Spread, Volatility and Monetary Policy: Emprical Evidences from the Indian Overnight Money Market

Saurabh Ghosh and Indranil Bhattacharyya*

Abstract

This study uses generalized autoregressive conditional heteroskedasticity (GARCH) model (Bollerslev, 1986) to estimate conditional volatility in Indian money market. It finds that the spread in the money market was positively related to conditional volatility. However, this relation has undergone a change in recent years and lagged spread plays an important role in modeling spread along with conditional variance of call rate. Regarding monetary policy and money market volatility, the empirical findings indicate that expansionary monetary policy reduces volatility of spread and weighted call rate. Among individual policy instruments, announcement of CRR changes have a negative impact on the volatility of spread and call rate. The other policy variables like Bank Rate, repo and reverse repo rates have mixed impact on volatility of call rate and spread.

Key words: GARCH model, market microstructure, determinants of spread, monetary policy.

JEL Classifications: G13, G24,

* The authors are Assistant Advisers in the Financial Markets Department and Monetary Policy Department, respectively, of the Reserve Bank of India. They are grateful to Shri Chandan Sinha, Sri H. S. Mohanty for their comments during the presentation of the same in the Financial Markets Department. Views expressed in this paper are those of the authors and not of the institution to which they belong. Other usual disclaimers apply.

Spread, Volatility and Monetary Policy:
Emprical Evidences from the Indian Overnight Money Market

Saurabh Ghosh and Indranil Bhattacharya

Introduction

The money market is the fulcrum of the financial system on which the monetary operations are conducted by the central bank in its pursuit of monetary policy objectives. It is now well established that central banks operate mainly at the short end of the money market and policy impulses get transmitted at the longer end of the financial system through the term structure of interest rates. Globally, operating procedures of monetary policy have converged on an increasing role of interest rates in the transmission mechanism. The sharper focus on interest rates as the operating target has gone hand in hand with a tendency to move towards targeting short-term interest rates. As a corollary, the overnight rate has emerged as the most commonly pursued operating target in the conduct of monetary policy[1]. The targeting of short-term interest rates is fully consistent with a market oriented approach whereby information about the expectations of future movements in interest rates is extracted from the prevailing market rates.

Central banks realise its monetary policy objectives by careful management of liquidity conditions and facilitate money market transactions while ensuring stable market conditions. As excessive money market volatility could provide confusing signals to the market about the stance and intent of monetary policy, it is critical to ensure orderly market behaviour from a financial stability perspective. A well-functioning money market is, therefore, essential for conducting indirect, market-based monetary policy operations and for providing the necessary liquidity for a market in government and corporate bonds.

Development of liquidity in the inter-bank market - the market for short-term funds amongst banks - provides the basis for growth and increased liquidity in the broader money market, including secondary market for Treasury Bills and private sector money market instruments. Successful management of market liquidity and effective regulation of money market conditions requires modulation of volatility in

[1] According to a survey conducted by the BIS (2007), 12 out of a total of 17 central banks/monetary authorities, target the overnight/short-term money market rate and/or modulate liquidity in the overnight/short-term money market as the central plank of their monetary policy operations.

order to smoothen short-term interest rates. In reality, however, money markets, particularly those in emerging market economies, are prone to volatile behaviour of short term rates which calls for a detailed analysis of market microstructure issues.

Market microstructure analyses as to how specific trading mechanisms affect the price formation process. It studies the process by which investors' latent demands are ultimately translated into prices and volumes. In particular, as information is important in decision-making, market outcome is highly sensitive to the assumed information structure. Research in this field has mainly focussed on the intertwined relationships between price volatility, liquidity (popularly proxied by bid-ask spreads[2] and trading volumes), price discovery and market design. Market microstructure models relate price changes to order flow and provide deep insights on the determinants of a deep and liquid market.

Research in money market microstructure has mainly focussed on developed markets. In the context of the US, Baumik and Coondoo (2003) tries to explain the spread in rates among money market instruments of different maturities by including a moderately long term measure of interest rate volatility in the specification. In contrast, this paper examines the case of an emerging economy, *viz.* India, where the transmission mechanism and operating procedure of monetary policy exhibit dynamics that are significantly different from more mature markets. Specifically, this paper has two objectives. First, it attempts to model the relationship between spread and volatility in the overnight segment of the money market. Second, it tries to assess the impact of various monetary policy instruments used by the Reserve Bank on market volatility and draw policy perspectives for the future.

The structure of the paper is as follows. Section-I presents a brief review of the literature on money market microstructure. Some stylised facts about the Indian money market are presented in Section-II. The data and methodology of the study along with the empirical results and its policy implications are presented in Section-III. Concluding observations are presented in Section-IV.

[2] In the Treasury Bills market, the bid-ask spread is found to be the best measure of liquidity (Fleming, 2003).

I. *Received Literature*

The initial theoretical literature on market microstructure tried to explain the bid-ask spread through the use of two approaches. The first *viz*., the inventory-based explanations beginning with Garman (1976) highlighted the importance of transaction costs in determining the bid-ask spread. The second, beginning with Bagehot (1971), emerged to explain market prices through the role of asymmetric information. In this approach, which draws heavily from the theory of adverse selection, new information gets reflected into prices as a result of the trading behaviour of informed and uninformed traders such that even in competitive markets without explicit transaction costs, spreads would exist.

The existing empirical literature on money market microstructure is rather limited and more recent in origin in contrast to bond, equity or foreign exchange markets. Most studies follow a traditional macroeconomic approach or look at the time series properties of short rates at a daily (or longer) frequency for the US fed funds market (Spindt and Hoffmeister, 1988; Griffiths and Winters, 1995, Hamilton, 1996) and the euro overnight market (Perez-Quiros and Rodriguez, 2000, Bindseil and Seitz, 2001).

In the context of the US fed funds market, Furfine (1999) describes the size, concentration, intra-day timing and analyses bank relationship patterns, particularly with respect to size of institutions. Angelini (2000) discusses the implications of timing of overnight transactions in the Italian electronic deposit market during periods of uncertain liquidity. Cassola and Morana (2006*a*, 2006*b*) estimate the factors that explain the volatility and its persistence in the overnight segment of the euro money market, which shows repetitive intra-day, daily and monthly patterns that can be explained by market microstructure.

There is an earlier literature that relates the behaviour of overnight inter-bank market rates by a representative bank to monetary policy operational procedures and money market accounting conventions (Ho and Saunders, 1985; Campbell, 1987). More recently, Bartolini *et al*. (1998) introduce a role for central bank liquidity provision. Perez-Quiros and Rodriguez (2000) analyse the behaviour of a representative bank during the minimum reserve maintenance period when there is a symmetric pair of standing facilities.

In the euro area, studies on the microstructure of the money market have shown that it is heavily influenced by the institutional environment of the ECB and its monetary policy operations (Hartmann *et al*, 2001). This study analyses the intra-week and intra-day behaviour of bid-ask spreads, volatility, quoting frequency and trading volume and finds that overnight market rate volatility and spreads are relatively high on days with ECB monetary policy announcements, particularly during mid-day when the ECB's interest rate decisions are released. Similarly, recent work by Prati *et al.* (2003), Bartolini and Prati (2003a), and Bartolini *et al.* (2002) document the close connection between the operational frameworks of monetary policy and the behaviour of overnight interest rates in the US, the euro area and other G-7 countries. Bartolini and Prati (2003b) demonstrate that short-term interest rate volatility also reflects differences in central banks commitment to interest rate smoothing. Ayuso *et al.* (1997) show the relevance of institutional details in influencing money market rates and their volatility.

One related strand in the literature has investigated how well the markets are able to anticipate the monetary policy actions of the Fed (Krueger and Kuttner 1996; Poole and Rasche 2000; Kuttner 2001; Demiralp and Jorda 2004) and the ECB (Gaspar *et al*. 2001; Perez-Quiros and Sicilia 2002; Ross 2002; Bernoth and von Hagen 2004), drawing on the methods of extracting market expectations from financial instruments (Sodartend and Svennson, 1997). Bernhbarden and Kloster (2002) and Coppel and Connolly (2003) provide cross-country comparison of some OECD countries. The main finding of this literature is that market participants in advanced economies presently, given the increased public availability of information about how monetary policy decisions are taken, are better able to anticipate monetary policy decisions than in the 1980s or early 1990s.

II. *Indian Money Market: Some Stylized Facts*

II.1 *Money Market Operations*

The instruments used by the RBI are daily repo/reverse repo transactions under the Liquidity Adjustment Facility (LAF), standing facilities and reserve requirements. Daily open market operations under the LAF are used to manage temporary liquidity and guide interest rates in the desired direction. Additional liquidity is made available through the standing facility of refinance given to banks, as and when required, for providing export credit. The RBI also has the discretion to conduct longer term repo auctions at fixed rate or at variable rates depending on market conditions and other relevant factors. Finally, the RBI also conducts Market Satbilisation Scheme (MSS) auctions to modulate liquidity conditions which have an impact over a longer period. This is done on a weekly basis against the issue of Treasury bills and dated securities.

Under the LAF which became operational since June 2000, two policy rates, namely the repo[3] and the reverse repo rates are specified for lending and borrowing of funds by the RBI. By accepting repo bids from banks and primary dealers, liquidity is injected while liquidity is absorbed from the banking system through the acceptance of reverse repo bids. These operations are conducted regularly by means of daily tenders at fixed rates for repo transactions with an overnight maturity under a uniform price auction. In this procedure, the RBI determines the overall quantity to be absorbed/injected on the basis of its own assessment of the liquidity needed by the banking system. The RBI can choose to absorb less liquidity from the banking system, either by reducing the total amount absorbed or by raising the LAF rate, which is done, however, only at discreet intervals.

In view of the objective of absorbing liquidity of a more enduring nature, the Reserve Bank introduced the Market Stabilisation Scheme (MSS) as an instrument of sterilisation, by issue of Treasury-bills and dated securities under MSS in March, 2004. The proceeds of MSS are held by the Government in a separate identifiable cash account maintained and operated by RBI. The amounts credited into the MSS account are appropriated only for the purpose of redemption and/or buy back of the Treasury Bills and/or dated securities issued under the MSS. The auctions are conducted by the RBI who decides the amount, tenor, modalities and the timing of issue.

II.2 *Money Market Structure*

The last two decades have witnessed substantial developments in the Indian money market in terms of introduction of newer instruments, building up of appropriate market infrastructure and strengthening of prudential practices. The broad policy objectives are to ensure stability, minimise default risk and achieve a balanced development of various segments through introduction of new instruments,

[3] Repos are financial instruments for the temporary exchange of cash against securities with a transfer of ownership.

broadening of participants' base and strengthening of institutional infrastructure. The policy thrust given to the growth of the collateralised segment has improved options for liquidity management while reducing risks. Developments in institutional and technological infrastructure have also helped in improving transparency, facilitating price discovery process and providing avenues for better liquidity and risk management.

In India, money market instruments mainly include call or notice money, term money, certificates of deposit, usance bills, commercial bills, commercial papers, inter-corporate deposits and any other debt instruments of original or initial maturity upto one year as specified by the Reserve Bank from time to time. In this paper, we focus on the overnight inter-bank deposit market, which is of particular interest to the central bank for liquidity management. Earlier, unsecured overnight call money trading was dominant over any of the other segments by a large margin. However, with concerted efforts being made by the Reserve Bank over the last few years to develop the collateralised segment through the introduction of market repo and Collaterised Borrowing and Lending Obligations (CBLO), the volume in the collateralized segment has overtaken the uncollateralized segment (Table-1). Gradually, the CBLO market is becoming the preferred option for money market participants.

Table-1: Shares in Money Market

(per cent)

Year	Call	Market Repo	CBLO
2003-04	55.67	41.59	2.74
2004-05	31.88	51.84	16.29
2005-06	30.45	35.77	33.78
2006-07	24.61	38.92	36.47

III. *Empirical Analysis*

Money market liquidity is typically based on three dimensions, *viz.*, tightness, depth and resilience. Tightness refers to how far transaction prices diverge from the average market price, *i.e.,* the general costs incurred irrespective of the level of market prices. One of the most frequently used measure of tightness is the bid-ask spread *i.e.,* the differential between the lowest bid quote (the price at which a market participant is willing to borrow in the inter-bank market) and the highest ask quote (at which the agent is willing to lend), representing an operational measure of the price of the agents' services in the absence of other transaction costs. Depth denotes either the volume of trades possible without affecting prevailing market prices, or the amount of orders on the order books of market makers at any time period. Depth is reflected by the maximum size of a trade for any given bid-ask spread. The turnover ratio, *i.e.,* the turnover in the money market as a percentage of total outstanding money market transactions, also provides an additional measure of the depth of the market[4]. Resilience refers either to the speed with which price fluctuations resulting from the trade are dissipated, or the speed with which imbalances in order flows are adjusted. While there is no appropriate measure of resilience, one approach is to examine the speed of the restoration of normal market conditions (such as the bid-ask spread and order volume) after transactions are completed. Other measures such as the number and volume of trades, trading frequency, turnover ratio, price volatility and the number of market participants are often regarded as readily available proxies for market liquidity. Thus, a relatively more liquid money market, *ceteris paribus*, requires less time to execute a transaction, operates on a narrower bid-ask spread, supports higher volumes for a given spread and requires relatively less time for the restoration of the "normal" bid-ask spread following a high value transaction.

III.1 *Data and Methodology*

For the empirical exercise, we look at the overnight segment of the money market. In the overnight segment, we use the daily data on weighted average call money rate and spread of the Mumbai Inter-bank Bid Rate (MIBID) and Mumbai Inter-bank Offer Rate (MIBOR) for the overnight money market from April 1, 1999 till December 31, 2006. The data of daily turnover in the overnight market, however, is only available from October 1, 2002. Major features of the data on bid-ask spread in the overnight market is presented in Table-2 (also see Chart 1). Furthermore, in order to assess the impact of monetary policy measures, we also take into account the changes in major monetary policy instruments of the Reserve Bank *viz.*, repo rate, reverse repo rate, Bank Rate and cash reserve ratio (CRR) changes used during this period.

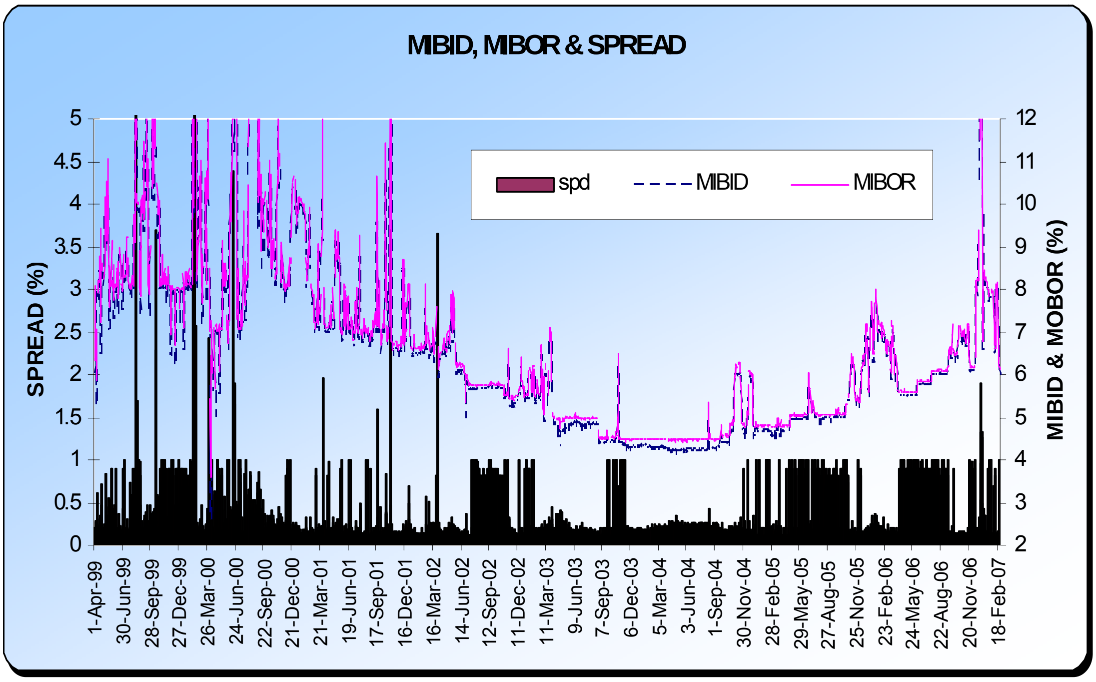
[4] A more accurate measure of market depth would take into account both actual transactions and potential transactions volume arising out of portfolio adjustments.

Table-2: Bid-Ask Spread in the Inter-Bank Money Market (per cent)

	1999-2000			2000-01			2001-02			2002-03		
	MIBID	MIBOR	Spread	MIBID	MIBOR	Spread	MIBID	MIBOR	Spread	MIBID	MIBOR	Spread
Average	8.82	9.12	0.31	9.03	9.32	0.29	7.08	7.31	0.23	5.83	5.97	0.14
S.D	1.68	2.23	0.67	2.13	2.34	0.34	1.29	1.57	0.39	0.48	0.51	0.06
C.V	0.19	0.24	2.19	0.24	0.25	1.17	0.18	0.22	1.72	0.08	0.09	0.43
Max	19.76	27.03	7.68	21.55	25.94	4.39	13.47	16.54	3.65	7.70	7.95	0.44
Min	5.26	5.88	0.06	2.60	3.60	0.06	6.29	6.47	0.08	4.89	5.06	0.06
	2003-04			**2004-05**			**2005-06**			**2006-07**		
	MIBID	MIBOR	Spread	MIBID	MIBOR	Spread	MIBID	MIBOR	Spread	MIBID	MIBOR	Spread
Average	4.53	4.71	0.17	4.56	4.76	0.20	5.54	5.68	0.14	6.96	7.24	0.28
S.D	0.26	0.27	0.05	0.46	0.44	0.06	0.80	0.84	0.06	4.08	5.05	1.04
C.V	0.06	0.06	0.30	0.10	0.09	0.30	0.14	0.15	0.42	0.59	0.70	3.76
Max	6.19	6.48	0.41	6.03	6.30	0.42	7.72	8.00	0.36	58.15	68.27	11.81
Min	4.19	4.41	0.07	4.11	4.41	0.08	4.67	4.78	0.06	4.80	5.21	0.07

Source: FIMMDA-NSE

Chart 1



From the data, it is pertinent to make few observations. First, the mean spread has been declining till 2005-06 but has increased significantly in 2006-07. Second, volatility, as measured by coefficient of variation (C.V) of the bid-ask spread, has gone up alarmingly during 2006-07 (Table-2). It is interesting to note that there have been several monetary policy tightening announcements during 2006-07 and *prima facie* it appears that the overnight market has reacted significantly to these developments. Therefore, it would be interesting to look at the response of bid-ask spreads to various monetary policy measures of the RBI, which is attempted in the second part of the empirical exercise.

The methodology of the empirical exercise concerns with the estimation of a generalised autoregressive conditional heteroskedasticity (GARCH) model due to Bollerslev (1986), which is the standard methodology in predicting the volatility of financial time series. If an autoregressive moving average model (ARMA model) is assumed for the error variance, the model is a GARCH model. This model is also a weighted average of past squared residuals, but it has declining weights which, however, never assumes the value zero. The GARCH specification asserts that the best predictor of the variance in the next period is a weighted average of the long-run average variance, the variance predicted for this period, and the new information in this period that is captured by the most recent squared residual. Such an updating rule is a simple description of adaptive or learning behavior and can be thought of as Bayesian updating.

Specifically, the GARCH (1,1) model specified with a mean equation and the conditional variance equation with first lag of squared residuals and the conditional variance itself offers the most popular methodology for studying the volatility patterns of high frequency financial time series. Besides, the choice of the GARCH (1,1) model is also based on its attribute of parsimony and its capacity to outperform most other models as shown by White (2000) and Hansen (2001).

For estimating volatility in the call money market, we used GARCH (1,1) model which is specified as under:

$$Yt = \alpha\, Y_{t-1} + \epsilon_t$$

$$\epsilon_t / \Phi_{t-1} \sim N(O, h_t)$$

$$h_t = \beta_o + \beta i\, \epsilon^2_{t-1} + \beta j\, h_{t-1}$$

III.2 *Empirical Exercise*

The coefficient of the mean equation and volatility equation derived from the above system of equations are summarised in Table-3. The significance of the coefficients of volatility equation below one per cent level indicates the presence of strong GARCH effect in the call market volatility. Therefore, the rest of this study uses the daily volatility estimated by the abovementioned GARCH equation.

Table-3: Mean and Volatility from GARCH(1,1)

	Co-efficient	P-value
C	0.19	0
WT_AVG(-1)	0.96	0
C	0.00	0
RESID(-1)^2	0.48	0
GARCH(-1)	0.70	0
R-squared	0.92	
D-W Stat	2.10	

III.2.1 *Modelling Spread and Volatility Relationship*

After estimating the volatility of overnight rates, this section attempts an estimation of relationship of volatility and money market spread (MIBOR-MIBID). Existing literature suggests a direct relation between volatility and bid-ask spread, as market makers are likely to respond to the additional risks (rise in volatility) by increasing the spread. The trading volume, on the other hand, is likely to have an inverse relationship as volume increases liquidity and thereby reduces the underlying risk to some extent.

Before modelling the spread-volatility relationship, we examine the monthly and daily patterns of MIBOR-MIBID spread by using monthly and day of the week dummies. The regression result using spread as dependent variables are summarized in the Annex. In terms of the day-of-the-week effect, the regression coefficients and their P-values indicate that spreads were significantly higher on Fridays. Similarly, results also indicate that spread is significantly higher during the month of March.

Data from March 1999 to December 2006 was considered for modelling the spread-volatility relationship. The regression results using spread as dependent variable and GARCH volatility as explanatory variable are presented in Table-4. The dummy variables for March and for Fridays were also included to control for month and day of the week effect.

Table-4

	Co-efficient	P-value
C	0.15	0.00
MAR	0.06	0.00
FRI	0.08	0.00
GARCH01	0.06	0.00
R-squared	0.17	
Durbin-Watson stat	1.90	

Though the coefficient of volatility (GARCH01) has positive (significant) coefficient, the low value of R^2 clearly indicates poor explanatory power of the underlying model and suggested possibility of structural changes/omitted variables over the period under consideration. To evaluate the possibility of a regime shift, we calculated Cumulative Sum of Squares (CUSUM)[5] and plotted the same against 5 % significance level in Chart-2. The plot indicates a structural shift during April 2002 and Chow's breakpoint test has confirmed an existence of a regime shift as indicated by statistically significant F-Statistics and log likelihood Ratio (Table-5).

Chart-2: CUSUM Plot

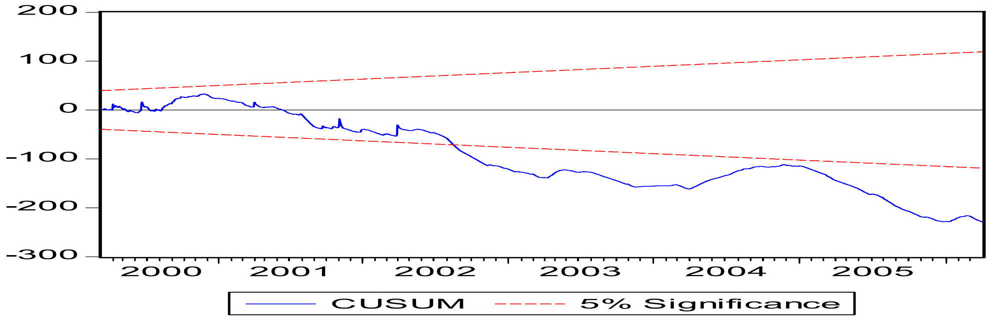


Table-5: Chow Breakpoint Test

F-statistic	14.90942	Prob. F(4,2230)	0.000000
Log likelihood ratio	59.06546	Prob. Chi-Square(4)	0.000000

Based on evidence of structural break, the entire period was divided into sub-periods and the regression results using same set of independent variables are presented in Table-6.

Table-6

(Period 1999:03 to 2002:03)

	Co-efficient	P-value
C	0.16	0.00
FRI	0.20	0.00
MAR	0.09	0.08
GARCH01	0.06	0.00
R-squared	0.17	
D-W stat	1.99	

(Period 2002:04 to 2006:12)

	Co-efficient	P-value
C	0.15	0.00
FRI	0.00	0.60
MAR	0.04	0.00
GARCH01	0.08	0.00
R-squared	0.16	
D-W stat	0.47	

[5] see endnote

The results indicate that for both the periods, the volatility term GARCH01 has significant positive coefficient indicating that volatility has incremental effect on MIBOR-MIBID spread. The dummy for March was significant for both the periods, while the Friday dummy was only significant for the first period. However, in the second period (*i.e.* 2002:03 to 2006:12), the Durbin-Watson statistics was very low which indicated presence of autocorrelation during the period under consideration. Therefore, lagged spread was introduced as an explanatory variable in the model which significantly improved the Durbin-Watson statistic along with R^2 in the augmented model. The regression results found that the lagged spread has a significant positive coefficient which indicates evidence of adaptive learning from past experience (Table-7).

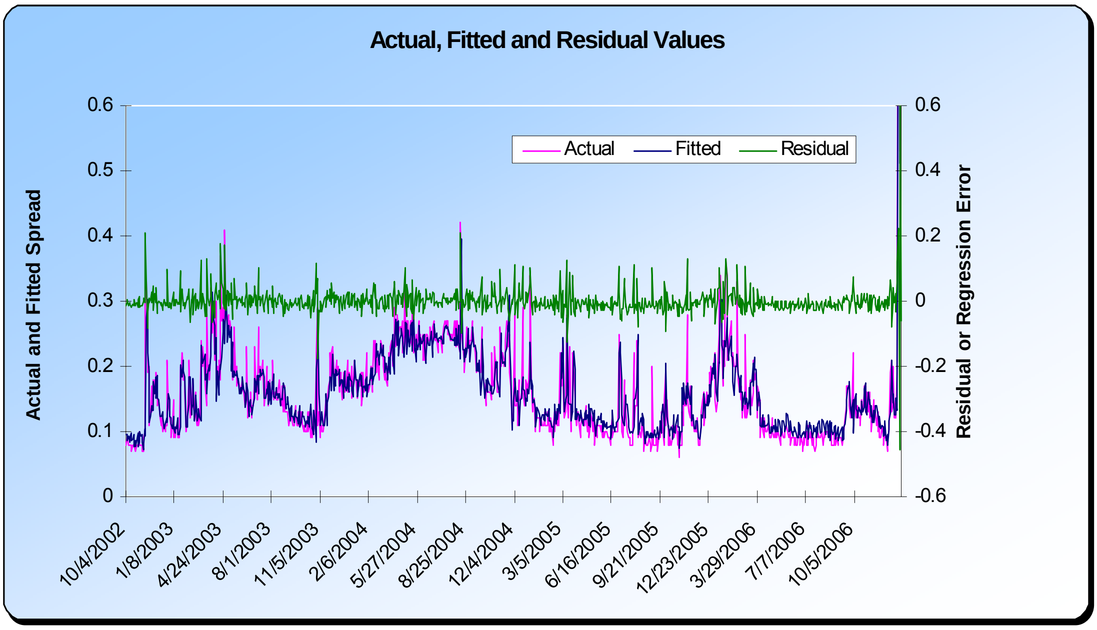
Table-7

	Co-efficient	P-value
C	0.02	0.00
FRI	0.01	0.04
MAR	0.01	0.12
GARCH01	0.01	0.00
SPD(-1)	0.90	0.00
R-squared	0.73	
Durbin-Watson stat	2.45	

Finally the turnover series was included in the model since October 2002 (since it was available) and the regression results indicate negative coefficient for turnover (indicating negative impact of liquidity on spread) (Table-8). Both GARCH volatility and lagged spread recorded positive coefficients as found earlier. Chart 3 indicates the movement of actual and fitted spreads. The residual (actual-fitted) spread so estimated was found to be free from autocorrelation (Box-Ljung test).

Table-8

	Co-efficient	P-value
C	0.073	0.000
FRI	0.009	0.015
MAR	0.008	0.132
GARCH01	0.022	0.000
SPD(-1)	0.862	0.000
LTURNOVER	-0.005	0.005
R-squared	0.737	
Durbin-Watson stat	2.930	



To sum up, volatility has a positive impact on money market spread. However, the spread-volatility relationship has undergone a change since March 2002. During the later period, lagged spread has played an important role in explaining MIBID-MIBOR spread along with GARCH volatility. Finally, as expected, turnover in the money market plays a significant role through a negative impact on spread.

III.2.2 *Impact of Policy Announcements on Money Market Volatility*

As noted earlier, the short term money market has emerged as the main arena for signaling monetary policy changes using indirect instruments. While rate in overnight market almost instantaneously reacts to policy rates, this section takes up the effect of monetary policy changes on the volatility of the same. For estimating the impact of policy changes on the underlying volatility, we have considered changes in Bank Rate, repo and reverse repo rate and the CRR hike that were undertaken during the period of study. Since the CRR changes become effective with a lag from its announcement date, we have considered changes in volatility around the announcement date and the effective date of changes in CRR. Finally, to classify the directional effect on volatility, the impact of expansionary and contractionary monetary policy (using any or a combination of the above instruments) on volatility was evaluated.

For empirically evaluating the nature, magnitude and the significance of the policy changes on the underlying volatility of overnight money market and spread, the GARCH volatility equation used in section III.1 was augmented to include a dummy variable. The augmented set of information used for estimating GARCH volatility is as follows:

$R_t = \alpha_o + \alpha_1 R_{t-1} + \epsilon_t$

$\epsilon_t / \Phi_{t-1} \sim N(O, h_t)$

$h_t = \beta_o + \beta_1 \epsilon^2_{t-1} + \beta_2 h_{t-1} + \boldsymbol{\lambda} * \mathbf{D_f}$

Where R_t is the dependent variable, signifying weighted average call rate / spread. D_f is a dummy variable which takes the value 1 on the date of monetary policy changes but 0 otherwise. D_f is created for each of the changes in various monetary policy instruments i.e. Bank Rate, repo, reverse repo, CRR effective/announcement dates and expansionary/contractionary policy. The magnitude, direction and significance of the coefficient ' **λ**' would indicate the impact of a particular policy change on the volatility of weighted average call rate and spread. The estimated results using the augmented GARCH model are presented in Table-9. The ' **λ**' coefficient of the GARCH volatility equation took negative value for both spread and weighted average call rate for CRR announcement (DCRRA) and for expansionary monetary policy in general. This indicates that the announcement of CRR changes reduced volatility in the overnight money market.

Table-9

	GARCH USING WT CALL AS DEPENDENT VARIABLE							GARCH USING SPREAD AS DEPENDENT VARIABLE					
	α0	α1	β0	β1	β2	λ		α0	α1	β0	β1	β2	λ
DBRATE	0.11	0.98	0.01	0.37	0.47	*0.004*		0.04	0.77	0.14	0.16	0.55	-0.30
DREPO	0.11	0.98	0.01	0.37	0.47	*0.07*		0.01	0.96	0.00	0.70	0.51	0.005
DRREPO	0.11	0.98	0.01	0.36	0.48	0.04		0.01	0.95	0.00	0.73	0.50	0.0001
DCRR	0.11	0.98	0.01	0.37	0.48	-0.01		0.01	0.95	0.00	0.61	0.53	0.02
DCRRA	-0.11	1.02	0.03	0.15	0.45	-0.06		0.04	0.76	0.14	0.16	0.55	-0.30
DEXPAN	0.27	0.95	0.04	0.12	0.52	-0.04		0.04	0.75	0.14	0.16	0.57	-0.17
DCONTRA	0.11	0.98	0.01	0.40	0.45	0.08		0.01	0.95	0.00	0.66	0.53	-0.0003

While expansionary monetary policy reduced volatility in the money market rates, contractionary policy had negative impact on spread volatility. The other policy changes (eg. changes in LAF rates, Bank Rate) had mixed effect on the rate and spread volatility (Table-10).

Table-10

	Weighted CALL	Spread
DBRATE	Not significant P=0.88	Negative and significant P~0
DREPO	Not significant P=0.24	Positive and significant P~0
DRREPO	Positive & P-value = 0.16	Positive But not significant P=0.61
DCRR	Negative & significant (P=0.03)	Positive and significant P~0
CRR-Announce	Negative & significant (P=0.03)	Negative and significant P~0
Expansionary	Negative significant (P=0.03)	Negative and significant P~0
Contractionary	Positive and significant (P=0.03)	Negative and significant P~0

IV. Conclusion:

This paper is the first systematic attempt to understand the determinants of volatility and spread in the overnight segment of the Indian money market over a fairly long period. In addition, it analyses the impact of monetary policy announcements on money market volatility and spreads. This study assumes added importance in view of the fact that it is only in the 1990s that the money market emerged from a highly restrictive policy regime.

The study finds evidence of a structural break from April 2002 signalling the various money market reforms ushered since that period which has brought about subtle changes in market microstructure. Since 2004, the traditionally dominant OTC market has lost out in terms of market activity while new collateralised instruments have gained importance, partly induced by policy preference for financial stability. As volatility has a positive impact on money market spread, monetary policy aimed at ensuring orderly market conditions in preserving financial stability.

In line with *a priori* expectations, the paper shows the dominance of policy interventions in the overnight money market. While expansionary monetary policy reduced volatility in market rates, contractionary policy had negative impact on spread volatility. These findings can enhance our understanding of the interaction between policy announcements and money market microstructure and serve as a useful guide in furthering money market reforms in India.

References

Angelini, P., (2000), Are banks risk-averse? A note on the intraday timing of operations in the interbank market, *Journal of Money, Credit, and Banking*, 32(1), 54-73.

Ayuso, J., A. G. Haldane, and F. Restoy, (1997), Volatility Transmission Along the Money Market Yield Curve, Review of World Economics, 133, 56-75.

Bagehot, W., (1971), "The Only Game in Town", *Financial Analysts Journal,* 27, pp. 12-14, 22.

Bank for International Settlements, 2007.

Bartolini, L., G. Bertola and A. Prati, (1998), Day-to-day monetary policy and the volatility of the federal funds interest rate, EUI *Working Paper ECO, no. 98/35*, European University Institute, November

Bartolini L., G. Bertola and A. Prati, (2002), Day-to-Day Monetary Policy and the Volatility of the Federal Funds Interest Rate, *Journal of Money Credit and Banking*, 34 (1), 137-159.

Bartolini L., and A. Prati, (2003 a), The Execution of Monetary Policy: a Tale of Two Central Banks, *Economic Policy*, 37, 435-467.

Bartolini L., and A. Prati, (2003 b), Cross-Country Differences in Monetary Policy Execution and Money Market Rates Volatility, *Federal Reserve Bank of New York Staff Report No. 175*, October.

Bernoth, K. and J. von Hagen (2004), "The Euribor Futures Market: Efficiency and the Impact of ECB Policy Announcements", *International Finance*, Vol.7, No.1, pp-1-24.

Bernhardsen, T. and A. Kloster (2002), "Transparency and Predictability in Monetary Policy", Economic Bulletin Q2, Norges Bank.

Bhaumik, S. K. and D. Coondoo (2003): Econometrics of yield spreads in the money market: a note, *Applied Financial Economics*, 13, pp 645–653.

Bindseil, U. and F. Seitz, (2001), The supply and demand for Eurosystem deposits - The first 18 months, ECB *Working Paper, no. 44, February.*

Bollerslev. T (1986): "Generalized Autoregressive Conditional Heteroskedasticity," Journal of Econometrics, Vol.31, pp.307-327.

Campbell, J.Y., (1987), Money announcements, the demand for bank reserves, and the behaviour of the federal funds rate within the statement week, *Journal of Money, Credit, and Banking*, 19(1), 56-67.

Cassola, N. and C. Morana, (2006a), Volatility of Interest Rates in the Euro Area: Evidence from High Frequency Data, *The European Journal of Finance*.

Cassola, N. and C. Morana, (2006b), Comovements in Volatility in the Euro Money Market, ECB *Working Paper No. 703*.

Coppel, J. and E. Connolly (2003), "What Do Financial Market Data Tell us About Monetary Policy Transparency?", Research Discussion Paper No.5, Reserve Bank of Australia.

Demiralp, S. and O. Jordà (2004), "The Response of Term Rates to FED Announcements", *Journal of Money, Credit, and Banking*, Vol.36, No.3, pp.387-405.

Dias, D. & C. R Marques, (2005), Using Mean Reversion as a Measure of Persistence, *ECB Working Paper No. 450.*

Furfine, C.H., (1999), The microstructure of the federal funds market, *Financial Markets, Institutions and Instruments, 8(5), 24-44.*

Garman, M., (1976), "Market Microstructure", *Journal of Financial Economics*, 3, pp. 257-275.

Gaspar, V., G. Perez-Quiros and J. Sicilia (2001), "The ECB monetary policy strategy and the money market", *International Journal of Finance and Economics*, Vol.6, pp.325-242

Griffiths, M, D. & Winters, D.B., (1995). : "Day-of-the-week effects in federal funds rates: Further empirical findings," Journal of Banking & Finance, Elsevier, vol. 19(7), pages 1265-1284, October.

Hartmann, P., M. Manna and A. Manzanares, (2001), The Microstructure of the Euro Money Market, *Journal of International Money and Finance*, 20, 895-48.

Hamilton J.D., (1996), The daily market for federal funds, *Journal of Political Economy*, 104(1), 26-56.

Ho, T.S.Y. and A. Saunders, (1985), A micro model of the federal funds market, *Journal of Finance*, 40(3), 977-990.

Krueger, J. and K. Kuttner (1996), "The Fed Funds Futures Rates as a Predictor of Federal Reserve Policy", *Journal of Futures Markets*, Vol.16, No.8, pp.865-879

Kuttner, K. (2001), "Monetary Policy Surprises and Interest Rates: Evidence from the Fed Funds Future Market", *Journal of Monetary Economics*, Vol. 47, No.3, pp.523-44.

Marques C. R, (2004), Inflation Persistence: Facts or Artefacts, *ECB Working Paper No. 371.*

Perez-Quiros, G. and H. Rodriguez, (2000), The daily market for funds in Europe: has something changed after the EMU?, Paper presented at the ECB conference "The Operational Framework of the Eurosystem and Financial Markets", Frankfurt, 5-6 May.

Perez-Quiros, G. and J. Sicilia (2002), "Is the European Central Bank (and the United States Federal Reserve) Predictable?", Working Paper No.192, European Central Bank.

Poole, W. and R.H. Rasche (2000), "Perfecting the Market's Knowledge of Monetary Policy", *Journal of Financial Services Research*, Vol. 18 No.2/3, pp.255-298

Prati, A., L. Bartolini, G. Bertola, (2003), The Overnight Interbank Market: Evidence From the G-7 and the Euro Zone, *Journal of Banking and Finance*, 27, 2045-2083.

Ross, K. (2002), "Market Predictability of ECB Monetary Policy: a Comparative Examinations", IMF Working Paper No.233.

Söderlind, P. and L.E.O..Svennson (1997): "New Techniques to Extract Market Expectations from Financial Instruments", *Journal of Monetary Economics* 40(2) 383-429.

Spindt, P.A. and J.R. Hoffmeister, (1988), The micromechanics of the federal funds market: implications for day-of-the-week effects in funds rate variability, *Journal of Financial and Quantitative Analysis*, 23(4), 401-416.

Notes:

CUSUM Test

In recursive least squares the equation is estimated repeatedly, using ever larger subsets of the sample data. The next observation is then added to the data set and observations are used to compute the second estimate. This process is repeated until all the sample points have been used, yielding estimates of the vector. At each step the last estimate of can be used to predict the next value of the dependent variable. The one-step ahead forecast error resulting from this prediction, suitably scaled, is defined to be a recursive residual. The CUSUM test (Brown, Durbin, and Evans, 1975) is based on the cumulative sum of the recursive residuals. Plots the cumulative sum together with the 5% critical lines is often considered for structural change or parametric instability. The test finds parameter instability if the cumulative sum goes outside the area between the two critical lines.

Chow Test for Structural Break

The idea of the breakpoint Chow test is to fit the equation separately for each subsample and to see whether there are significant differences in the estimated equations. A significant difference indicates a structural change in the relationship. For example, one can use this test to examine whether the demand function for energy was the same before and after the oil shock. The test may be used with least squares and two-stage least squares regressions.

To carry out the test, we partition the data into two or more subsamples. Each subsample must contain more observations than the number of coefficients in the equation so that the equation can be estimated. The Chow breakpoint test compares the sum of squared residuals obtained by fitting a single equation to the entire sample with the sum of squared residuals obtained when separate equations are fit to each subsample of the data.

The log likelihood ratio statistic is based on the comparison of the restricted and unrestricted maximum of the (Gaussian) log likelihood function. The LR test statistic has an asymptotic χ^2 distribution with degrees of freedom equal to $(m-1)k$ under the null hypothesis of no structural change, where is the number of 'm' subsamples.

Ref: Eviews User Manual

Annex

A1: Day of the week effect on spread

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.176361	0.016978	10.38779	0.0000
MON	0.000413	0.023957	0.017249	0.9862
WED	0.014532	0.024046	0.604343	0.5457
THUR	0.008683	0.023957	0.362439	0.7171
FRI	0.097292	0.024082	4.040038	0.0001
SAT	0.066238	0.024211	2.735861	0.1063
R-squared	0.013984	Mean dependent var		0.207169

A2: Month of the year effect on spread

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.164261	0.023615	6.955711	0.0000
FEB	0.088114	0.034222	2.574777	0.1101
MAR	0.079571	0.033844	2.351104	0.0188
APR	0.045809	0.035340	1.296248	0.1950
MAY	0.041445	0.033691	1.230154	0.2188
JUNE	0.075274	0.033591	2.240902	0.9251
JULY	0.011540	0.033166	0.347942	0.7279
AUG	0.079034	0.033397	2.366495	0.1081
SEP	0.031906	0.033844	0.942744	0.3459
OCT	0.046810	0.033792	1.385226	0.1661
NOV	0.023959	0.034056	0.703522	0.4818
DEC	-0.002490	0.033445	-0.074449	0.9407
R-squared	0.009597			

Note: Month January and Tuesday are not considered in the above regression to avoid multicolliniarity and dummy variable trap problems

A3: Changes in monetary policy instruments

Changes in Monetary Policy Instruments					
Effective Date	Bank Rate	Repo	Rev. Repo	CRR	CRR (Ann.)
08-05-1999				10.00	20-04-1999
06-11-1999				9.50	29-10-1999
20-11-1999				9.00	29-10-1999
2-Apr-2000	7.0				
08-04-2000				8.50	1/4/2000
22-04-2000				8.00	1/4/2000
22-Jul-2000	8.0				
29-07-2000				8.25	21-07-2000
12-08-2000				8.50	21-07-2000
17-Feb-2001	7.5				
24-02-2001				8.25	16-02-2001
2-Mar-2001	7.0				
10-03-2001				8.00	16-02-2001
27-04-2001		9.00	6.75		
30-04-2001		8.75			
19-05-2001				7.50	12/5/2001
28-05-2001			6.50		
7-Jun-2001		8.50			
23-Oct-2001	6.5				
03-11-2001				5.75	22-10-2001
29-12-2001				5.50	22-10-2001
5-Mar-2002			6.00		
28-Mar-2002		8.00			
01.06.2002				5.00	18.05.2002
27-Jun-2002			5.75		

Changes in Monetary Policy Instruments					
Effective Date	Bank Rate	Repo	Rev. Repo	CRR	CRR (Ann.)
30-Oct-2002	6.25		5.50		
12.11.2002		7.50			
16.11.2002				4.75	29.10.2002
3-Mar-2003			5.00		
7-Mar-2003		7.10			
19-Mar-2003		7.00			
30-Apr-2003	6.0				
14.06.2003				4.50	29.04.2003
25-Aug-2003			4.50		
31-Mar-2004		6.00			
18.09.2004				4.75	11.09.2004
02.10.2004				5.00	11.09.2004
27-Oct-2004			4.75		
29-Apr-2005			5.00		
26-Oct-2005		6.25	5.25		
24-Jan-2006		6.50	5.50		
8-Jun-2006		6.75	5.75		
25-Jul-2006		7.00	6.00		
31-Oct-2006		7.25			
23.12.2006				5.25	11.12.2006
06.01.2007				5.50	11.12.2006
31-Jan-2007		7.50			
17.02.2007				5.75	14.02.2007
03.03.2007				6.00	14.02.2007
31-Mar-2007		7.75			