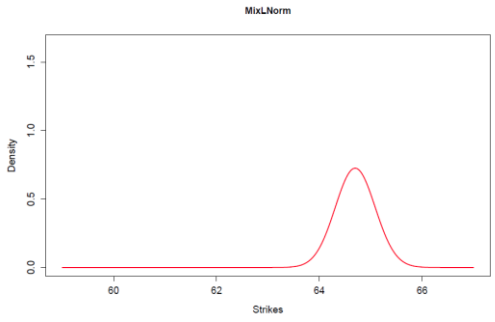


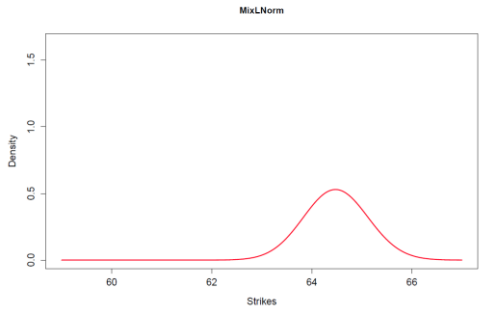
Parameters of implied mixed-log-normal density

mln.alpha.1=0.7051387	mln.alpha.1=0.6960163(↓)
mln.meanlog.1=4.169755	mln.meanlog.1 =4.16942 (↔)
mln.meanlog.2 =4.15104	mln.meanlog.2 =4.152051 (↔)
mln.sdlog.1=0.005998237	mln.sdlog.1=0.008948043(↑)
mln.sdlog.2=0.000000028	mln.sdlog.2=0.00000145(↑)

Figure 6b: The Original and perturbed RNDs with put options writing intervention

no intervention (spot xr= 64.0868)	A put option written at strike=64.00





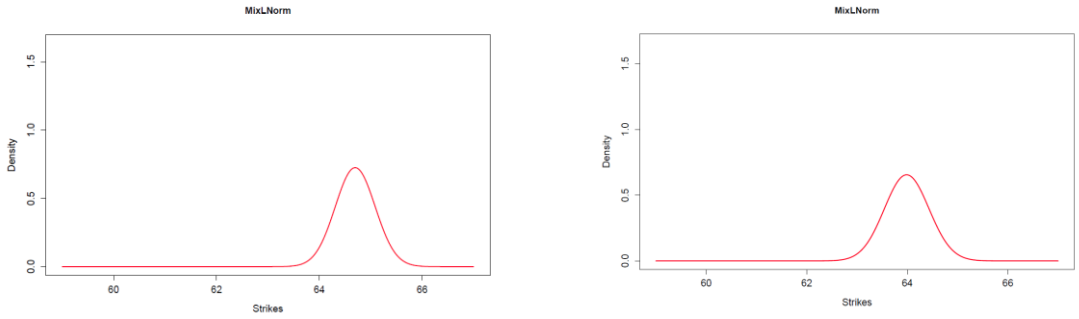
Parameters of implied mixed-log-normal density

mln.alpha.1=0.7051387	mln.alpha.1=0.1433506(↓↓)
mln.meanlog.1=4.169755	mln.meanlog.1 =4.15104 (↓)
mln.meanlog.2 =4.15104	mln.meanlog.2 =4.166368(↑)

mln.sdlog.1=0.005998237	mln.sdlog.1=0.000000118 (↓↓)
mln.sdlog.2=0.000000028	mln.sdlog.2=0.01001027(↑↑)

Figure 6c: The Original and perturbed RNDs with call & put options writing intervention

no intervention (spot xr= 64.0868) A short straddles at strike=64.00



Parameters of implied mixed-log-normal density

mln.alpha.1=0.7051387	mln.alpha.1=0.270858 (↓↓)
mln.meanlog.1=4.169755	mln.meanlog.1 =4.178226 (↑)
mln.meanlog.2 =4.15104	mln.meanlog.2 =4.15871(↑)
mln.sdlog.1=0.005998237	mln.sdlog.1=0.0000000072(↓↓)
mln.sdlog.2=0.000000028	mln.sdlog.2=0.0069355(↑↑)

Risk-management for Options-based Intervention

A market-friendly way to intervene in options market is to place trades with careful analysis of order-book of the options. Any number of combinations of buy or sell of single or more call or put options at same or several strikes are possible and can be implemented. Each combination comes with its antecedent risks. Each options contracts are cash-settled in Indian rupees, traded on-shore and are non-deliverables. This is advantageous for the intervening institution, such as, central bank or the government. In any case, the intervening institution is not liable to meet the liabilities in terms of foreign currency arising out of options written which might be in-the-money at expiry. Therefore, net-liabilities (however, unlimited) for an options contract written, may not matter in terms of foreign currency. A central bank can meet unlimited liability in terms of domestic currency (Indian rupees); and thus can possess unlimited intervention potential. Writing of options involve both initial and variable margin requirements. Therefore, it is a necessity that we have a 'deep pocket' intervening institution, with high risk tolerance. As it was done by Reserve Bank of Australia, it is possible to sequentially write options at a series of lower strikes and resell the options later on (near the expiry) with a profit (Reserve Bank of Australia, 1999). It may also be appropriate not to over use this tool. The options-based intervention tool can be a better policy

alternative as a crisis management strategy than spot-market intervention. The choice becomes more obvious because it anchors the market expectation and does not require to drain finite foreign exchange reserves. A central bank thus possess potentially unlimited intervention capacity, as they need not buy/sell dollars, which are limited.

Conclusion

The foreign exchange intervention strategy is gaining renewed attention in the context of current dynamics of the world economy. It is possible to protect an economy from adverse external shocks, smoothen exchange rate volatility and anchor market expectations. With possible exit from easy monetary policy in advanced economies, rippling effects are likely to hamper financial stability in emerging market economies. Most emerging market economies (including India) are accumulating foreign exchange reserves to cope with possible turbulence. Therefore, considering options-based intervention as a policy alternative may be an imperative in restoring financial stability. The theoretical sanctity of the proposed policy alternative is already been established (Basu, 2009; Basu, 2012; Basu, 2013; Basu & Varoudakist, 2013). Moreover, the extracted risk-neutral densities are useful monitoring mechanism to gauge market expectations.

The possible extensions for future research could be to examine the interrelation among parameters of the risk-neutral densities and levels of volatility in line with (García-Verdú & Ramos-Francia, 2014). For quantifying effects various options-trading strategies, we will adopt a numerical simulation model following (Keefe & Rengifo, 2014). A comparative analysis of the legal, regulatory and institutional framework between India and the countries where currency options-based intervention strategy was experimented will offer insights into implementation aspects and microstructure issues. An order-book simulation model (Kane, Liu, & Nguyen, 2011) can be developed to determine the interrelation between parameters of the pdf, volatility and options-prices. From the literature, it is still unclear, why and how the risk-neutral densities influence the actual trading behavior of market participants. Short-lived arbitrage opportunities could be one explanation. A typical trader values options-prices proportional to volatility. Thus, reduced options-prices should lead to lower volatility and perturb the resultant risk-neutral density. While trading, market participants use this perturbed risk-neutral density to assess market expectations. Therefore, the perturbed risk-neutral density from lowered options-prices should potentially be reinforcing and anchoring market expectations. Hence, future research can be conducted using orderbook data to quantify and identify the order-flow channel within the order-book simulation model.

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Appendix A: Sample order-books for near-the-money options

Order-book| Call options; strike=64.00

Buy Qty.	Buy Price	Sell Price	Sell Qty.
175	0.43	0.4375	4
39	0.4275	0.4425	516
100	0.38	0.445	650
19	0.37	0.4475	100
2	0.3625	0.45	203
3,129	Total Quantity		1,821

Order-book| Put options; strike=64.00

Buy Qty.	Buy Price	Sell Price	Sell Qty.
187	0.105	0.11	285
16	0.1025	0.1125	5
291	0.1	0.115	600
6	0.0975	0.1175	600
200	0.095	0.1225	5
2,189	Total Quantity		3,421

Order-book| Call option; strike=64.25

Buy Qty.	Buy Price	Sell Price	Sell Qty.
212	0.29	0.295	304
366	0.28	0.2975	203
275	0.2775	0.3	256
71	0.2725	0.3025	178
101	0.27	0.305	2
2,493	Total Quantity		1,192

Order-book| Put options; strike=63.75

Buy Qty.	Buy Price	Sell Price	Sell Qty.
683	0.05	0.0525	200
300	0.0475	0.0575	300
205	0.045	0.06	576
200	0.0425	0.0625	400
400	0.04	0.0675	200
2,733	Total Quantity		1,998

Appendix B: Currency options specification traded at National Stock Exchange

Symbol	USDINR
Instrument type	Currency option
Option type	Premium style European Call & Put Options
Premium	Premium quoted in INR
Traded units	1 contract denotes US$1000
Underlying	Indian rupees per unit of US dollar (exchange rate)
Tick-size	0.0025 INR
Trading hours	Monday to Friday 9am to 5pm
Contract trading cycle	3 serial monthly contracts followed by 1 quarterly contracts of the cycle March/June/September/December
Strike price	12 In-the-money, 12 Out-of-the-money and 1 Near-the-money. (25 CE and 25 PE)
Strike price intervals	0.25 INR
Price operating range	A contract specific price range based on its delta value is computed and updated on a daily basis
Quantity freeze	10,001 or greater
Base price	Theoretical price on the 1st day of the contract. On all other days, daily settlement price of the contract.
Expiry date	Two working days prior to the last business day of the expiry month at 12 noon.
Exercise at expiry	All in-the-money open long contracts shall be automatically exercised at the final settlement price and assigned on a random basis to the open short positions of the same strike and series.
Final settlement day	Last working day (excluding Saturdays) of the expiry month. The last working day will be the same as that for Interbank Settlements in Mumbai.
Position limits	For Foreign Portfolio Investors: Gross open position across all contracts shall not exceed 6% of the total open interest or USD 10 million, whichever is higher. For Non-Bank Stock Brokers: Gross open position across all contracts shall not exceed 15% of the total open interest or USD 50 million, whichever is higher. For Banks: Gross open position across all contracts shall not exceed 15% of the total open interest or USD 100 million, whichever is higher. For the purpose of computing the proprietary level gross open position, Long position are considered as Long Futures, Long Calls, and Short Puts. Short Position are considered as Short Futures, Short Calls, and Long Put.
Initial margin	SPAN based margin
Extreme loss margin	1.5% of Notional Value of open short position
Settlement	Premium to be paid by the buyer in cash on T+1 day
Settlement cycle	Daily settlement : T + 1; Final settlement : T + 2
Mode of settlement	Cash settled in Indian Rupees
Final settlement price	RBI reference rate on the date of the expiry of the contact

Source:
http://www.nseindia.com/products/content/derivatives/curr_der/cd_contract_specifications.htm#

Appendix C: Data for USD-INR options on Jun/15/2015

openint.c	vol.c	impliedvol.c	bid.c	ask.c	**strike**	bid.p	ask.p	impliedvol.p	vol.p	openint.p
0	0	49.38	0	0	**58.5**	0	0.005	0	0	0
589	0	48.13	5.47	0	**58.75**	0	0	0	0	0
6118	7	18.9	5.2725	5.3225	**59**	0	0.0025	18.72	0	2
0	0	0	4.97	0	**59.25**	0	0	0	0	0
253	0	44.96	4.775	0	**59.5**	0	0.005	0	0	0
0	0	0	4.47	0	**59.75**	0	0	0	0	0
1619	0	13.81	4.2825	0	**60**	0	0.0025	15.41	0	179
0	0	0	3.97	0	**60.25**	0	0	0	0	0
0	0	0	3.72	0	**60.5**	0	0.005	0	0	0
0	0	0	3.47	0	**60.75**	0	0	0	0	0
118	0	8.41	3.22	0	**61**	0	0.005	13.87	0	100
0	0	0	0	0	**61.5**	0	0.005	0	0	0
0	0	0	0	0	**61.75**	0	0.11	0	0	0
741	361	10.6	2.295	2.3275	**62**	0.0025	0.005	9.53	458	4548
0	0	0	0	0	**62.25**	0	0	0	0	0
1321	0	5.07	1.3325	0	**62.5**	0.0025	0.005	7.01	1600	3245
0	0	0	1.55	0	**62.75**	0	0.015	12.85	0	1
4624	100	7.13	1.0125	1.4	**63**	0.005	0.01	6.21	11704	46112
100	0	5.83	0	1.33	**63.25**	0.01	0.015	5.72	254	6088
15679	1400	5.98	0.7	0	**63.5**	0.0225	0.025	5.27	26268	77603
7567	2265	5.92	0.2525	0.6325	**63.75**	0.05	0.0525	5.23	38729	30869
211154	36749	5.66	0.43	0.4375	**64**	0.105	0.11	5.09	98943	160859
54754	78947	5.88	0.29	0.295	**64.25**	0.205	0.22	5.33	27504	19095
272512	94012	6.03	0.18	0.185	**64.5**	0.3475	0.4175	5.65	45117	155009
19254	11574	5.94	0.1	0.12	**64.75**	0.52	0.5375	5.7	714	2944
237033	78623	6.36	0.0625	0.0675	**65**	0.725	0.88	5.37	18464	43340
4328	1233	6.81	0.03	0.04	**65.25**	1.0975	0	7.65	0	377
66895	14990	6.83	0.02	0.025	**65.5**	1.0825	0	8.49	112	573
420	0	7.92	0.005	0	**65.75**	0	0	0	0	0
30548	9498	8.22	0.01	0.0125	**66**	1.5825	0	18.97	0	204
0	0	0	0	0	**66.25**	0	0	0	0	0
6547	550	9.35	0.005	0.01	**66.5**	2.0825	0	13.99	25	30
0	0	0	0	0	**66.75**	0	0	0	0	0
45413	503	10.49	0.005	0.0075	**67**	2.44	0	20.94	0	3886
0	0	0	0	0.0075	**67.25**	0	0	0	0	0

Note: openint.c= open interest for call options; vol.c= traded volume for call options; impliedvol.c= implied volatility for call options; bid.c= bid price for call options; ask.c= ask prices for call ptions; openint.p= open interest for put options; vol.p= traded volume for put options; impliedvol.p=implied volatility for put options; bid.p= bid prices for put options; ask.p= ask price for put options; strike= strikes (exercise prices).