ISSN(E):2522-2260
ISSN(P):2522-2252

Indexing/Abstracting

Journal of Quantitative Methods

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Published by

Department of Quantitative Methods

School of Business and Economics

University of Management and Technology, Lahore, Pakistan

Manuscript Information

Kumar, U., & Jain, G. (2018). An Empirical Investigation on the Relationship between Onshore and Offshore Indian Rupee Market. *Journal of Quantitative Methods*, *2*(1), 1-36.

This manuscript contains references to 20 other manuscripts.

The online version of this manuscript is available at

http://journals.umt.edu.pk/sbe/jqm/volume2issue1.aspx#

DOI: 10.29145/2018/jqm/020101

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An Empirical Investigation on the Relationship between Onshore and Offshore Indian Rupee Market

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Abstract

Exchange rate movements have important ramifications for the economy's business cycle, trade and capital flows. For India, the exchange rates fluctuations have consequences for being competitive in terms of international trade and capital flows, tourist destination and for maintaining a healthy international reserve. This paper attempts to explore the relationship between rupee-dollar exchange rate in spot market, domestic forward market and off-shore forward i.e. non-delivery forward market (Singapore) to understand the information flow in between these markets. Suitable econometric techniques including causality analysis was used for the study for the period 2002 to 2014 after considering structural breaks and sub period analysis was also done. It was found that the relationship between all three markets is quite dynamic with evidences of causality in one sub period and reverse direction or no causality in other sub periods, conditional upon intervention done by RBI to curb the volatility and on various macroeconomic shocks such global financial crisis.

Keywords: exchange rate, spot market, forward market, causality, structural breaks

1. Introduction

The global financial crisis of 2008 has accentuated the need to understand the macroeconomic and financial stability framework in emerging economies like India. In the world of growing capital

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movement from Industrial nations to emerging economies in search of better returns, it is pertinent to understand the risks associated with this volatile capital flowing into the emerging economy.

In India, it becomes a challenging task for the central bank to manage high inflation driven by domestic factors like poor agriculture-produce market management and global factors primarily crude oil prices. The high interest rate required to contain inflation makes the capital market more attractive for global players looking for higher returns. This adds to the complexity of Indian central bankers as it creates downward pressure on rupee. To address this issue, the central bank intervenes in the exchange rate market in the scenario of high volatility. This helps the RBI to build up their foreign reserves to be used to curb exchange rate volatility making rupee a managed-float exchange rate.

The Indian rupee is fully convertible on current account but not on capital account. This nature of rupee is one of the impediments in internationalization of rupee in the world. India, a current account deficit country uses this as a policy to control the high volatile movements in the currency that free float exchange rate would bring. Despite this policy in force, we have seen Indian rupee getting converted in off-shore market. Ehlers and Packer (2013) show that the turnover of Indian rupee trade in offshore market is 53% of total global turnover and 27% of total turnover is in Hong Kong Special Administrative Region and Singapore. The report clearly indicates that rupee has become an international currency with forex investors showing increasing interest in the rupee trade.

The internationalization of Indian rupee can be vulnerable in containing exchange rate volatility and current account deficit mandate. Market is the place where price discovery of an asset takes place. In present case where trading of rupee takes place in off-shore (non-delivery forward market) and on-shore market creates an information flow between these two markets. NDF market is a cash settled forward contract market where the profit or loss at the time of settlement date is calculated by taking the difference between the agreed upon exchange rate and the spot rate at the time of settlement, for an agreed upon notional amount of funds. This can create a spill-over effect on the value of the rupee where price in one market can be used to forecast expected price in other market. In fact, in 2013, the spill-over effect from NDF (non-delivery forward) market was one of the most cited factors for the recent depreciation.

Many studies are done by RBI and other researchers to check the effectiveness of RBI interventions in exchange rate market but there is no study to check the spill-over between NDF market and On-shore market and secondly to check the effectiveness of RBI's steps to curb the impact of spill-overs on onshore-exchange rate. There is global research done on this topic but not much in Indian context. Research done by Park and Song (2011), Shu, He and Cheng, (2015) indicates that when there are restrictions on onshore trading of currency, NDF markets allow the market agents to hedge their exposures and speculators to take a position on future movements in domestic currency.

In general, as market players' interest grows in a particular currency having convertible restrictions, overseas market generally gains momentum (Hutchison, Sengupta & Singh, 2010). The position taken by market players in different currency markets reflects the market sentiment on Indian rupee which is not reflected contemporaneously in domestic market because of the restrictions in place. This motivates us to examine the inter-linkages or transmission of information from the off-shore market to onshore market in the back drop of RBI's intervention.

2. Literature Review

In emerging economies like Korea and China, there are studies conducted to understand the inter-relationship between these currency markets like Park and Song (2011), Wang, Fawson, Christopher (2006), Ma, Ho and McCauley (2004), Colavecchio and Funke (2006) etc. However in Indian context there are limited numbers of studies that have been carried out to study the inter-linkages of currency market. Misra and Behera, (2006) found that the NDF market is generally influenced by spot and forward markets and the volatility spillover effect exists from spot and forward markets to NDF market. Evidences are also observed for volatility spillover in the reverse direction, i.e., from NDF to spot market, though the extent is marginal. Goyal, Jain and Tewari (2013), concluded that there exists a long term relationship between onshore and NDF markets and relationship is bidirectional but that bidirectional relationship turns unidirectional from NDF to onshore during the period when rupee comes under downward pressure.

The research on the transmission of information from one financial market to another market assumes significance since it helps to understand the dynamics of inter-connected financial world. The focus of various studies i.e. Ludwig and Slok (2004), Pedroni (2004), Case, Quigley and Shiller (2005) was mainly on spillovers within equity, fixed income securities and foreign exchange markets. However, literature on the inter-linkages between offshore NDF market, onshore spot and Forward market segment of foreign exchange markets are scarce. One of the main reasons is that it's only in 2013 as per the Ehlers and Packer (2013) that Indian currency has increased its global foreign exchange turnover to 5 billion mark in this 5000 billion dollar market. The event of sharp depreciation in rupee in 2013 also makes this study important because of the inter-connected financial world which was not as intricate as it is today.

Park (2001) examined the impact of financial deregulation on the relationship between onshore and offshore market of Korean won and concluded that the interrelationship is dynamic and varies with the extent of deregulation in the foreign exchange market and liberalization of capital flows. He argued that in the Korean economy with a managed float exchange rate and restriction on capital flows, movements in the domestic spot market influences the NDF market. This was reversed as the exchange rate policy was shifted to free float and capital flow restrictions were reduced. The domestic market was mainly driven by offshore NDF market where price innovations originated.

Similarly, Wang et al. (2006) shows that the NDF market seems to be the driver for the domestic spot market of Korean won, while for the Taiwanese dollar, it is the spot market which contains more information and influences the NDF market. Ma et al. (2004) provided evidence that volatility in NDF currency rates has been higher than that in the local spot markets for six Asian currencies namely Chinese renminbi, Indian rupee, Indonesian rupiah, Korean won, Philippine peso and New Taiwan dollar.

In Indian context there are only few studies. Misra and Behera (2006) found that NDF market is generally influenced by spot and forward markets and the volatility spillover effect exists from spot and forward markets to NDF market. Research was also done for volatility spillover in the opposite direction, i.e., from NDF to spot market, though it was found that the extent of spillover is marginal. Guru (2009) also finds somewhat similar evidence on interdependencies between the NDF and onshore segments (spot and forward) of rupee market. It is argued that the dynamics of relationship between onshore and offshore markets has undergone a change with the introduction of the currency future market in 2008 and returns in NDF market seem to be influencing the domestic spot as well as forward market.

Darbha (2012) finds that offshore markets are important in price discovery process, particularly in India and China. It is concluded that NDF markets do have significant impact on onshore markets. He emphasized that until full capital convertibility is achieved; NDF market rates and activity are important information signals and thus need to be monitored by investors and regulators. Goyal, et al. (2013), concluded that there exists a bidirectional relationship between onshore and NDF markets and relationship is bidirectional but that bidirectional relationship turns unidirectional from NDF to onshore during the period when rupee comes under downward pressure.

The above studies have tried to answer the relationship between different currency markets. However in the previous studies, one of the limitations which were found is that the relationship among currency markets was not subjected to structural shocks and therefore no structural break points were identified. In this back drop, this study was conducted to study the inter-relationship between offshore forward markets, onshore forward and spot market of INR/USD exchange rate to understand whether there is any impact of information flow from one market or not.

3. Data and Methodology

The time period for the study is from January 2002 to November 2014. For the purpose of VAR-Granger causality approach, all the data taken is monthly in nature. For the AR-GARCH-BEKK approach all the data taken is of daily weekly returns on rolling basis. Data pertaining to Indian market is extracted from RBI publications. Data pertaining to Singapore market is collected from Reuter's database. Log Returns were calculated to ensure the normality of the data given by the formula below:

$$R_t = 100 \times \log\left(\frac{p_t}{p_{t-1}}\right)$$

where, Pt is the closing value of the stock index on day t. The return series is therefore continuously compounded daily returns expressed as a percentage Singapore market is considered as NDF market. The study uses Toda and Yamamoto (1995) test which is a modified Wald test for restriction on the parameters of the VAR (p) with p being the lag length of the VAR system. However, VAR explains the causality structure between time series based on return spillovers but is doesn't consider volatility spillovers and conditional volatility persistence.

To explore transmission of volatility from one market to another, we have used AR-GARCH-BEKK model as well. To check the stationarity of the series and to determine the order of integration, this study uses Augmented Dickey-Fuller (ADF) Test. This study uses Quandt Andrews and chow test to determine structural beak points in the series.

3.1. VAR-Granger Causality

The study uses Toda and Yamamoto (1995) test which is a modified Wald test for restriction on the parameters of the VAR (p) with p being the lag length of the VAR system. It is important to highlight that T & Y approach is selected to model given the non-stationarity in the time series. This is because in Wald test which is done test linear restrictions on the parameters of a VAR model if time series is non-stationary, then the Wald test statistic does not follow its usual asymptotic chi-square distribution under the null.

As Lutkepohl, (2006) has identified that if one applies the test in the usual way, the test statistics asymptotic distribution involves noise making it totally non-standard. In this approach, the correct order of the system (p) is augmented by the maximal order of integration (m). It is important that coefficients of extra m lags to be excluded by treating them as exogenous variable while performing Wald test since they are used to just fix asymptotics. The VAR between two series (X and Y) can be represented in the below form with a null hypothesis of α1 (12) = α2 (12) = α3 (12) = …..αk (12) = 0 where α (12) are the coefficients of X.

$$\begin{bmatrix} X_t \\ Y_t \end{bmatrix} = A_0 + A_1 \begin{bmatrix} X_{t-1} \\ Y_{t-1} \end{bmatrix} + \ldots\ldots\ldots\ldots + A_K \begin{bmatrix} X_{t-p} \\ Y_{t-p} \end{bmatrix} + A_{K+1} \begin{bmatrix} X_{t-p-1} \\ Y_{t-p-1} \end{bmatrix} + \ldots\ldots\ldots + A_{K+d} \begin{bmatrix} X_{t-k-d} \\ Y_{t-k-d} \end{bmatrix}$$

If the null hypothesis is rejected, then the one-way effect can be confirmed. Parameter d is the maximum of order of integration of series X and Y and K is determined using information criterion approach such as AIC, SIC, HQ etc. Any serial correlation present in the errors is removed by increasing the lag. The VAR model with additional lags of each of the variables is made and then the model is tested for dynamic stability i.e. whether all the roots of characteristic equation positive and less than unity.

3.2. AR-GARCH-BEKK Model

Considering the international literature, AR-GARCH model (Behera, Narasimhan, & Murty, 2008) is a very good choice for modeling volatility transmission among market indices. The following mean equations were estimated for each market's return calculation.

$$r_t = \alpha + \beta r_{t-1} + u_t$$

$$u_t|\Omega_{t-1} \sim \mathrm{N}(0, H_{t-1})$$

where r_t is an 2x1 vector of rolling weekly returns on daily basis at time t for each market $u_t|f_{t-1}$ ~N(0, H_t) is an 2x1 vector of random errors for each market at time t, H_t is with its corresponding 2x2 conditional variance-covariance matrix. The parameters in the conditional variance-covariance matrix can be modeled in several ways. This study uses bivariate BEKK GARCH process for modeling variance co-variance structure. BEKK formulation enables us to reveal the existence of any transmission of volatility from one market to another (Engle & Kroner, 1995). The BEKK for bivariate GARCH can be parameterized is the following way.

$$H_t = C_0'C_0 + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}' \begin{bmatrix} \xi_{1,t-1}^2 & \xi_{1,t-1}\xi_{2,t-1} \\ \xi_{1,t-1}\xi_{2,t-1} & \xi_{2,t-1}^2 \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} + \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix}' H_{t-1} \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix}$$

where C_0 is a 2x2 lower triangular matrix of constants and the purpose of decomposing the constant term into a product of two triangular matrices is to guarantee the positive definiteness of H_t. The symmetric matrixes A captures the ARCH effects, the elements aij of the symmetric matrix A measure the degree of innovation from market i to market j. While the matrix G focus on the GARCH effects, the elements gij in matrix G represent the persistence in conditional volatility between market i and market j. The diagonal parameters in matrices A and G measure the effects of own past shocks and past volatility of market i on its conditional variance. The off-diagonal parameters in matrices A and G, aij and gij, measure the cross-market effects of shock and volatility, also known as volatility spill-over.

The full BEKK representation is used to analyze the degree of volatility spillover between currency markets. Hence, bivariate BEKK can be further expanded by matrix multiplication and presented as follows:

$$\begin{aligned} h_{11,t} = c_{11}^2 + a_{11}^2 \xi_{1,t-1}^2 + 2a_{11} a_{22} \xi_{1,t-1}\xi_{2,t-1} + a_{21}^2 \xi_{2,t-1}^2 + g_{11}^2 h_{11,t-1} \\ + 2g_{11} g_{22} h_{12,t-1} + g_{21}^2 h_{22,t-1} \end{aligned}$$

$$\begin{aligned} h_{22,t} = c_{21}^2 c_{22}^2 + a_{12}^2 \xi_{1,t-1}^2 + 2a_{12} a_{22} \xi_{1,t-1}\xi_{2,t-1} + a_{22}^2 \xi_{2,t-1}^2 \\ + g_{12}^2 h_{11,t-1} + 2g_{12} g_{22} h_{12,t-1} + g_{22}^2 h_{22,t-1} \end{aligned}$$

$$h_{12,t} = c_{11}c_{21} + a_{11}a_{12}\xi_{1,t-1}^2 + (a_{21}a_{12} + a_{11}a_{22})\xi_{1,t-1}\xi_{2,t-1} + a_{21}a_{22}\xi_{2,t-1}^2 + g_{11}g_{12}h_{11,t-1} + (g_{21}g_{12} + g_{11}g_{22})h_{12,t-1} + g_{21}g_{22}h_{22,t-1}$$

$$h_{12,t} = h_{21,t}$$

4. Estimation and Results

All the three series are non-stationary in nature as shown below by the Augmented Dickey-Fuller Test. Table A.1-A.3 show the results of ADF conducted in levels and in 1st difference. It is concluded that all the three series are of I (1) in nature since the 1^{st} difference of all the three series is stationary (P-value < 0.05). However this will not affect the T-Y procedure to examine the Granger Causality.

4.1. Relationship between Spot Market and NDF Market

However not much has been studied despite the increasing turnover in the NDF market. In the literature one of the studies done by Park (2001) finds that the interrelationship is dynamic and changes with the extent of deregulation in the foreign exchange market and liberalisation of capital flows. He argues that in the Korean economy with a managed float exchange rate and restriction on capital flows, movements in the domestic spot market is influenced by the NDF market. This was reversed as the exchange rate policy was shifted to free float and capital flow restrictions were reduced. The domestic market was mainly driven by offshore NDF market where the price innovations originated. A similar study by (Wang et al., 2006) shows that the NDF market seems to be the driver for the domestic spot market of Korean won, while for Taiwanese dollar, it is the spot market which contains more information and influences the NDF market.

As per the procedure of T-Y Granger Causality VAR model was setup in the levels of data to determine the appropriate lag length. With NDF exchange rate and spot exchange rate as endogenous variable and constant as exogenous variable, two out of three information criteria says that lag of 2 is appropriate. The results are shown in Table A.4. However to remove the serial correlation present in the residuals lag of 3 was selected. The results of lag autocorrelation LM test in Table A.5 shows that there is no serial correlation at lag length of three. The roots of AR characteristic Polynomial as shown in Figure 1 (see Annexure-B) are inside the unit circle, this shows that the model is also dynamically stable.

Since both the series are I(1) therefore m=1, from the above analysis it is concluded p=3. Now two exogenous variable i.e. NDF exchange rate (-4) and spot exchange rate (-4) was included. These way coefficients of these extra lags will then not be included when the subsequent Wald tests are conducted. If all the lags had been specified in the lag interval to be from 1 to 4, then the coefficients of all four lags would be included in the Wald tests, and this would be incorrect. This is because the Wald test statistic would not have its usual asymptotic chi-square null distribution.

The Granger causality test was done and of which the results are given in Table A.6. From the upper panel of results, we see that we can reject the null of no causality from spot to NDF. From the lower panel we see that we cannot reject the null of no causality from NDF to spot, at the 5% significance level. It is customary to check for the structural break in the model. Therefore the system of VAR (p) model was created and tested with Quandt Andrews break point test with 5% trimmed data. The result shows that 67th observation has maximum value of LR F-statistic, which was verified by doing chow test and it was found that there is a break in the model at 67th observation (2008 (Sept)). Therefore analysis has been split in two parts, one is for the observation 1-66 and other is 68 to 146.

For the period 1 to 66 the results are presented in Table A.7 and for the period 68 to 146 in Table A.8. The split analysis has given an interesting observation that for the period 2008 (August) to 2014 (Feb) there is a two way causal relationship since the P-value is 0 and 0.0368 but for the period 2002 (Jan) to 2008 (Aug) there is only unidirectional causal relationship i.e. from spot to NDF but not vice-versa.

VAR (p) model for the two periods is as follows:

For the period 2014 (Feb) to 2008 (Sept)

$$NDF = 0.3743\times NDF(-1) + 0.3115\times NDF(-2) + 0.0186\times NDF(-3) + 0.9935\times Spot(-1) - 0.3305\times Spot(-2) - 0.3619\times Spot(-3) - 0.0087$$

$$Spot = 0.8556\times NDF(-1) - 3.6841\times NDF(-2) + 0.1335\times NDF(-3) + 1.3463\times Spot(-1) - 1.4564\times Spot(-2) + 3.7882\times Spot(-3) + 0.0308$$

For the period 2008 (July) to 2002 (Jan)

$$NDF = 0.6012\times NDF(-1) + 0.0595\times NDF(-2) + 0.0015\times NDF(-3) + 1.0211\times Spot(-1) - 0.6315\times Spot(-2) - 0.0487\times Spot(-3) - 0.0050$$

$$Spot = -0.2664\times NDF(-1) - 0.0231\times NDF(-2) - 0.0944\times NDF(-3) + 1.2409\times Spot(-1) - 0.0408\times Spot(-2) + 0.1529\times Spot(-3) + 0.0519$$

As per the BIS paper published (2013) RBI has taken major steps to curb interventions which are as follows:

4.2. Measures Aimed at Curbing Speculative Behavior by Market Participants

- Rebooking of cancelled forward contracts involving the rupee booked by the residents to hedge transactions has not been permitted - since July 2012, exporters have been allowed to cancel and rebook 25 per cent of the total contracts booked for hedging their export exposure.
- The facility for importers availing themselves of the past performance facility was reduced to 25 per cent of the average of actual import/export turnover of the previous three financial years or the actual import/export turnover of the previous year, whichever is higher -- all forward contracts are mandated to be structured on a fully deliverable basis.
- Transactions undertaken by Authorised Dealers (ADs) on behalf of clients are for actual remittances/delivery only and cannot be cancelled/cash settled.
- Rebooking of cancelled forward contracts booked by FIIs is not permitted -- the forward contracts may, however, be rolled over on or before maturity.

- The Net Overnight Open Position Limits (NOOPL) and intra-day open position/daylight limit of AD banks has been reduced -- some of the above measures have been relaxed subsequently for the genuine hedging requirements of the real sector and to smooth liquidity pressure in the market.
- Positions taken by banks in currency futures/options cannot be offset by undertaking positions in the OTC market.
- The NOOPL of the banks as applicable to the positions involving the rupee as one of the currencies would not include positions taken by banks on the exchanges.

In 2008 (Sept) Lehman Bros. collapsed and the inter-connected world was in financial crisis with the value of currencies falling and Indian rupee also started feeling pressure till RBI intervened. This was structural change in the market which is observation number 67 rightly predicted in this analysis. The slew of measures taken by RBI has created constraints in the domestic forward market and has therefore propelled market participants to take position in the off-shore market. It can be observed that the global Turnover of Indian rupee has increased from 23.6 billion U.S. dollars in 2007 to 52.8 billion U.S. dollars in 2013 i.e. an increase of 123% which is a very huge increase as compared to all the emerging markets except China. This recent increase in the depth of the market can be the reason of its influence to the spot market.

4.3. Relationship between Spot and Forward Market

Next pair of analysis is of Spot and Forward market and same steps were followed as in first pair of analysis. First step was to arrive at appropriate lag length. In this approach two out of three Information criteria was used and the results are presented in Table A.9. However the Lag length of 1 is recommended but the autocorrelation effect in the residuals vanishes at a lag length of 3. The result of Autocorrelation LM test is presented in Table A.10. The stability of model is also tested and model was found stable as shown in Figure 2 (see Annexure-B) since all the roots are inside the unit circle.

Now as per the procedure Augmented VAR model VAR (p+m) was established to examine the Granger Causality (T-Y approach). Since both the series are I (1) therefore m=1, from above analysis it is concluded p=3. Now two exogenous variable i.e. Forward exchange rate (-4) and Spot exchange rate (-4) was included. These way coefficients of these extra lags will then not be included when the subsequent Wald tests are conducted. If all the lags had been specified in the lag interval to be from 1 to 4, then the coefficients of all four lags would be included in the Wald tests, and this would be incorrect. This is because the Wald test statistic would not have its usual asymptotic chi-square null distribution.

The Granger Causality test was done and result of the same is presented in Table A.1.1. From the upper panel of results, we see that we can reject the null of no causality from Spot to Forward market. From the lower panel we see that we can reject the null of no causality from Forward to Spot, at the 5% significance level. This implies that spot and forward market both has an impact on each other. Again VAR (p) model was tested for structural break points and for this purpose Quandt Andrews break point test with 5% trimmed data was performed. It was found that there is a break point in the series at an observation number 13 i.e. 2013 (Feb). This observation was further verified by chow test and it was concluded that there is a break in the model at 13th observation. The study was further divided into two parts. One is from 1 to 14 (Since 14th observation is minimum required in this case to run a VAR (p + k) model). For the period from 2013 (Jan) to 2014 (Feb) result is presented in Table A.12. For the period from 2002 (Jan) to 2013 (Feb) result is presented in Table A.13.

The above split period analysis shows that till 2012-2013 financial year there was a bidirectional causal relationship between the two markets but now in the last one year the relationship is unidirectional i.e. causal relationship exists only from spot to forward rate. VAR (p) model for the two periods is as follows:

For the period from 2013 (Jan) to 2014 (Feb) equations are shown below

$$\text{Forward Rate} = -1.4132\times \text{Forward Rate}(-1) - 2.0165\times \text{Forward Rate}(-2) + 0.5302\times \text{Forward Rate}(-3) + 0.9697\times \text{Spot}(-1) + 1.6994\times \text{Spot}(-2) + 2.1103\times \text{Spot}(-3) - 1.5660$$

$$\text{Spot} = 0.9521\times \text{Forward Rate}(-1) + 1.3650\times \text{Forward Rate}(-2) - 0.6361\times \text{Forward Rate}(-3) + 1.0460\times \text{Spot}(-1) - 0.8309\times \text{Spot}(-2) - 1.6871\times \text{Spot}(-3) + 1.4076$$

For the period from 2002 (Jan) to 2013 (Feb) equations are shown below

$$\text{Forward Rate} = -0.0333\times \text{Forward Rate}(-1) + 0.0150\times \text{Forward Rate}(-2) + 0.0331\times \text{Forward Rate}(-3) + 1.0658\times \text{Spot}(-1) - 0.0230\times \text{Spot}(-2) - 0.0514\times \text{Spot}(-3) - 0.0092$$

$$\text{Spot} = 0.1047\times \text{Forward Rate}(-1) - 1.1834\times \text{Forward Rate}(-2) - 0.1138\times \text{Forward Rate}(-3) + 1.3495\times \text{Spot}(-1) - 0.6213\times \text{Spot}(-2) + 1.4209\times \text{Spot}(-3) + 0.0732$$

This result is perfectly explaining the fact that the steps taken by RBI after the U.S. downgrade in 2011 August which prompted a decline in the emerging market currencies has helped to curb the Volatility and unidirectional speculative pull. RBI took steps as stated above which has helped to prevent the spillover effect from forward market to spot market. That is why in the period 2013-2014 there is no causality relationship from forward market to spot market which was present in the earlier period. The causal relationship from spot market to forward market exists because of the technical reason as the underlying asset in forward is U.S. dollar and forward rate is apparently the future spot price. This major step is one of the reasons that there is structural break in the model.

4.4. Relationship between NDF and Forward Market

In this case also the same T-Y methodology was adopted. First optimum lag length has to be determined. The result of which is presented in Table A.14. In this case two out of three information criterias say that the optimal lag length is of two. However the serial correlation in the residuals is removed at lag of three. The result of autocorrelation LM tests is presented in Table A.1.

The model is also tested and model was found stable since all the roots are inside the unit circle as displayed in Figure 3 (see Annexure-B).

Now as per the procedure Augmented VAR model i.e. VAR (p+m) was established to examine the Granger Causality (T-Y approach). Since both the series are I(1) therefore m=1, from above analysis it is concluded that p=3. Now two exogenous variable i.e. forward exchange rate (-4) and NDF exchange rate (-4) were included. These way coefficients of these extra lags will then not be included when the subsequent Wald tests are conducted. If all the lags had been specified in the lag interval to be from 1 to 4, then the coefficients of all the four lags would be included in the Wald tests, and this would be incorrect. This is because the Wald test statistic would not have its usual asymptotic chi-square null distribution.

The Granger Causality test was performed and result is presented in Table A.16. The above results show that there exists a causal relationship from NDF market to forward market since P-value is 0.0001 but the causal relationship from forward market to NDF market is significant just at the margin with P-value of 0.0493. Again VAR (p) model was tested for structural break points and for this purpose Quandt Andrews break point test with 5% trimmed data was performed. It was found that there are 9 break points in the model at an observation number 12, 27, 33, 42, 43, 47, 48, 66, 84, 121. These observations were further verified by Chow test and it was concluded that break points do exist at these places. First period of analysis is from 2014 (Feb) to 2011 (Dec).

The VAR-Granger Causality results are presented in Table A.17. The above results clearly show that there exists no causality between the NDF market and forward market in the period of 2011 (Dec) to 2014 (Feb). This again is due to the fact that RBI intervention in the forward market has restricted many speculative players to take position in the forward market. This has helped to insulate the forward market from the off-shore forward market. Next period of study is from 28 to 50 i.e. from 2011 (Nov) to 2010 (Jan) and the results of which are presented in Table A.18. The above results show that for the period 2011 (Nov) to 2010 (Jan) there was a causal relationship between the NDF market and forward market. This is the period before RBI intervened hence the period of flow of information from Off-shore market to domestic market and vice-versa. Next period of study is from 2009 (Dec) to 2008 (Sept) i.e. from when the world was in crisis after the collapse of Lehman.

The results of which are presented in Table A.19 and for the period 68 to 84 i.e. 2008 (Aug) to 2007 (March) in Table A.20. For the above periods the results are quite consistent with the previous study i.e. there exists a causal relationship between the NDF market and forward market.

For the period 85 to 121 i.e. 2007 (March) to 2004 (March) as presented in Table A.21

This period shows that no causal relationship exists between NDF and forward market as P-value is more than 0.05, therefore enough evidence is not there to not reject the Null Hypothesis of no causality.

VAR (p) model for the recent period (Feb 2014 to Dec 2011)

$$\text{NDF} = 1.0575\times\text{NDF}(-1) - 0.4133\times\text{NDF}(-2) + 0.4251\times\text{NDF}(-3) + 0.0795\times\text{Forward Rate}(-1) + 0.2375\times\text{Forward Rate}(-2) - 0.4708\times\text{Forward Rate}(-3) + 0.1453$$

$$\text{Forward Rate} = 1.6195\times\text{NDF}(-1) - 0.5349\times\text{NDF}(-2) + 0.7260\times\text{NDF}(-3) - 0.1696\times\text{Forward Rate}(-1) + 0.0810\times\text{Forward Rate}(-2) - 0.7765\times\text{Forward Rate}(-3) + 0.0913$$

4.5. AR-GARCH-BEKK Model

4.5.1. Testing ARCH Effect

To investigate whether a GARCH family model is appropriate for modeling, the variability of the exchange rates discussed, it is important to check whether there is ARCH effect or not. The residuals of the following regression were carried for linear dependencies. The results are presented in Table A.22.

$$R_t = \beta_0 + \beta_1 R_{t-1} + \varepsilon_t$$

In all the three series, the above Null hypothesis of no ARCH effect is rejected and hence confirms the presence of ARCH effect in the series.

4.5.1.1. Model Used: AR-GARCH-BEKK

Why AR is used in place of MA because the data is showing AR effect. As we know in the MA process the maximum value of correlation between Rt and Rt-1 is 0.5 but in all the three series the correlation is more than 0.5. Hence we can conclude that it is not MA process but AR process.

Also from the correlogram of residuals as shown in Figure 4-6 (see Annexure-B), we observe that the correlation follows the geometric decay. It can be concluded that the decay in the correlation effect is geometric and hence one can use AR process to model the data.

4.5.1.2. Model 1: Relationship between Spot (1) and NDF Market (2)

The results in Table A.23 show that IaiiI>IgiiI, suggesting that the behaviour of current variance and covariance is not much affected by the value of lagged variances and covariance as the magnitude of past innovations. Moreover, the statistical significance of GARCH parameters gii is revealing the extent of volatility clustering.

The off-diagonal elements of matrices A and G capture the cross-market effects of shocks and volatility spillovers among the markets. It was found that the bi-directional link regarding transmission of shocks between spot and NDF as off-diagonal parameter a12 and a21 is statistically significant. This suggests volatility spillover from spot to NDF, since innovations initiating in one market affect volatility in the other; this is because innovation $\xi1,2_{t-1}$ and $\xi2,1_{t-1}$ does significantly affect the behaviour of h22 and h11 respectively. Finally, there is also a strong evidence of bi-directional volatility persistence linkages between spot and forward, as both the coefficient g12 and g21 are significant.

Similarly, covariance equation is also significant in returns. This significant conditional covariance together with the spillover effect noticeably implies that both the markets are influenced by common information. The model was found stable as there was no heteroskedasticity left in the residuals and roots of AR equation are also positive and less than 1. The results of the ARCH test are shown in the Table A.24. As P-value is greater than 0.05 so we fail to reject the Null Hypothesis of no ARCH effect.

Table 1: Roots of Inverted AR Characteristic Polynomial

Spot	0.830
NDF	0.826

4.5.1.3. Model 2: Relationship between NDF (1) and Forward (2) Market

In Table A.25, the value of coefficients IaiiI = IgiiI suggests that the behavior of current variance and covariance is as much affected by the value of lagged variances and covariance as the magnitude of past innovations. The values of the coefficient are also high of the range of 0.5 which implies that the bi-directional relationship between NDF market and forward market is quite strong as compared to the other markets.

The model was found stable as there was no ARCH effect in the residuals as shown in Table A.26.As P-value is greater than 0.05 so we fail to reject the Null Hypothesis of no ARCH effect and roots of the AR polynomial is also positive and less than 1 as shown in the Table 2.

Table 2: Roots of Inverted AR Characteristic Polynomial

Spot	0.82
NDF	0.82

4.5.1.4. Model 3: Relationship between Spot (1) and Forward (2)

In Table A.27 we have observed that the magnitude of $g_{12} > g_{21}$ which implies that the volatility persistence spill over from spot to forward is greater than from forward to spot similarly magnitude of a_{21} is greater than a_{12} which implies that the spillover of innovations from Forward to spot is greater than from spot to forward.

Table 3: Roots of Inverted AR Characteristic Polynomial

Spot	0.83
Forward	0.83

The model was found stable as there was no ARCH effect in the residuals as shown in Table A.28.As P-value is greater than 0.05 so we fail to reject the Null Hypothesis of no ARCH effect and roots of the AR polynomial is also positive and less than 1 as shown in the Table 3.

5. Conclusions

In this study, the inter-relationship between three currency markets was analyzed. It was found that the relationship between all the three markets is quite dynamic owing to the policy measures taken by RBI to curb the volatility in 2012. This impact of RBI intervention and various macroeconomic shocks such as the crash of Lehman Brothers is corroborated by using structural tests like Quandt Andrews and chow test. The period for analysis is separated from one structural break point to other structural break point and it was found that the relationship among periods doesn’t remain same. This study adds more knowledge to the existing body of knowledge to understand the impact of various shocks on the relationship between the markets which no other study has considered.

The split analysis has given an interesting observation that for the period 2008 (August) to 2014 (Feb) there is two way causal relationship but for the period 2002 (Jan) to 2008 (Aug) there is only unidirectional causal relationship i.e. from spot to NDF but not vice-versa. On 2008 (Sept) Lehman Bros. collapsed and the inter-connected world was in financial crisis with the value of currencies falling and Indian rupee also started feeling pressure till RBI intervened. This was structural change in the market from which the observation number 67 was rightly predicted in this analysis. The slew of measures taken by RBI has created constraints in the domestic forward market and has therefore propelled market participants to take position in the off-shore market. It can be observed that the global turnover of Indian rupee has increased from 23.6 billion U.S. dollars in 2007 to 52.8 billion U.S. dollars in 2013 i.e. an increase of 123% which is a very huge increase as compared to all the emerging markets except china.

The recent increase in the depth of the market can be the reason of its influence to the spot market. Again in 2012, many restrictions were put in place for example: the facility of cancellation and rebooking of forward contracts by residents was withdrawn. It was also decided that all forward contracts booked by the FIIs to hedge currency risk, once cancelled, cannot be rebooked by RBI to wipe out the speculative attacks, this has also helped to protect the domestic spot market against external shock. This can be the reason that why there is no causal relationship in this period (2013-2014) from forward market to the spot market.

However, the relationship between NDF and forward market is more dynamic than the other markets because of the evolving nature of these markets. Till 2007, there was no causal relationship between the markets but it was only after the expansion of both the markets with an increase in turnover and evolution of more sophisticated products that the markets started passing information to each other. But in the period 2012-2014 there was again no causal relationship owing to the measures taken by RBI to curb the speculative attacks by the market participants in 2012.

It is also observed from AR-GARCH-BEKK model 1, spot and NDF market, and model 3, spot and Forward market, spot market dominates as far as volatility persistence spillover is concerned, as in both the model the magnitude of $g12>g21$. Talking of innovations spillover is concerned it is other way around as magnitude of $a21> a12$ and also the sign of a21 is negative that means any new innovation or news in Forward or NDF market has a negative impact on the spot market. Whereas NDF market and Forward market have same impact on each other as the magnitude of $g12=g21$ and $a12=a21$. This means that both the markets are dynamically impacting each other in terms of volatility persistence spillover and information spillover.

This study concludes that steps taken by RBI were helpful in preventing the volatility spill-overs from NDF market and Forward market to spot market. Also, it prevented spill-over in forward market from NDF market. Going forward it seems Rupee will become more international and insulation of domestic currency market from speculative attacks in the off-shore market will become more difficult. RBI can coordinate with central banks of Singapore, Hongkong, UAE etc. where rupee is speculated highly to enforce partial convertibility regime of rupee in the off-shore market as well.

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Annexure-A

Tables

Table A.1: The Augmented Dickey-Fuller Test without Intercept and without Trend

Series		ADF Test Statistic	P-value
LnSpot	Level	-0.8301	0.3470
	First Difference	-8.4600	0.0000
LnNDF	Level	-0.8052	0.3656
	First Difference	-8.6200	0.0000
LnFW	Level	-0.8386	0.3510
	First Difference	-9.8530	0.0000

Table A.2: The Augmented Dickey-Fuller Test with Intercept and without Trend

Series		ADF Test Statistic	P-value
LnSpot	Level	-2.8128	0.0589
	First Difference	-8.4810	0.0000
LnNDF	Level	-2.7140	0.0740
	First Difference	-8.6440	0.0000
LnFW	Level	-2.7440	0.0691
	First Difference	-9.8690	0.0000

Table A.3: The Augmented Dickey-Fuller Test with Intercept and with Trend

Series		ADF Test Statistic	P-value
LnSpot	Level	-2.2995	0.4312
	First Difference	-8.6750	0.0000
LnNDF	Level	-2.1490	0.5135
	First Difference	-8.8480	0.0000
LnFW	Level	-2.1351	0.5215
	First Difference	-10.0830	0.0000

Table A.4: Lag Length Criteria (Spot Market and NDF Market)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	722.3893	NA	1.00E-07	-10.4404	-10.3980	-10.4232
1	1223.1750	979.7977	7.48E-11	-17.6402	-17.5129	-17.5885
2	1256.8640	64.9381	4.87E-11	-18.0705	-17.8584×	-17.9843×
3	1262.2590	10.2423×	4.77e-11×	-18.0907×	-17.7938	-17.9700
4	1264.0720	3.3893	4.92E-11	-18.059	-17.6772	-17.9039
5	1267.1090	5.5906	4.99E-11	-18.0451	-17.5784	-17.8554
6	1269.3530	4.0646	5.13E-11	-18.0196	-17.4681	-17.7955
7	1272.1190	4.9300	5.22E-11	-18.0017	-17.3654	-17.7431
8	1272.5100	0.6866	5.51E-11	-17.9494	-17.2282	-17.6563

Table A.5: Autocorrelation LM test (Spot Market and NDF Market)

Lags	LM-Stat	P-value
1	4.5911	0.3319
2	5.8083	0.2139
3	0.4714	0.9762
4	4.7534	0.3135

Table A.6: VAR Granger Causality (Spot Market and NDF Market)

VAR Granger Causality/Block Exogeneity Wald Tests
Sample 1-146

Dependent Variable: NDF			
Excluded	**Chi-sq**	**df**	**P-value**
Spot	11277.4410	3	0.0000
Dependent Variable: Spot			
Excluded	**Chi-sq**	**df**	**P-value**
NDF	5.4458	3	0.1419

Table A.7: VAR Granger Causality (2008 (Aug.) to 2014 (Feb.), (Spot Market and NDF Market)

VAR Granger Causality/Block Exogeneity Wald Tests
Sample 1-66

Dependent Variable: NDF			
Excluded	**Chi-sq**	**df**	**P-value**
Spot	5948.2402	3	0.0000
Dependent Variable: Spot			
Excluded	**Chi-sq**	**df**	**P-value**
NDF	8.4936	3	0.0368

Table A.8: VAR Granger Causality (2002 (Jan.) to 2008 (Aug.), (Spot Market and NDF Market)

Dependent Variable: NDF	Sample: 68 146		
Excluded	**Chi-sq**	**Df**	**P-value**
Spot	4056.4732	3	0.0000
Dependent Variable: Spot	Sample: 68 146		
Excluded	**Chi-sq**	**Df**	**P-value**
NDF	0.3327	3	0.9538

Table A.9: Lag Length Criteria (Spot and Forward Market)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	722.799	NA	1.24E-07	-10.224	-10.1823	-10.207
1	1114.87	767.468	5.06E-10	-15.728	-15.6032×	-15.678×
2	1118.13	6.269	5.11E-10	-15.718	-15.5092	-15.633
3	1125.11	13.276×	4.90e-10×	-15.760×	-15.4676	-15.641
4	1127.47	4.409	5.02E-10	-15.737	-15.3607	-15.584
5	1130.29	5.208	5.11E-10	-15.720	-15.2603	-15.534

Table A.10: Autocorrelation LM Test (Spot and Forward Market)

VAR Residual Serial Correlation LM Tests Null Hypothesis: No Serial Correlation at Lag Order h

Lags	LM-Stat	P-value
1	5.1229	0.2749
2	5.6447	0.2273
3	5.1579	0.2715
4	5.0986	0.2773

Table A.11: VAR Granger Causality (Spot and Forward Market)

VAR Granger Causality/Block Exogeneity Wald Tests: Included Observations: 142

Dependent Variable: Forward Rate			
Excluded	**Chi-sq**	**df**	**P-value**
Spot	1363.2501	3	0.0000
Dependent Variable: Spot			
Excluded	**Chi-sq**	**df**	**P-value**
Forward Rate	13.1128	3	0.0044

Table A.12: VAR Granger Causality (2013 (Jan.) to 2014 (Feb.) : Spot and Forward Market

VAR Granger Causality/Block Exogeneity Wald Tests

Dependent Variable: Forward Rate			
Excluded	**Chi-sq**	**df**	**P-value**
Spot	51900.05	3	0.0000
Dependent Variable: Spot			
Excluded	**Chi-sq**	**df**	**P-value**
Forward Rate	0.1507	3	0.9851

Table A.13 VAR Granger Causality (2002 (Jan.) to 2013 (Feb.) (Spot and Forward Market)

VAR Granger Causality/Block Exogeneity Wald Tests			
Dependent Variable: Forward Rate			
Excluded	**Chi-sq**	**Df**	**P-value**
Spot	1847.01	3	0.0000
Dependent Variable: Spot			
Excluded	**Chi-sq**	**Df**	**P-value**
Forward Rate	16.66	3	0.0008

Table A.14: Lag Length Criteria (NDF and Forward Market)

Lag	Log L	LR	FPE	AIC	SC	HQ
0	881.13	NA	0.00	-12.30	-12.25	-12.28
1	1120.93	469.54	0.00	-15.59	-15.47×	-15.54
2	1129.44	16.41×	5.44e-10×	-15.66×	-15.45	-15.57×
3	1133.38	7.50	0.00	-15.66	-15.37	-15.54

Table A.15: Autocorrelation LM Test (NDF and Forward Market)

Lags	LM-Stat	P-value
1	9.3628	0.0526
2	9.3994	0.0519
3	9.8205	0.0436
4	5.5007	0.2397

Table A.16: VAR Granger Causality (NDF and Forward Market)

VAR Granger Causality/Block Exogeneity Wald Tests Included observations: 142			
Dependent Variable: NDF Rate			
Excluded	**Chi-sq**	**df**	**P-value**
Forward	7.8459	3	0.0493
Dependent Variable: Forward			
Excluded	**Chi-sq**	**df**	**P-value**
NDF Rate	21.0860	3	0.0001

Table A.17: VAR Granger Causality (2011 (Dec.) to 2014 (Feb.)) (NDF and Forward Market)

VAR Granger Causality/Block Exogeneity Wald Tests
Sample:1 27, Included Observations: 23

Dependent Variable: NDF			
Excluded	**Chi-sq**	**df**	**P-value**
Forward Rate	1.4876	3	0.6851
Dependent Variable: Forward Rate			
Excluded	**Chi-sq**	**df**	**P-value**
NDF	6.0280	3	0.1103

Table A.18: VAR Granger Causality (2011(Nov.) to 2010(Jan.)) (NDF and Forward Market)

VAR Granger Causality/Block Exogeneity Wald Tests
Sample: 28 50, Included Observations: 23

Dependent Variable: NDF			
Excluded	**Chi-sq**	**df**	**P-value**
Forward Rate	27.3378	3	0.0000
Dependent Variable: Forward Rate			
Excluded	**Chi-sq**	**df**	**P-value**
NDF	18.7352	3	0.0003

Table A.19: VAR Granger Causality (2008 (Sept.) to 2009 (Dec.)) (NDF and Forward Market)

VAR Granger Causality/Block Exogeneity Wald Tests
Sample: 51 67, Included observations: 17

Dependent Variable: NDF			
Excluded	**Chi-sq**	**df**	**P-value**
Forward Rate	10.5228	3	0.0146
Dependent Variable: Forward Rate			
Excluded	**Chi-sq**	**df**	**P-value**
NDF	9.3775	3	0.0247

Table A.20: VAR Granger Causality (2007(Mar.) to 2008 (Aug) (NDF and Forward Market)

VAR Granger Causality/Block Exogeneity Wald Tests
Sample: 68 84

Dependent Variable: NDF			
Excluded	**Chi-sq**	**df**	**P-value**
Forward Rate	9.1084	3	0.0279
Dependent Variable: Forward Rate			
Excluded	**Chi-sq**	**df**	**P-value**
NDF	9.9752	3	0.0188

Table A.21: VAR Granger Causality (2004 (Mar.) to 2007 (March) (NDF and Forward Market)

VAR Granger Causality/Block Exogeneity Wald Tests
Sample: 85 121

Dependent Variable: NDF			
Excluded	**Chi-sq**	**df**	**P-value**
Forward Rate	2.2257	3	0.5269
Dependent Variable: Forward Rate			
Excluded	**Chi-sq**	**df**	**P-value**
NDF	1.6777	3	0.6419

Table A.22: Parameters of the Regression and LM Statistic of ARCH Test

Return Series	**β0**	**β1**	**LM-Test statistic**	**P-value**
Spot	8.48e-05	0.82	225.97	0.00
Forward	8.54e-05	0.82	216.39	0.00
NDF	8.54e-05	0.82	216.51	0.00

Table A.23: Parameters of AR-GARCH-BEKK Model of spot and NDF Market

		Coefficient	Std. Error	z-statistic	P-value
	MU(1)	0.0000	0.0000	-0.3400	0.7300
	MU(2)	0.0000	0.0000	-0.2700	0.7900
	TETA(1)	0.4900	0.0100	54.1800	0.0000
	TETA(2)	0.4900	0.0100	52.7600	0.0000
C11	OMEGA(1)	0.0000	0.0000	-15.4000	0.0000
g11	BETA(1)	0.4900	0.0000	662.9200	0.0000
g21	BETA(3)	0.3800	0.0100	52.1500	0.0000
a11	ALPHA(1)	1.2100	0.1100	10.8500	0.0000
a21	ALPHA(3)	-0.6900	0.1100	-6.4800	0.0000
c22	OMEGA(3)	0.0000	0.0000	39.4000	0.0000
c21	OMEGA(2)	0.0000	0.0000	-15.2200	0.0000
g22	BETA(4)	0.3700	0.0100	52.7500	0.0000
g12	BETA(2)	0.4900	0.0000	651.2700	0.0000
a22	ALPHA(4)	0.2000	0.1100	1.9100	0.0600
a12	ALPHA(2)	0.3200	0.1100	2.8600	0.0000

Table A.24: Stability of the Model 1

Heteroskedasticity Test ARCH	LM Statistic	P-value
Spot	1.33	0.25
NDF	0.69	0.40

Table A.25: Parameters of AR-GARCH-BEKK Model of NDF Market and Forward Market

		Coefficient	Std. Error	z-statistic	P-value
	MU(1)	0.0001	0.0001	0.4953	0.6204
	MU(2)	0.0001	0.0001	0.5224	0.6014
	TETA(1)	0.0999	0.0101	9.8700	0.0000
	TETA(2)	0.0999	0.0101	9.8772	0.0000
	OMEGA(1)	0.0001	0.0000	2102	0.0000
g11	BETA(1)	0.5000	0.0000	3350000000	0.0000
g21	BETA(3)	0.4993	0.0000	65671	0.0000
a11	ALPHA(1)	0.5001	0.0553	9.0475	0.0000
a21	ALPHA(3)	0.5002	0.0526	9.5093	0.0000
c22	OMEGA(3)	0.0000	0.0000	-201.9	0.0000
c21	OMEGA(2)	0.0001	0.0000	597	0.0000
g22	BETA(4)	0.4994	0.0000	87858	0.0000
g12	BETA(2)	0.5000	0.0000	3830000000	0.0000
a22	ALPHA(4)	0.5001	0.0537	9.3092	0.0000
a12	ALPHA(2)	0.4999	0.0566	8.8356	0.0000

Table A.26: Stability of the Model 2

Heteroskedasticity Test ARCH	LM statistic	P-value
NDF	0.696	0.40
Forward	0.694	0.40

Table A.27: Parameters of AR-GARCH-BEKK Model of Spot (1) and Forward (2)

		Coefficient	Std. Error	z-statistic	P-value
	MU(1)	0.0220	0.0011	20.2991	0.0000
	MU(2)	0.0226	0.0011	20.8991	0.0000
	TETA(1)	0.4693	0.0358	13.1054	0.0000
	TETA(2)	0.4908	0.0358	13.7155	0.0000
	OMEGA(1)	-0.0015	0.0047	-0.3142	0.7533
g11	BETA(1)	0.7045	1.0687	0.6592	0.5097
g21	BETA(3)	-0.2534	0.9436	-0.2685	0.7883
a11	ALPHA(1)	0.3698	0.6229	0.5937	0.5527
a21	ALPHA(3)	0.6289	0.5396	1.1654	0.2439
c22	OMEGA(3)	-0.0002	0.0125	-0.0138	0.9890
c21	OMEGA(2)	-0.0006	0.0071	-0.0834	0.9336
g22	BETA(4)	-0.2598	0.9472	-0.2743	0.7838
g12	BETA(2)	0.7050	1.0680	0.6601	0.5092
a22	ALPHA(4)	1.2824	0.5321	2.4101	0.0159
a12	ALPHA(2)	-0.2816	0.5918	-0.4759	0.6341

Table A.28: Stability of the Model 3

Heteroskedasticity Test ARCH	LM statistic	P-value
Spot	1.33	0.24
Forward	0.69	0.40

Annexure- B

Figures: Roots of Characteristics Equation and Correlograms

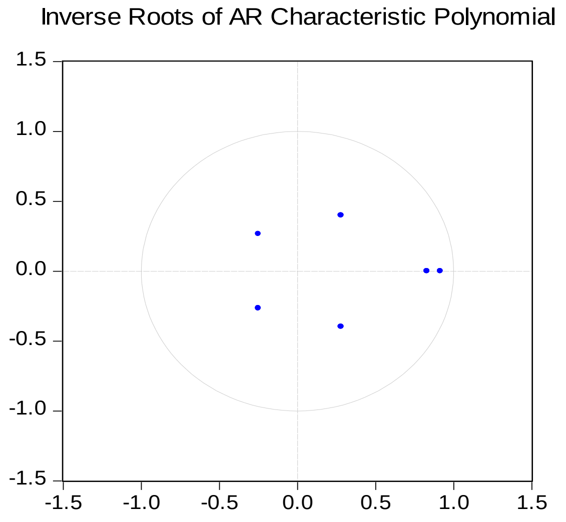

Figure 1: Spot Market and NDF Market

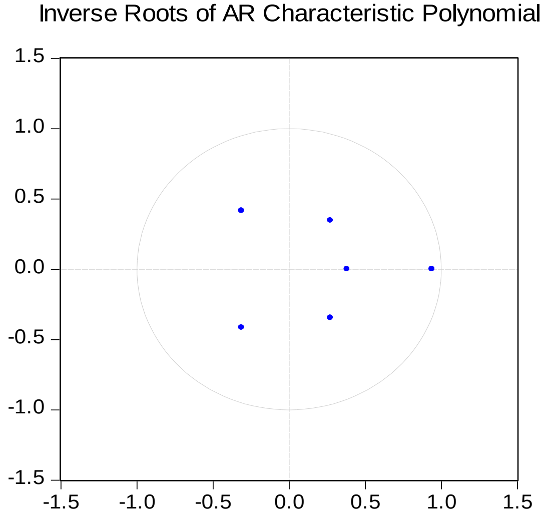

Figure 2: Spot and Forward Market

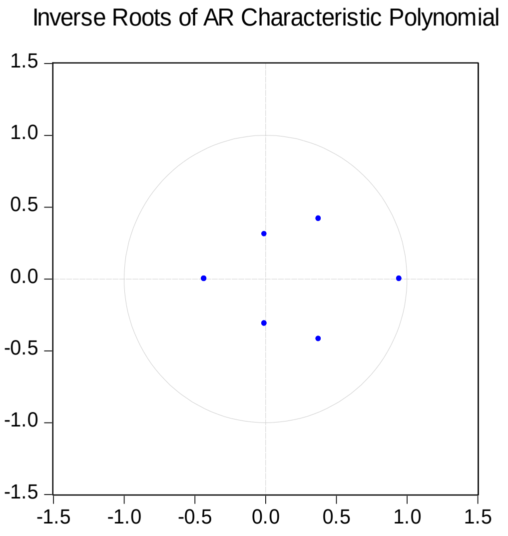

Figure 3: (NDF and Forward Market)

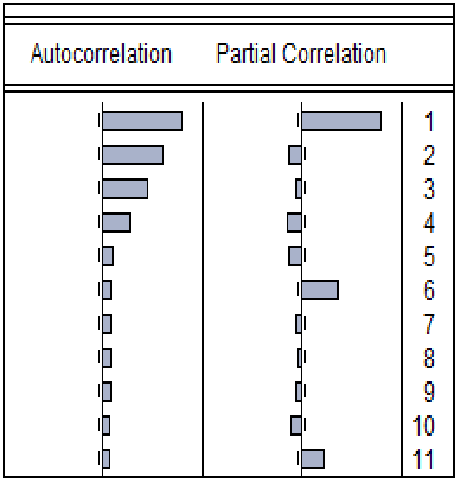

Figure 4: Correlogram of Spot Returns

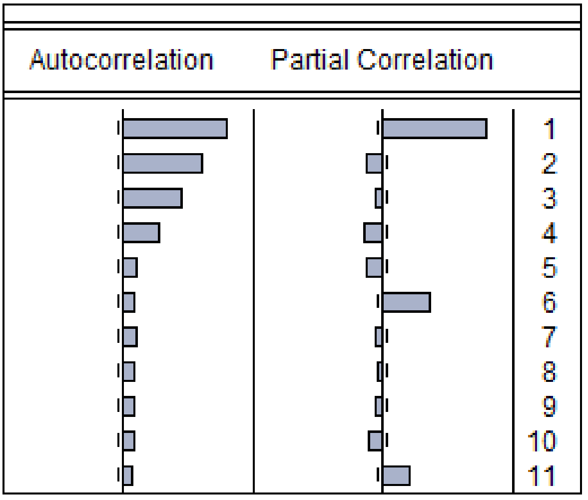

Figure 5: Correlogram of Forward Return

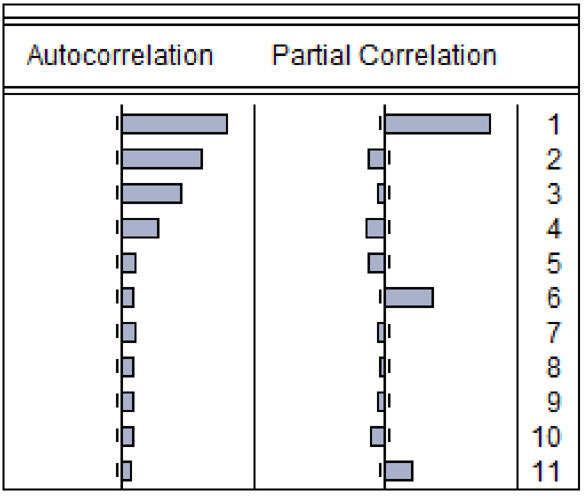

Figure 6: Correlogram of NDF Return