AN EMPIRICAL ANALYSIS OF THE INTERRELATION BETWEEN SPOT MARKET & NON-DELIVERABLE FORWARD MARKET OF USD/INR IN THE PRE AND POST CURRENCY FUTURES ERA

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ABSTRACT

The main objective of this paper is to study whether the introduction of the currency futures had an impact of the interrelation and information flows between the INR-USD spot and offshore forward (i.e., non-deliverable forward) markets. The econometric models have been used in this study, and long term equilibrium relationship is measured through Johansen Co-integration test and Granger causality test is employed measure the short term relationship. The result of the co-integration test proves that, there exists a significant long-term equilibrium relation between the USD- INR spot and NDF rates. Causality test confirms that there is bidirectional causality between the spot and the NDF market in Sub-period 1, whereas a unidirectional causality exists in the Sub-period 2. We adopt the augmented GARCH formulation to compare NDF and spot market. We find that before currency future was introduced there existed a mean and volatility spillover effect from the NDF to spot market and vice versa, i.e., both directions. But after the introduction of currency futures, however, the results reversed with unidirectional mean spillover effect only from the NDF to the spot market. Also, the volatility spillover effect is unidirectional. These findings suggest that there are information flows between NDF and spot markets. Hence it is concluded that introduction of currency future has changed the direction of the dynamic relation in these two markets.

Keywords: Spot Market, Non-deliverable forward, Volatility spillover; GARCH

JEL Classification: G13, F31, C51

1. Introduction

The non-deliverable forward (NDF) market for developing market currencies has perpetuated over the years even though participation of the non-residents in the onshore market is either completely restricted or very limited. NDF is a currency forward contract in which cash settlement occurs instead of physical delivery. The importance of the NDF market cannot be simply overlooked because of its trading takes place in the offshore market. The growing activities in the NDF market, generally traded in an offshore centre, are
expected to have spillover impact on onshore market through the common players in both the NDF and deliverable forward (DF) market. Therefore, there could be mean spillover from one market to another, i.e. exchange rate movement in one market could influence another market and thereby help in price discovery. Driven by speculation and noise trading, the volatility in one market can also transmit to another market. Moreover, one might expect that arbitrage of exchange rates across markets should result in volatility spillover between markets. Thus, exchange rate in the onshore market could be affected by the exchange rate changes in the offshore (NDF) market beyond what is conceivable by connections through economic fundamentals (Harendra Kumar Behera (2011)). NDFs are contracts for the difference between an exchange rate agreed months before and the actual spot rate at maturity. The spot rate at maturity is taken as the officially announced domestic rate or a market determined rate. The contract is settled with a single US dollar payment.

NDFs trade principally outside the borders of the currency’s home jurisdiction ("offshore"). This enables investors to avoid restrictions on trading in the home market ("onshore") and limits on delivery of the home currency offshore. Market participants include direct and portfolio investors wishing to hedge currency risk and speculators (Ma et al (2004)). Banks and firms with onshore and offshore operations arbitrage, and thereby reduce, differences in forward rates. In recent years the growing importance of non-resident investors in local currency bond markets has increased the salience of NDF markets, particularly in times of strain (McCauley et al (2014)).

The Reserve Bank of India (RBI) cultivates the Indian rupee (INR) in a managed floating regime. The value of the rupee is tracked against the Real Effective Exchange Rate (REER). However, the rupee exchange rate has been known to vary significantly from the long-term REER average. Despite there being a stated policy

\[ \text{REER is calculated by the Reserve Bank of India (RBI) based on a basket of 36 global currencies} \]
of permitting market moves based on underlying fundamentals, the RBI can intervene actively in the foreign exchange market in cases of excessive volatility.

Both, the government and the RBI establish exchange controls. Although market participants are able to buy the rupee freely from any bank for most current account transactions, the rupee remains restricted on the capital account. Anything not specifically allowed under the Foreign Exchange Management Act (FEMA) is deemed to be disallowed. There is limited access to onshore FX contracts for resident entities. Foreign Direct Investors (FDI) & Non Resident Indians (NRIs) can also hedge their exposure subject to compliance with specific conditions. Interrelation and information flows across markets have long been an issue in financial economics. Increasing importance has been given by recent researches to short term dynamics of price changes and information transmission mechanisms. This paper scrutinizes the interrelation and information flows between the INR–USD spot and its offshore forward, namely NDF markets. The major objective of the article is to see whether there are any change in the relationship between the spot, and NDF markets after the introduction of currency futures in India.

2. Review of Literature

Jinwoo Park (2001) investigated the interrelation and information flows between the Won–Dollar spot and NDF markets. They focused on the impact of the reform in the Korean exchange rate systems, on the relation between the two markets. They found that during the pre-reform period a mean spillover effect exists from the spot to the NDF market but not vice versa, and a volatility spillover effect exists in both directions. After the reform, however, the results are reversed and a mean spillover effect exists from the NDF to the spot market. Also, the volatility spillover effect exists only in the same direction. They suggest that there are information flows

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between the two markets, and the reform has changed the direction of the dynamic relation.

Sangita Misra and Harendra Behera (2006) studied the inter-linkages among the spot, forward and NDF markets for Indian rupee. They found that the NDF market was influenced by spot and forward markets and the volatility spillover effect exists from spot and forward markets to NDF market. They also found that volatility spillover in the reverse direction, from NDF to spot market, though the extent is marginal. They suggested for close monitoring of NDF market.

Izawa Hideki (2006) analyzed after the revaluation, the efficiency hypothesis in context of daily non-deliverable forward (NDF) renminbi in the Hong Kong market. Daily data of 1, 3, 6 and 12 month NDF terms by CEIC Data Company Ltd. are used in this paper, from July 2004 to May 2006. Unit root test, Engle-Granger cointegration test and efficiency hypothesis (serial correlation or white noise) have been used in this paper. The efficiency hypothesis for the renminbi 1 and 3 month NDF market is rejected. It was concluded that NDF rates are not equitable predictors of the future spot rate.

Michael Hutchison et.al (2009) studied the degree to which the adequacy of capital controls in India, measured by the domestic less net outside investment rate differentials have changed over the long haul. They found that accepted capital control obstructions are (1) arbitrage action closes deviations from CIP when the edge limits are surpassed in all sub-inspects, (2) asymmetric over inflows and outpourings (3) have changed after some time from basically confining surges to adequately limiting inflows (measured by band widths and positions).

Anuradha Guru (2010) tested the linkages between spot, domestic forward and NDF markets for INR/USD using Granger causality tests, co-integration tests and ARCH-GARCH models, over the period January, 2007 to April, 2009. They found that NDF markets are now exercising greater influence on the domestic currency markets
through better information content and spillover effects.

Yayat Cadarajat and Alexander Lubis (2012) analyzed the information transmission between off-shore and on-shore Rupiah currency in Indonesian markets. They found the evidence of constant volatility in all IDR/USD markets. They evidenced that mean spillover are observed to be unidirectional i.e. from NDF to both spot and forward rupiah markets.

Harendra Kumar Behera (2013) examined the onshore-offshore linkages of the Indian rupee with GARCH technique for the period of November 2000 to November 2009. They found that while shocks and volatilities in the non-deliverable forward market influence the onshore markets, there is no mean spillover effect of the offshore non-deliverable forward market on onshore spot, forward and futures markets.

3. Data and Methods

3.1. Data

The data used in this paper constitutes daily closing rates of the spot and NDF value of USD/INR. Monthly forward contracts are utilized for NDF data because they have the largest trading volume among the varied maturity values. Spot data is collected RBI website and the NDF data from Bloomberg database. The data period starts from January 1, 2003 and ends at December 30, 2013. The movements in spot and NDF rates for the period of study are shown in Fig. 1. The data period encompasses the time since the introduction of exchange traded currency futures in the NSE i.e.29th August, 2008.

The main objective of this paper is to study whether the introduction of exchange traded currency futures had an impact on of integration of onshore spot market and offshore markets i.e. NDF. To see how this currency future market introduction interacts with NDF and spot markets. Therefore the data is divided two sub-periods (hereafter denoted as the “Before introduction of currency future” and “After introduction of currency future”), and investigate the impact of the introduction of future contract on the
relation between the offshore NDF and domestic spot markets i.e. onshore market.

3.2. Econometric methods

The methods used in this research include (1) a unit root test for checking the stationarity of the data, (2) a co-integration test for examining the long-term equilibrium relation between the NDF and spot market rates, (3) error correction model for testing causality, and (4) ARCH and GARCH models for explaining time varying volatility in time series data. In particular, based on the Jinwoo Park (2001) design, the GARCH model is broadened to incorporate exogenous variables and is utilized to investigate mean and volatility spillover effects between the spot markets and NDF.

This section starts with a brief review of the Unit root test and (ADF and PP tests), ARCH family of statistical models that are used for estimating the variance and conditional mean for spot rate changes and NDF. Then, we specify the extended GARCH model that is used to examine the mean and volatility spillover effects between the NDF and spot markets.

3.2.1. Unit root test

As a pre-condition of time series analysis, a unit root test is performed using an autoregressive model to check whether a time-series variable is non-stationary or not. A series is stationary if the mean and auto covariances of the series are not dependent on time. Unit root tests based on Augmented Dickey-Fuller (ADF) test and non-parametric Phillips-Perron (PP) approaches were used in this study to examine the stationarity of NDF the and spot price series. The test of stationarity of futures and spot prices were carried out by estimating the following regression equation: (Jabir Ali 2011).

\[ \Delta X_t = b_0 X_{t-1} + \sum_{i=1}^{\tau} b_i \Delta X_{t-i} + \varepsilon_t \]  

................................. (1)
Where $X_t$ represents the base level or the first difference of the variables. The null hypothesis of non-stationarity is $b_0 = 0$. If the null hypothesis is accepted at the base level of the series but rejected at the first difference of the series, then the series is taken as stationary at the first difference level, and it is denoted by $I(1)$. The above tests have been performed using a constant intercept and lag length has been determined though Schwarz information criterion.

### 3.2.1. Johansen Cointegration Test

Co-integration has emerged as a powerful tool for investigating typical trends in multivariate time series and provides a robust methodology for modeling both long term and short term relationships in a system. The aim of the co-integration test is to identify whether a group of non-stationary series are co-integrated or not, and explores the long-run equilibrium relationship among the variables. Under this study, co-integration tests have been used to assess the long-run equilibrium between NDF and Spot rate of USD/INR, using the co-integration test, assuming an $\eta$ -dimensional vector $X_t$ with integration of on order $I(1)$, estimates a vector autoregressive models. Johansen and Juselius (1990) further improved the model by incorporating an error correction depicted as follows (Jabir Ali 2011)

\[
X_t = C + \sum_{i=1}^{k} \prod_{i} X_{t-1} + \varepsilon_t
\]

\[
\Delta X_t = \mu + \sum_{i=1}^{k-1} \gamma_i \Delta X_{t-i} + \prod_{i} X_{t-k} + \varepsilon_t
\]

where $X_t$ is an $n \times 1$ vector of the $I(1)$ variables representing NDF and Spot rate of USD/INR respectively, $\mu$ is a deterministic component which might include a linear trend term, an intercept term, or both, $\Delta$ denotes the first difference operator, $\Pi_i$ is an $n \times r$ matrix of parameters indicating $c$ is
a vector of constants, $k$ is lag length based on the Hannan-Quinn criterion, and it is a $\varepsilon_t$ random error term, which indicates how many linear combinations of $X_{t-1}$ are stationary.

The residual vectors of the above model construct two likelihood ratio test statistics, i.e. the trace test and the maximal eigen value test. The trace statistics tests the null hypothesis of $r$ cointegrating relations against the alternative of the $k$ cointegrating relations. The maximum eigen value statistics tests the null hypothesis of $r$ cointegrating relations against the alternative of $r + 1$ co-integrating relations. The utility of the two tests of co-integration is subject to diverse views. While, Johansen and Juselius (1990) argued that as compared to the maximal eigen value test, the trace test may lack power. In contrast, Cheung and Lai (1993) viewed that the $\lambda$ trace test shows more robustness than the maximal eigen value test. The Johansen likelihood ratio test statistic, $\lambda$ trace, and the maximal eigen value, $\lambda$ max for the null hypothesis that there are at most $r$ cointegrating vectors are given by:

$$
\lambda_{trace} = -T \sum_{i=r+1}^{k} \ln \left( 1 - \hat{\lambda}_i \right) 
$$

$$
\lambda_{max} = -T \ln \left( 1 - \hat{\lambda}_{r+1} \right)
$$

3.2.2. Granger causality test

Granger causality test has been applied to identify the direction and causal relations between NDF and Spot rate of USD/INR. The Granger (1969) approach predicts how much of the current value of one variable can be explained by past values of other variable and then tries to see whether adding lagged values of prior variable can improve the explanation. For instance, $Y$ is said to be Granger-caused by $X$ if $X$ helps in the prediction of $Y$, or
equivalently if the coefficients on the lagged $X$ is statistically significant. Specifically, $Y_t$ is causing $X_t$ if some coefficient, $a_i$, is non-zero in the following equation (Jabir Ali 2011):

$$X_t = C_0 + \sum_{i=1}^{p} a_i Y_{t-1} + \sum_{j=1}^{p} b_j X_{t-j} + \mu_t \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots 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3.2.3. ARCH and GARCH Models

Numerous studies suggest that financial time series are restrictively heteroskedastic, indicating that vast price changes tend to be trailed by large changes and minor changes tend to be trailed by little changes (see Mandelbrot, 1963; Fama, 1965). To catch hold of the temporal reliance in the second moment of time series data, Engle (1982) developed an autoregressive conditional heteroskedastic (ARCH) model of the following form:

The time series data utilized as a part of this paper, i.e., changes in the spot and NDF rates, best fits the MA(1)–GARCH (1,1) model. To capture serial dependency in currency rate changes, a first-order moving average (MA (1)) term is included in the currency mean equation. The MA (1)–GARCH (1, 1) model utilized in this paper can be summarized as follows:

\[ R_{it} = a_i + \phi_i \varepsilon_{i,t-1} + \varepsilon_{it}, \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (9) \]

\[ \sigma_{it}^2 = \sigma_{0i}^2 + \alpha_{1i} \varepsilon_{i,t-1}^2 + \beta_{1i} \sigma_{i,t-1}^2, \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (10) \]

Where \( R_{it} \) is the change in the NDF or spot rate changes in period \( t \) and \( \sigma_{it}^2 \) represents the conditional variance of \( R_{it} \).

3.2.4. Model for testing spillover effects

In the ARCH clan of statistical models, both variance equations and conditional mean can be extended to include exogenous variables. By including exogenous variables from other stock markets, Hamao et al. (1990) test the spillover effects in volatility and conditional mean across countries. Following the Hamao–Masulis–Ng specification, this paper inspects the spillover effects between the domestic spot markets and offshore NDF using the following model:

\[ R_{it} = a_i + \delta_i R_{jt,t-1} + \phi_i \varepsilon_{i,t-1} + \varepsilon_{it}, \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (11) \]
\[
\sigma_{it}^2 = \alpha_{0i} + \alpha_{1i} \varepsilon_{i,t-1}^2 + \beta_{1i} \sigma_{i,t-1}^2 + \gamma_i \varepsilon_{j,t-1}^2, \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (12)
\]

where \( R_{j,t-1} \) represents the past changes in currency rate in the counterpart market, and \( \sigma_{j,t-1}^2 \) is the squared residual derived from the MA(1)–GARCH(1,1) model applied to \( R_{j,t-1} \). Therefore, the significance of coefficients \( \delta_i \) and \( \gamma_i \) indicates the presence of spillover effects from market \( j \) to \( i \) in conditional mean and volatility, respectively.

4. Results and Discussions

4.1. Preliminary Statistics

Table #1 presents the descriptive statistics for the spot and NDF rate changes. We find a negative mean in the Sub-period 1 and a positive mean in the sub-period 2. Also, we note that the volatilities (standard deviation) of both spot and NDF rate changes increase dramatically in the sub-period 2. In particular, a comparison of volatility between the spot (0.155946) and NDF (0.069587) rate changes exhibits an interesting result in that the volatility of spot rate changes is only half of NDF volatility in the Sub-period 1 whereas the difference (NDF 0.389881 and Spot 0.344862) is reduced in the Sub-period 2. These results indicate that prior to introduction currency futures; regulations distorted the spot rates but helped to reduce their volatility. But, after the advent of currency futures, the extent of increase in the NDF rate volatility is larger than that in the spot rate volatility. As a result, the spot and NDF volatility in the sub-period 2 increased in a similar pattern.

This table presents the descriptive statistics and distribution properties of the spot and NDF rate changes. The null hypothesis is that the time series data have a normal distribution. The \( Q (10) \) and \( Q^2 (10) \) are for serial correlation of the spot and NDF rate changes and their squared series, respectively. The null hypothesis is that all serial correlations up to lag 10 are jointly zero.
Table #1 also exhibits the distribution properties of the spot and NDF rate changes. Measures for excess kurtosis and skewness imply that the currency series are skewed and leptokurtic (If the kurtosis is more than 3 the distribution is leptokurtic relative to the normal) with respect to the normal distribution. The null hypothesis of a normal distribution is rejected for all the series using the Jacque–Bera normality test. The Q statistics for serial correlation of the spot and NDF rate changes and their squared series are also reported in Table 1 for 10 lags. The Q(10) statistics are statistically significant (based on Probability value) for all series, indicating the presence of serial correlation (linear dependency). This suggests that the spot and NDF processes should be estimated in a manner so as to allow for greater moving average processes to be predicted. The $Q^2$(10) statistics for all series are statistically significant (based on Probability value), indicating the presence of serial correlation in squared series (nonlinear dependency). This suggests the existence of autoregressive restrictive heteroskedasticity, i.e., volatility clustering, which can be correctly indicated by the ARCH or GARCH models.

4.2 Unit root test

A necessary condition for time series analysis is the stationarity of the time series data. A common approach for testing stationarity is the Augmented Dickey–Fuller (ADF) and Phillips-Perron (PP) test unit root test with a time trend. The null hypothesis is that the time series data have a unit root. Results in Table #2 indicate the presence of a unit root in the level (level values (-1.7052) is more than Critical values (-3.45)) of the spot and NDF rates i.e., the null hypothesis cannot be rejected. However, there is no evidence to reinforce the existence of a unit root in first differences (first differences value (-36.6188) is than Critical value (-3.45)). The null hypothesis of a unit root in first differences is rejected for both the spot and NDF rates in the entire period that the data with first differences is stationary. As a result, in the following analysis, with the cointegration test being
the exception, this paper uses percentage changes in spot and NDF rates computed as:

\[ R_{lt} = \ln y_{lt} - \ln y_{l,t-1} \]

### 4.3. Cointegration test

If A group of non-stationary time series does not have a stochastic trend i.e. a linear combination of them is stationary, the time series is said to be co-integrated. The linear combination is known as the cointegrating equation. A normal interpretation of co-integration is the existence of a long-term equilibrium relationship. The co-integration tests for the relation between the INR–USD spot and NDF rates are shown in Table 3.

In testing for co-integration, we used the procedure developed by Johansen (1991). In Table 3, the hypothesized number of co-integration equations (CE) denoted as “none” exhibits the result of testing the hypothesis of no co-integration, whereas one denoted as “at most 1” indicates the outcome of testing the hypothesis that both series are stationary. We find that the spot and NDF rates are co-integrated and each individual series is not stationary in both Sub-period 1 and Sub-period 2. The coefficients of the co-integration equations (Sub-period 1: 0.999793 and Sub-period 2: 1.020946) are close to one. This result indicates that, there exists a long-term equilibrium relation between the USD- INR spot and NDF rates.

### 4.4. Granger causality test

According to Engle and Granger (1987), if two variables are cointegrated, then there exists a vector autoregressive representation of the first differences of the variables, with each equation augmented by one lag of the cointegrating residuals. In this model specification, changes in one variable can be related to the lagged changes of the other variable and its own past changes. The Granger causality test involves testing for the combined significance of the coefficients of the lagged changes of the other variables, which can be determined by the F-statistic. An issue concerning the construction of the vector error correction model is the selection of optimal lag lengths. Akaike’s minimum
final prediction error (FPE) criterion is frequently used to determine the lag length.

The Granger causality suggests testing for the combined significance of the coefficients of the lagged changes of the other variables, which can be determined by the F-statistic. The optimal structure for the model, as per Akaike’s criterion, contains five lags.

Table 4 reports the results for the Granger causality test. It is noteworthy that there is a structural change in the causal relationship between the INR-USD spot and NDF markets surrounding the reform. Before introduction of currency futures, there is bidirectional causality in the spot and the NDF market, whereas a unidirectional causality exists in the after introduction of currency futures. This result implies that the currency future introduction had a significant impact on the relation between the spot and NDF markets.

4.5. Spillover effects between spot and NDF markets

As summarized earlier, Preliminary analysis of the data indicates the existence of strong conditional heteroskedasticity and significant autocorrelation, and demands the application of the ARMA–GARCH model to capture these effects. We find that the MA (1)–GARCH (1, 1) model results in the best explained fit to the data series of the spot and NDF rate changes. The estimation results of the MA (1)–GARCH (1, 1) model are shown in Table #5.

The Q (10) and Q^2 (10) statistics for the normalized GARCH residuals and their squares are not significant at conventional levels, indicating that there is no serious problem in the model specification. The coefficients for the MA (1) term (\(\phi\)) are all statistically significant except for the NDF series in the pre-reform period. The coefficients for the GARCH (1, 1) terms (\(\alpha_1, \beta_1\)) are all statistically significant.

Given these generally encouraging results, the squared residual from the MA(1)–GARCH(1,1) model is introduced into the conditional variance as an exogenous variable. As indicated in
Equations. (11) and (12), in this augmented GARCH model, the exogenous variable $R_{j,t-1}$ represents the exchange rate changes in the counterpart market on the previous trading day, and the exogenous variable $\varepsilon^2_{j,t-1}$ represents the previous day’s squared error from the MA(1)–GARCH(1,1) Model applied to the variable $R_j$. The coefficient ($\delta$) of $R_{j,t-1}$ indicates the spillover effect of the variable $j$ onto the conditional mean in the variable $i$. The coefficient ($\gamma$) $\varepsilon^2_{j,t-1}$ of indicates the potential volatility spillover effect in the conditional variance of variable $i$ from variable $j$. The outcomes of analyzing spillover effects are depicted in Table #6.

Test results show mean and volatility spillovers effect from NDF to the spot and spot to the NDF market in Sub-Period 1. These results indicate that information revealed in the previous trading day in one market is taken into account in the other market. These findings are consistent with those obtained from the causality tests in which we noted two way causal effects from spot to NDF to spot and spot to NDF.

Let us see what happens after introduction of currency futures i.e. from September, 2008 to December 2014 when there is a new currency future market also made available to the market players. In particular, since the currency future introduction, the NDF market has attracted more attention from participants in the Indian financial market because it played a role as a leading indicator of the INR–USD exchange rate. The clear unidirectional mean and volatility spillover effect from the NDF to the spot market during the Sub-Period 2, this result reflects the direction of information flows from NDF to spot market. This result is also consistent with that from a causality test in which unidirectional causality from the NDF to the spot market is observed during the after currency future introduction period.

5. Summary and Conclusions

First, this paper investigated the interaction and information flow between the INR-USD spot and offshore forward, i.e., NDF markets over the period 1st
January, 2003 to 31st December, 2013. In particular introduction of exchange traded currency futures during September 2008 had an impact on integration of onshore spot market and offshore markets i.e. NDF. First, the results of sub-period 1 indicate bidirectional causality between NDF and Spot markets. These two way causality outcomes are further confirmed with MA (1) GARCH (1, 1) tests showing mean and volatility spillovers between these markets, from one to the other. These results indicate that information revealed in the previous trading day in one market is taken into account in the other market. There is evidence of co-integration between NDF and spot markets, indicating that the prices have a long-term equilibrium relationship among them in these markets.

These results change substantially in the Sub-period 2 in contrast to the result in the Sub-period 1. The results show that the unidirectional causality between NDF to spot markets and not vice versa. Further, investigating the spillover effects between NDF and spot market, the results show that unidirectional mean and volatility spillover effect from the NDF to the spot market in Sub-period 2. These reveal that currency future introduction changed the direction between NDF and spot markets.

NDF prices of INR-USD are presently reflecting market forces that cannot be tracked in onshore markets. Once onshore market players in India are permitted to transact with international counterparts in NDFs and a more convertible exchange rate regime is established, NDF market liquidity can significantly contribute to liquidity and volume in onshore currency product markets. NDF markets would tend to disappear as ad when INR becomes fully convertible, as was seen in the case of Australia (Debella et al. (2006)). NDF markets would remain a hedging instrument for foreign entities that are unable to do so in the onshore markets till INR becomes fully convertible.

References


Figures & Tables

Figure: 1. USD–INR spot and NDF rate movements
Table #1 Summary statistics for Spot and NDF rate changes

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>Jarque-Bera</th>
<th>Q(10)</th>
<th>Q^2(10)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sub-period 1: Before introduction of currency futures (N= 1380)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>∆NDF</td>
<td>-0.004089</td>
<td>0.155946</td>
<td>0.476702</td>
<td>11.50509</td>
<td>4208.564</td>
<td>12.724</td>
<td>170.74</td>
</tr>
<tr>
<td>∆SPOT</td>
<td>-0.003104</td>
<td>0.069587</td>
<td>0.053843</td>
<td>7.064662</td>
<td>949.9627</td>
<td>30.648</td>
<td>586.02</td>
</tr>
<tr>
<td><strong>Sub-period 2: After introduction of currency futures (N= 1264)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>∆NDF</td>
<td>0.014822</td>
<td>0.389881</td>
<td>0.023768</td>
<td>8.239442</td>
<td>1444.768</td>
<td>7.7143</td>
<td>256.86</td>
</tr>
<tr>
<td>∆SPOT</td>
<td>0.014705</td>
<td>0.344862</td>
<td>0.373554</td>
<td>8.615562</td>
<td>1688.879</td>
<td>14.050</td>
<td>327.03</td>
</tr>
</tbody>
</table>

Source: computed by Authors’ (2014), Figures in brackets are p-value

Table #2 Unit root test

The null hypothesis is that the time series data have a unit root.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Augmented Dickey-Fuller (ADF)</th>
<th>Phillips-Perron (PP)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Critical value</td>
<td>Level</td>
</tr>
<tr>
<td><strong>Sub-period 1: Before introduction of currency futures</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spot</td>
<td>-3.45 (1 %)</td>
<td>-1.7052</td>
</tr>
<tr>
<td>NDF</td>
<td>-3.45 (1 %)</td>
<td>-1.7612</td>
</tr>
<tr>
<td><strong>Sub-period 2: After introduction of currency futures</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spot</td>
<td>-3.45 (1 %)</td>
<td>-0.3355</td>
</tr>
<tr>
<td>NDF</td>
<td>-3.45 (1 %)</td>
<td>-0.6413</td>
</tr>
</tbody>
</table>
Source: computed by Authors’ (2014), ** denotes significance at 1% level.

### Table # 3 Johansen Co-Integration

<table>
<thead>
<tr>
<th>Co-integration Between Spot and NDF</th>
<th>Hypothesis</th>
<th>Trace Statistics</th>
<th>Max-Eigen Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>λ trace</td>
<td>p-value</td>
</tr>
<tr>
<td></td>
<td></td>
<td>λ max</td>
<td>p-value</td>
</tr>
<tr>
<td><strong>Sub-period 1: Before introduction of currency futures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NDF$_t$ = 0.102357 + 0.999793 SPOT$_t$</td>
<td>None</td>
<td>311.7026</td>
<td>(0.0001)**</td>
</tr>
<tr>
<td>USD / INR</td>
<td>At most 1</td>
<td>3.018757</td>
<td>(0.0823)</td>
</tr>
</tbody>
</table>

| **Sub-period 2: After introduction of currency futures** | | | |
| NDF$_t$ = -0.782866 + 1.020946 SPOT$_t$ | None       | 291.5227         | (0.0001)** | 291.3561 | (0.0001)** |
| USD / INR                          | At most 1  | 0.166539         | (0.6832) | 0.166539 | (0.6832) |

Source: computed by Authors’ (2014) **1% & *5% level significant

### Table # 4 Granger causality test

<table>
<thead>
<tr>
<th>Null hypothesis</th>
<th>F-statistics</th>
<th>P-Value</th>
<th>Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sub-Period 1: Before introduction of currency futures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>∆SPOT does not Granger Cause NDF</td>
<td>6.18377</td>
<td>1.E-05**</td>
<td>NDF ↔ SPOT</td>
</tr>
<tr>
<td>∆NDF does not Granger Cause SPOT</td>
<td>131.174</td>
<td>1E-113**</td>
<td></td>
</tr>
</tbody>
</table>

| **Sub-period 2: After introduction of currency futures** | | | |
| ∆SPOT does not Granger Cause NDF | 1.96904     | 0.0805  |
| ∆NDF does not Granger Cause SPOT | 273.112    | 2E-197** |

Sources: computed by authors (2014), **1% level significant
Table # 5 Estimates of MA(1)–GARCH(1,1) model

<table>
<thead>
<tr>
<th>Variable</th>
<th>C</th>
<th>MA(1)</th>
<th>C</th>
<th>ARCH</th>
<th>GARCH</th>
<th>Q (10)</th>
<th>Q² (10)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>aᵢ</td>
<td>φ</td>
<td>a₀</td>
<td>α₁</td>
<td>β₁</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Sub-Period 1: Before introduction of currency futures**

| ΔNDF     | -0.000169 ** | 0.040977 [1.308770] | 2.26E-06* [10.24448] | 0.370589* [9.652197] | 0.498713* [12.04191] | 7.9725 (0.537) | 3.9194 (0.917) |
|ΔSPOT     | -0.000120 ** | 0.015735 [0.610916] | 1.45E-07 * [6.586711] | 0.326976* [16.05618] | 0.724785* [56.61017] | 25.132 (0.003) | 17.476 (0.042) |

**Sub-period 2: After introduction of currency futures**

| ΔNDF     | -2.14E-05 [-0.138322] | -0.019343 [-0.659611] | 5.35E-07* [2.856403] | 0.069838* [9.434986] | 0.922980* [134.5637] | 8.0931 (0.525) | 7.1742 (0.619) |
|ΔSPOT     | 5.60E-05 [0.352857] | 0.026976 [0.927811] | 1.06E-06* [3.220286] | 0.149343* [6.982812] | 0.831570* [35.80857] | 10.392 (0.320) | 8.3691 (0.497) |

Sources: computed by authors (2014) Figures in square brackets are t-stats and those in round brackets are p-values * Significant at the 1% level of significance & ** Significant at the 5% level of significance

Table # 6 Mean and volatility spillovers between spot and NDF

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>aᵢ</td>
</tr>
</tbody>
</table>

**Sub-Period 1: Before introduction of currency futures**
<table>
<thead>
<tr>
<th></th>
<th>i= ΔNDF</th>
<th>j= ΔSPOT</th>
<th>i= ΔSPOT</th>
<th>j= ΔNDF</th>
<th>i= ΔSPOT</th>
<th>j= ΔNDF</th>
<th>i= ΔSPOT</th>
<th>j= ΔNDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>i= ΔNDF</td>
<td>-7.70E-05*</td>
<td>9.974882*</td>
<td>-0.71297*</td>
<td>6.77E-07*</td>
<td>0.173954*</td>
<td>0.741635*</td>
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<tr>
<td>j= ΔSPOT</td>
<td>[.817673]</td>
<td>[17.02179]</td>
<td>[-33.87651]</td>
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<td>[8.557480]</td>
<td>[28.98736]</td>
<td>[88.41842]</td>
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<tr>
<td>i= ΔNDF</td>
<td>-0.000160*</td>
<td>19.05032*</td>
<td>-0.007317</td>
<td>1.43E-07*</td>
<td>0.332568*</td>
<td>0.721111*</td>
<td>-0.001801</td>
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<tr>
<td>j= ΔNDF</td>
<td>[-3.508798]</td>
<td>[-0.202100]</td>
<td>[-0.262137]</td>
<td>[6.323940]</td>
<td>[14.43689]</td>
<td>[50.74366]</td>
<td>[-0.202100]</td>
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</table>

* Significant at the 1% level of significance & ** Significant at the 5% level of significance

Sub-period 2: After introduction of currency futures

<table>
<thead>
<tr>
<th></th>
<th>i= ΔNDF</th>
<th>j= ΔSPOT</th>
<th>i= ΔSPOT</th>
<th>j= ΔNDF</th>
<th>i= ΔSPOT</th>
<th>j= ΔNDF</th>
<th>i= ΔSPOT</th>
<th>j= ΔNDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>i= ΔNDF</td>
<td>-1.59E-05</td>
<td>0.450016</td>
<td>-0.928608*</td>
<td>2.91E-07*</td>
<td>0.087255*</td>
<td>0.902283*</td>
<td>1.000387*</td>
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<tr>
<td>j= ΔSPOT</td>
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<td>[1.612485]</td>
<td>[-95.04651]</td>
<td>[3.599666]</td>
<td>[8.055486]</td>
<td>[87.19105]</td>
<td>[176.3971]</td>
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<tr>
<td>i= ΔSPOT</td>
<td>-5.92E-06**</td>
<td>2.292145**</td>
<td>0.056181</td>
<td>1.14E-06*</td>
<td>0.155640*</td>
<td>0.823188*</td>
<td>-0.083780</td>
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</tr>
<tr>
<td>j= ΔNDF</td>
<td>[-0.031776]</td>
<td>[2.083313]</td>
<td>[1.934294]</td>
<td>[3.233660]</td>
<td>[6.721873]</td>
<td>[32.45371]</td>
<td>[-4.272831]</td>
<td></td>
</tr>
</tbody>
</table>

Sources: computed by Authors’ (2014, Figures in square brackets are t-stats,