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Volatility in the Call Money Rate and Efficacy of Monetary Policy Operations in Bangladesh

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November 2007

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Volatility in the Call Money Rate and Efficacy of Monetary Policy Operations in Bangladesh

Md. Shahiduzzaman*
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Abstract

This paper examines the pattern of volatility in the call money rate and its association to monetary policy operations of Bangladesh Bank (BB). In the process, it explores empirical issues like the co-movement of money market rates and the presence of heteroscedasticity in the call money rate. The first stage analysis supports the view that money market rates co-move and there is a co-integration relationship between overnight money market rate and BB's policy interest rates. At the second stage, long-run properties of the data were incorporated while trying to investigate the efficacy of operational policy of BB in the indirect policy regime by separating the short-run and long-run effects. As the variances of the error terms are not constant,, OLS estimation provides a false sense of precision. A GARCH model is therefore estimated which suggests that the operational policy of BB is effective in influencing the rate volatility in Bangladesh. The empirical evidence of this study will assist in better understanding the interest rate channel of monetary transmission, overnight money market behavior, and operational policy of BB.

Key words: *Call money rate, volatility, policy rate, co-movement*

JEL classification: *G21, E52, E58*

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1. Introduction

With economic reforms and financial liberalization, Bangladesh started to put greater reliance on a market based financial system since the early 1990s. Overtime, among others, administered interest rate structures have been abolished and deregulation in the banking sector has taken place. Accordingly, Bangladesh Bank (BB), the central bank of the country, started reinforcing indirect monetary policy operations. The transition to this framework has been accompanied by some indirect monetary policy arrangements, namely *repo* (repurchase agreement), *reverse repo* and *interbank repo* from July 2002, April 2003, and July 2003 respectively. Bangladesh also entered into a floating exchange rate system in May 2003. All these developments have generated a profound influence over the functioning and development of the country's money market. Through time, an increasing focus has also been given to monitor the day-to-day activities in the overnight money market (call money market) in order to pursue a prudent monetary policy by the central bank.[2]

There are various reasons why central banks around the world pay greater attention to the stability of the call money market. It is generally viewed that the uncertainty caused by volatility in the call money rate[3] gives confusing signals to the market participants about the stance of the monetary policy. In addition, as other interest rates in the money market come with different lags, it is the call money rate, which the central bankers and market participants can monitor on a daily basis. It is also believed that volatility in the overnight money market can be radiated out to other money market rates as these rates reflect the underlying changes in marginal cost of borrowing.

In a market where overnight rates fluctuate from a very high to a very low end, market players, especially banks, are encouraged to keep higher excess reserve than under normal situation to meet the uncertainties and can even be reluctant to purchase near cash assets like bills and bonds from the primary market. The situation exacerbates if there is no active secondary market for bills and bonds where banks can easily convert those to cash reasonably quickly. In such a situation, open market operations (OMOs) conducted by the central bank may not be such effective as to influence the excess liquidity in the market.

Volatility can also be transmitted to foreign exchange market; the difficulty specially arises when both the call money and foreign exchange markets are in pressure. In case of shortage of liquidity and/or higher demand for liquidity, central bank usually injects money to minimize the deviation of call rate from its policy interest rates. In such a situation, the injection of liquidity may in turn increase the demand side pressure in the foreign exchange market, creating a possibility of the exchange rate to depreciate further. In Bangladesh, a situation like this happened in the second half of FY06, when the weighted average daily call money rate varied between 7.07 percent and 40.37 percent and the monthly average call rate ranged between 10.84 percent and 21.54 percent. However, this was the period when foreign exchange market was also under pressure; BB found difficulties in injecting fresh money for the fear of deterioration in the domestic currency value.

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[2] Theoretically, call money market is the institutional arrangement where short-term funds flow from banks and other financial institutions holding excess liquidity to banks and financial institutions in need of immediate funds without any collateral security. Call money market is synonymously used as overnight money market in different occasions.

[3] Call money rate is the interest rate, which is determined in the call money market. Throughout the paper, call money rate is synonymously used as call rate, overnight money market rate, and overnight rate.

Call money rate for overnight transactions reflects the demand for and supply of liquidity in the market. Therefore, the use of monetary policy instruments to influence the liquidity position in the market places a substantial impact on the rate. A common objective of the central bank's monetary policy is thus to minimize the persistent deviations of the overnight money market rates. It is therefore expected day-to-day implementation of monetary policy is linked to the stability of the overnight money market rate. On the other side, if market participants find that the central bank's operational measures can effectively control the movement of market rates then they incorporate the belief into their demand. Obviously, the success of this process depends on the effectiveness of the transmission channel of the interest rates. However, if such success holds, credibility of the central bank would be enhanced, which further helps policy measures to become more effective. It is also argued that central banks can use open mouth operations (signaling) rather than any actual interventions to keep market rates at a target level, if such credibility holds (Guthrie and Wright 2000). Some studies also suggest that interest rates tend to move together, especially in the long run, and there is a tendency that market-clearing rates converge towards the central banks' rate for open market operations.

Given the above reasons, there is a common objective of a central bank's operational policy to minimize the persistent deviations of the overnight money market rate(s) from its policy rates. This study investigates whether the choice of operational framework of monetary policy has been related to the pattern of call money rate in Bangladesh. In order to do so, we first examine the long-run relationship between call money rate and 28-day Treasury bill (T-bill) rate. We have chosen these two rates because of their importance and visibility in the short run money market in the country. Call money rate is the market-clearing rate and an information variable in the process of implementing monetary policy while 28-day T-bill rate is the default risk free rate in the Bangladesh money market. Having investigated the long-run relationship between these two important rates, we then build up an empirical model that captures the feature of the data, in particular the time-varying nature of volatility, in order to investigate the efficacy of various monetary policy arrangements to stabilize the volatility in the call money rate. The empirical results presented in the paper have important implications for monetary policy, particularly with respect to the interest rate channel of monetary transmission.

The outline of the paper is as follows. Following the introduction in section 1, section 2 reviews some previous studies in this area in the context of Bangladesh and some other countries. Section 3 discusses the practices of monetary policy operations and various factors influencing volatility in the call money rate. Section 4 enumerates some stylized facts and statistical characteristics of the data and section 5 incorporates the empirical analysis. Finally, section 6 offers the conclusions and recommendations.

2. Review of Previous Studies

In recent decades, a significant body of empirical research has emerged on the behavior of the call money market and its relationship with monetary policy in the context of developed countries; the empirical research on the issue is however scarce in the context of developing countries like Bangladesh. This is probably because of the underdevelopment of the money market or non-following an interest rate targeting for monetary policy operations. In addition, unlike monetary target, interest rate channel is not well understood. Nevertheless, movements in the interest rates have a profound impact on businesses and economic activities in any country, therefore studies in this regard can bring out important policy implications.

In Bangladesh, few studies that so far have been done on the issue are descriptive in nature and ignore various statistical properties of data. The studies, in general, attempted to study the sources and impacts of fluctuations in the call money rate and implications of the trend of the market behavior (see, for example, Sarker 1999; Akhtaruzzaman, Mahfuza and Masuduzzman 2005). These studies, however, enumerate some important observations and recommendations to facilitate further development of call money market and to limit fluctuations. These include, enforcing indicative limits on individual banks to restrict their exposure in inter-bank transactions, which draw funds disproportionately to their capital or deposit base.

Sarno and Thornton (2002) investigate the dynamic relationship between two important short-term interest rates in US financial markets-the federal funds rate and the 3-month T-bill rate using a general non-linear asymmetric vector equilibrium correlation model (ECM). Regardless of whether the argument that federal funds rate and T-bill rate move together because they are linked as the expectations hypothesis (EH)[4] holds, finding of their empirical results provide strong evidence of a co-integrating relationship between the federal funds rate and the T-bill rate.

Wetherilt (2002) examines whether the choice of policy instruments and other reforms to Bank of England's money market operations affect the Bank's objective of minimizing persistent deviations of the relevant money market rates(s) from its policy rate using daily money market rates, ranging from the overnight to twelve-month maturity. The author developed an empirical modeling framework, namely a single equation component GARCH model, to analyze the dynamic behavior of overnight and other short-term rates and a vector error correction model (VECM) to analyze the dynamic interactions between the entire spectrum of short-term rates. This model captures the time varying nature of volatility of the key money market rates i.e., the overnight and two-week rate. The study demonstrates that higher spreads between the two-week market rate and the official *repo* rate result in lower money market volatility and rate dynamics at the short end of the money market curve, and hence, the effects at the longer end are much weaker.

Palombini (2003) found that the in the Italian interbank market, largest increase in volatility and the most notable variations of its intraday pattern occur at the last working day of reserve maintenance period and at the end of each quarter. Furthermore, he found that overnight interest rate volatility is not influenced by trading volume. This finding indicates the difference between a financial market, where interest rate level is determined by information arrival and the market for overnight liquidity, where the volume of trading is more influenced by institutional factors like the functioning of the payment system.

Joshi (2004) assesses the volatility pattern of the call money rate in India to estimate its sensitivity vis-à-vis the Reserve Bank of India's liquidity adjustment facility (LAF) decisions.

[4] According to the expectation hypothesis of the term structure of interest rate, it is assumed that the T-bill rate is equal to the market's expectation for the federal funds rate over the term of the T-bill rate plus a risk premium.

Moreover, he attempted to show how regulatory changes related to other instruments in the money market might have affected the functioning of the inter-bank money market. He used Nelson Beveridge (NB) time series decomposition and an ARCH-M [1,1] model. The NB decomposition is used to differentiate between permanent and cyclical components in a time series while ARCH imposes a systematic structure to the variance process making it amenable to interpretation and use in forecasting. The evidence provided by the empirical model brings out that while the call money rate is tracked reasonably accurately during surplus liquidity conditions, the predictive power suffers a loss when liquidity shortage suddenly emerges. In addition, it argues that introducing a wider range of eligible collateral in the *repo* market could help in improving the efficiency of interest rate targeting.

The above review provides some empirical evidence toward understanding the behavior of overnight money market rates, and implications of monetary policy measures in maintaining the rate stability. Two important findings are noteworthy in view of the present study. One is that money market rates are interlinked and there exit long-run relationships between money market rates and policy rate of the central bank. The other is that recent arrangements of the indirect monetary policy operations place significant impact of the movement of overnight money market rates. In addition, identifying and capturing the time varying nature of volatility in the empirical models is an important lesson for the methodology part of this study.

3. Overnight Money Market and Monetary Policy Operations in Bangladesh

The large swings in the overnight call money rates are usually not isolated occurrences, but are stemmed from overall economic activity and conduct of day-to-day monetary policy operations by the central bank. In influencing interest rates, BB has a choice of instruments grouped under three headings: Open Market Operations (OMOs), discount window, and reserve requirements. The procedures that BB employs in using these instruments to implement monetary policy affect the demand and supply conditions in the inter-bank market for short-term funds, which forms part of money market named market for bank reserves, where banks and other financial institutions trade in their reserve balances at BB to meet intraday liquidity needs.[5] The call money rate arises, in large part, as an interaction of the demand for and supply of bank reserves jointly determined by the optimizing behavior of the money market participants and of the BB and the efficient distribution of reserves throughout the banking system.

Banks settle transactions among each other on the books of the central bank. The bank reserves-banks balances at the central bank- are the ultimate means of settlement. Therefore, banks have a demand for reserve balances that arise firstly from the demand for required reserve in order to fulfill legal reserve requirement, the portion of reserve balance that BB requires the banks to maintain.[6] Secondly, demand for reserve balances arises from demand

[5] In the rest of this article the term 'banks' will generally be used to cover both banks and other financial institutions who take time deposits and are required to maintain a certain portion of their deposit liabilities as statutory reserve.

[6] The BB regulation requires that the banks and non-bank financial institutions licensed from the Bank be required to maintain a certain percent of their deposit liabilities as statutory reserve. Presently BB requires the scheduled banks to maintain 18 percent of their deposits as Statutory Liquidity Ratio (SLR), where Cash Reserve Requirement (CRR) must be kept at the rate of 5 percent on daily average on two-week basis but no less than 4 percent on any day. Non-bank financial institutions who take term deposits are required to maintain

for excess reserve. Excess reserve is the portion of reserve-balance that banks willingly keep in order to settle transactions among themselves and between their customers, which takes place through the transfers from the account of one bank at BB to that of another bank. The demand for bank reserves affected by opportunity cost of holding reserves i.e. market interest rate, expectations of future market interest rate, and the cost of avoiding default.

A required reserve is calculated as a proportion of average level of deposits held over a month, called the *reserve computation period*. The calculated amount of reserve requirement must be satisfied on average over a two-week period, called *reserve maintenance period*. BB, like most other central banks, builds a lag between the computation period and the maintenance period where the reserve maintenance period follows the reserve calculation period. The lagged reserve accounting system helps the banks to estimate accurately their reserve demand for a maintenance period.

From August 2004, BB allowed reserve-averaging system within a maintenance period with a limitation that the daily reserve balance must not remain below a minimum requirement level.[7] The reserve averaging provision in bank reserves permits individual banks to enjoy considerable flexibility to manage their daily accounts and to use part of their reserves to offset short-term or seasonal fluctuations in liquidity. This flexibility in turn provides greater interest rate sensitivity in the demand for bank reserves during the early and the middle part of the maintenance period. Because required balance is met on a two-week daily average basis, banks can substitute balance across days. For example, if a bank finds itself with balance above the average requirement level on a particular day, it can offset the surplus balance by holding lower balances (but not below the minimum levels) on subsequent days in reserve maintenance period. Similarly, if a bank finds itself with balance below the average requirement level on a particular day, it can make it up on subsequent days in the reserve maintenance period. This ability to adjust reserve holdings across a maintenance period eases the pressure on banks to borrow or lend on a single day, reducing the possibility that supply and demand forces will cause call money rate to fluctuate abruptly.

Banks, however, would be indifferent about the amount of reserves they hold if they expect no significant fluctuations in the inter bank rate. Moreover, they may be cautious to deviate from the average level of reserve position they maintain for the fear of not being able to adjust their position as the number of days remaining in the maintenance period reduces. As a result, the demand for bank reserves tends to be interest inelastic especially at the end of the reserve maintenance period. In contrast, if the banks are maintaining a higher balance requirement, they would face less risk of an end-of day balance below required level and have more flexibility to postpone purchases of funds within the maintenance period. If enough banks are in low reserve positions or when payment flows in the banking system are heavy because of seasonality, a distributional imbalance of funds among banks or an aggregate surplus or shortage of funds is more likely to trigger volatility in the call money rate (Bennell and Hilton 1997).

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rate of 5 percent of total liabilities as SLR, of which 2.54 percent of term deposit must be kept as CRR on daily average on bi-weekly basis but no less than 2 percent on a day.

[7] According to reserve averaging provision, banks are required to keep with Bangladesh Bank cash reserve requirement daily at the rate of 5 percent of their average deposit liabilities on two-week basis provided that the amount of cash reserve would not be less than 4 percent in any day effective from 10 October 2005.

With lagged reserve accounting, total reserve in a given period-the bulk of which are required reserve-are essentially predetermined by the level of deposits one month earlier. As changes in demand for bank reserves arise mainly from changes in reserve requirement, hence demand for bank reserves does not fluctuate considerably over a shorter period. Therefore, it is the supply factors, which mainly affect the equilibrium interest rate in the market over a short run. As the supply factors are largely influenced by various monetary policy operations including OMOs, central banks do have enough control over the movement of the equilibrium interest rates in the market. Therefore, the movements of the interest rates are strongly linked with the daily conduct of monetary policy operations by central bank in the short end.

The supply of bank reserves in a single day is determined by BB's holding of government securities, borrowing by banks from BB, and autonomous supply of bank reserves, if no OMOs are conducted. Some of the transactions causing liquidity flows are pre-known to BB; these include, among others, holding of government. securities i.e. *repo*, reverse *repo* and T-bills etc. However, transactions like changes in currency demand and transfer of public funds to and from BB are referred to as autonomous supply, which is not pre-known by BB at the time of conducting OMOs.

In addition to sudden autonomous changes in liquidity, some seasonal factors cause significant day-to-day variations in the central bank's balance sheet, disrupt the central bank’s management of liquidity, and lead to lower degree of precision of liquidity projections. As a result, in anticipating the supply condition, projection of autonomous flow of liquidity (autonomous supply of bank reserves) arising from various transaction of BB with the rest of the economic system is very important in determining the market clearing rates.

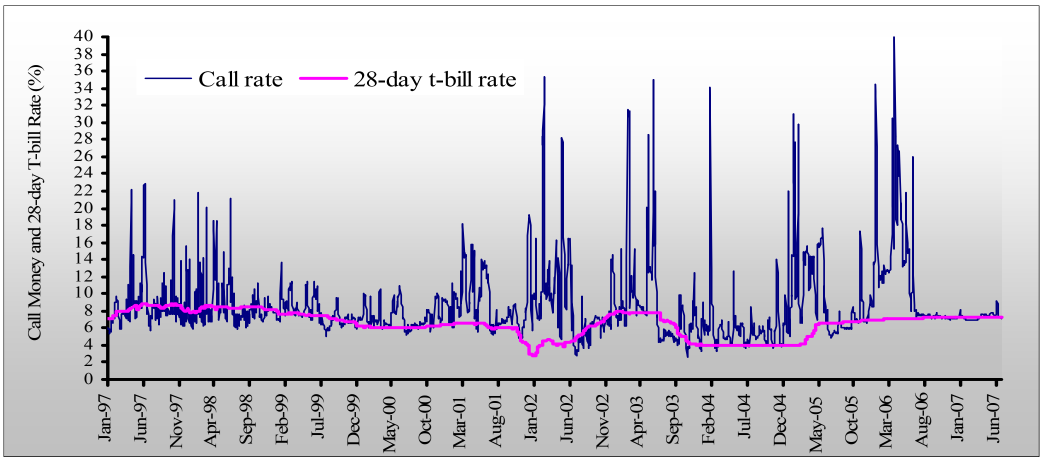
In implementing daily OMOs, BB attempts to ensure that the supply of balances satisfies demand at a rate consistent with its policy interest rates. BB makes estimates of the changes in factors affecting its balance sheet and causing autonomous supply of bank reserves in order to project the quantity of reserves that would be available before conducting any OMOs. BB at the same time predicts demand for bank reserves to achieve its operational objective. The excess reserves prior to BBs liquidity operations could then be estimated *ex ante* by taking differences in demand and supply of bank reserves. BB considers these differences in order to assess the required scale of its intervention in the money market through daily OMOs.

If the demand for bank reserves exceeds the supply, BB judges that it needs to make more reserves available and it will add reserves through open market purchase i.e. lending more that the counterparties have to repay in OMOs maintaining on that day. If demand is less than supply of bank reserves, BB drains reserves through an open market sale i.e. lending less than the amount the counterparties are repaying. BB thus offsets the deviations by injecting (withdrawing) liquidity into the banking system in an equivalent amount and thus bring the amount of reserve money expansion in line with its target so that supply of broad money can be kept under control. Therefore, while BB with its OMOs directly affects the amount of liquidity in the market by shifting the supply curve, it can also affect the slope of the demand curve by changing the reserve requirement. Through reserve requirements and conducting appropriate OMOs, BB affects demand for or supply of bank reserves or both, thereby limiting the fluctuations in the equilibrium rate in the market.

4. Data and Stylized Facts

Figure1 portrays the movement of interbank call money rate and the 28-day T-bill rate for the last one decade. The figures reveal that the call rates have been highly volatile since 2002 as compared with the historical average followed by an unprecedented stability in FY07. Table 1 shows that the average call rate and standard deviation were highest in 2006. Weighted average call rate during the last ten years varied from 4.25 percent to 21.54 percent. On a yearly basis, starting from 8.66 percent in 1997, the mean call rate dropped in the following three consecutive years and reached at 7.31 percent in 2000, then rose again to 9.18 percent in 2002 before touching the bottom at 5.91 percent in 2004-the lowest ever in the entire period. The call rate again rose sharply to 11.10 percent in 2006 along with substantial increase in volatility.

Figure 1: Historical Evolution of Call Money (daily) and 28-day T-bill Rates: Jan 1997 to Jun 2007



Source: Bangladesh Bank

Month-by-month analysis for the period 1997 to 2007 suggests that call rates have an upward trend starting from March to June and the standard deviations are high in these months (Table 1). Thereafter, a gradual downward movement sets in up to November. After a brief slowdown, the rates again move up for the month in December for the practice of 'window dressing' by the commercial banks. From January to March, the rates gently firm up again. As compared with the 28-day T-bill rate, it is apparent from Figure 1 that call money rate was lower than the policy rate on different occasions, especially in the earlier periods. However, this is the daily call rate, which went below the central bank policy rate in different individual days; the monthly average call rate always remains above the 28-day T-bill rate in Bangladesh (Table 1).

One important fact regarding the pattern of call money rate is that the variance does not remain constant over the periods. As can be seen from Figure 2, volatility in the call money rate follows clustering at some particular points of time; there are periods of high volatility followed by periods of low volatility. In recent years, volatility in the call rate saw a break during Feb-Jun 2003. This is the period when the floating exchange rate system was introduced in Bangladesh.[8] In the period immediately before the change, BB tightened liquidity in the market as a precautionary measure to curb speculative tendencies in the

[8] Bangladesh stepped into fully market based exchange rate effective from 31 May 2003.

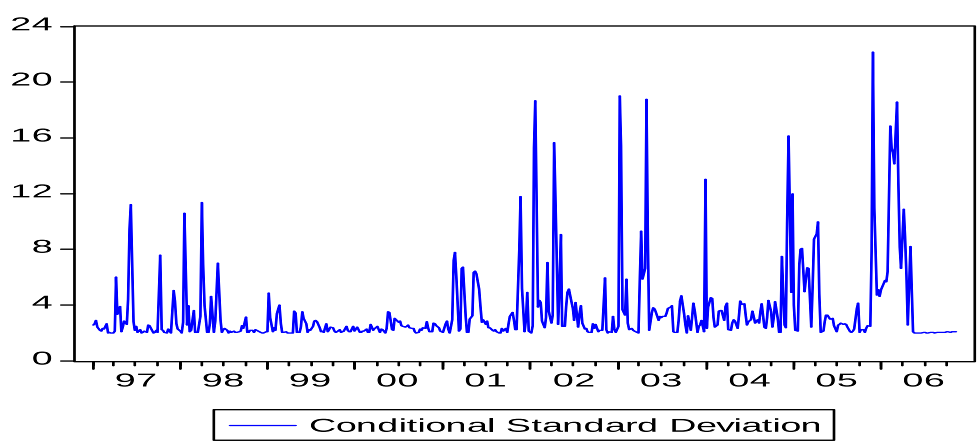
foreign exchange market. Because of tight OMOs, the overnight money market interest rates faced additional pressure and reached high levels. From the end of 2004, the call rate, however, became volatile, which continued during the whole of the first quarter and a part of the second quarter of 2005. In this period, the central bank tightened liquidity in the market as it found problems relating to the prices of essentials and balance of payment situation more pressing. In 2006, the call money rate remained relatively unstable in the first half before settling down in the second half.[9]

Table 1: Monthly Weighted Average Call Money Rate: Jan 1997- Jun 2006

Month	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**AVG**	**SD**
January	6.1	9.2	8.2	7.9	7.6	9.0	7.9	9.7	11.4	14.9	7.3	9.0	2.4
February	7.9	8.7	9.0	6.9	9.0	16.8	15.0	5.9	12.0	12.1	6.9	10.0	3.5
March	7.3	8.2	8.8	7.1	11.6	10.2	10.0	5.7	13.9	14.6	7.0	9.5	2.9
April	9.6	11.8	7.6	6.5	11.2	10.4	8.2	5.0	12.3	21.5	7.5	10.1	4.4
May	8.8	8.8	8.7	8.2	9.9	15.7	14.1	6.6	16.0	15.2	7.6	10.9	3.6
June	13.3	10.6	9.4	8.7	11.7	9.1	12.1	5.4	6.8	10.8	7.7	9.6	2.4
July	7.5	6.7	6.4	5.7	5.9	4.3	5.1	5.0	5.5	7.6		5.9	1.1
August	8.5	7.5	6.3	6.2	6.7	5.0	5.2	5.4	5.9	7.5		6.4	1.1
September	8.6	8.2	7.9	6.6	7.2	6.6	5.5	5.1	6.1	7.4		6.9	1.1
October	9.5	8.5	6.8	7.0	7.6	6.7	5.2	5.5	7.2	7.3		7.1	1.3
November	7.6	7.9	7.0	8.2	5.7	6.7	6.4	6.0	8.2	7.2		7.1	0.9
December	9.4	7.9	6.8	8.7	12.0	9.8	5.6	5.9	8.4	7.1		8.1	1.9
AVG	8.7	8.6	7.7	7.3	8.8	9.2	8.4	5.9	9.5	11.1			
SD	1.8	1.4	1.1	1.0	2.4	3.9	3.6	1.3	3.5	4.7			

Source: Bangladesh Bank

Figure 2: Conditional Standard Deviation of Weekly Average Call Rate (Jan 1997-Jun 2007)



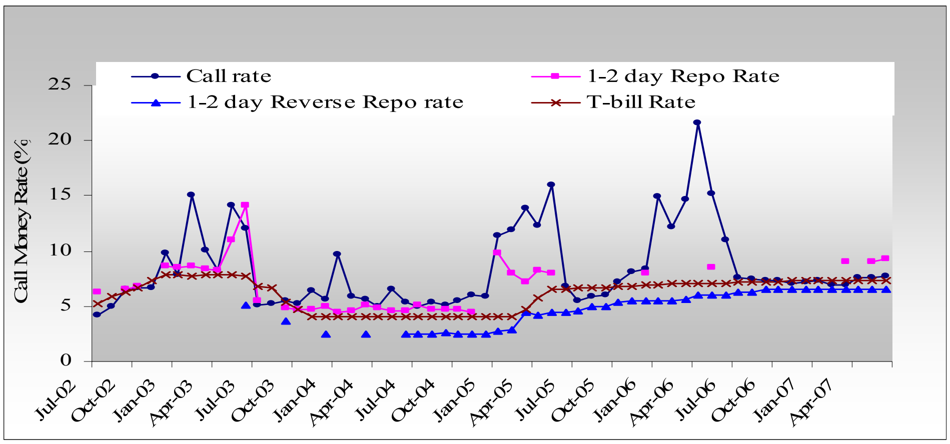
Co-movement of *repo*, *reverse-repo*, T-bill and call money rates in recent years

While BB traditionally conducts the weekly T-bill auction as part of OMOs, recent developments regarding monetary policy measures are the introduction of *repo* (repurchase agreement), *reverse repo* and interbank *repo* operations. Figure 3 shows the monthly trend of T-bill rate, 1-2 day *repo* rate, 1-2 day *reverse repo* rate and the call money rate. The first

[9] For details on recent pattern in call money market, see Bangladesh Bank (2006, 2007).

three rates emerge from an auction process at BB and the call money rate is determined in the marketplace. While all the four rates positively correlate with each other, the call money rate has the highest correlation with the 1-2 day *repo* rate (0.67, Table 2). However, the correlation coefficient between call money rate and 1-2 day *repo* rate is still less than perfect because of the withholding of *repo* operations by BB for most of the periods since June 2005 because of tight monetary policy. Again, 28-day T-Bill rate shows high correlation with *repo* and *reverse repo* rates, where for the latter the correlation coefficient is close to unity. This is because both the instruments are used to mop-up excess liquidity from the market through the auction process with participating agents.

Figure 3: Overnight Money Market Rates (Jul 2002- Jun 2007)



Source: Monetary Policy Department and Economic Trends, BB

Table 2: Correlation Coefficients among Various Money Market Rates (Jul 2002- Jun 2007)

	Call rate	*1-2 day Repo Rate*	*1-2 day Reverse Repo rate*	T-bill rate
Call rate	1.00			
1-2 day Repo Rate	0.67	1.00		
1-2 day Reverse Repo rate	0.27	0.68	1.00	
T-bill rate	0.34	0.75	0.96	1.00

Generally, it can be said that all the four rates are closely linked with each other, which suggests that money market rates co-move in Bangladesh. Recent studies also suggest that the 28-day bill rate is highly correlated with *repo* and *reverse repo* rate (see, Shahiduzzaman and Naser 2007). Therefore, the 28-day T-bill rate can be used as a good proxy of central bank policy changes regarding monetary policy operations, especially for the period prior to the separation of debt management from monetary management, which took place only recently.[10]

[10] The volume auctions introduced from September 2006 have segregated the BB's role in government debt management from its monetary policy operations. Auction of government T-bills and bonds are being held only for government debt management. On the other hand, to perform monetary policy operations, Bangladesh Bank re-introduced 30-day and 91-day Bangladesh Bank bills from October 2006 as its own monetary policy instrument.

5. Empirical Analysis

The total sample for the study is weekly average data covering the period 1 January1997 to 30 June 2007. However, data for all variables are not available for the whole sample period because of their inception in the recent period. As BB introduced *repo* arrangement in July 2002 and *reverse repo* in April 2003, data for these variables are available after these periods. In addition, Bangladesh entered into the floating exchange rate regime on 31 May 2003, which is an important event in the money market development. While under the floating exchange rate system, the market is expected to bring about any necessary adjustment in the exchange rate, the central bank is left with the residual responsibility to smoothen the short-term volatility in the exchange rate. Therefore, under the changing scenario BB has to keep a close eye on the foreign exchange market while trying to maintain stability in the overnight money market.

Our estimated models are constraint by the availability of data for the variables in consideration. The first model is for the full sample period, which investigates the long-run relationship between call money rate and 28-day T-bill rate using cointegration and equilibrium correction models. Cointegration and equilibrium correlation modeling techniques provide effective tools to investigate the relationship between interest rates: the forces that generate a long-run equilibrium relationship between rates of different maturities imply mean reversion of the spread and the existence of an equilibrium correlation model (ECM). Empirically, the central bank's ability to change interest rates through day-to-day monetary policy can be checked by means of a test for cointegration between short and long run term interest rates in vector error correction form.

The second model is a single equation model for the sub-sample of Nov 2002 to Jun 2007, which investigates the effectiveness of various monetary policy measures on the stability of the call money rate. The second model is thus a first difference dependent variable model, which particularly deals with the volatility issue and efficacy of monetary policy operations of BB. The choice of variables for the second model needs further discussion. Like the first model, 28-day T-bill rate has been taken as a proxy of the central bank's policy interest rate. The 28-day T-bill rate emerges from the weekly auction procedure at BB. A better measure of the central bank's policy interest rate could be *repo* or the *reverse repo rate.* However, neither the *repo* rate nor the *reverse repo* rate is available on a continuous basis; *repo* and *reverse repo* operations at the central bank are held only sporadically. Therefore, there would be a significant reduction in the number of observation if we consider *repo* or *reverse* rates as a proxy of policy rate. Secondly, there are different maturities of *repo* and *reverse repo* bids and rates differ for different maturities. In each auction day, there may be the case that BB accepts one-day bid but in another day, it accepts 7-day bid or both. Therefore, weighted average rates between two auction dates can differ significantly, which compelled us to use the 28-day rate as a measure of central bank's policy stance. In addition, the T-bill rate is highly correlated with the *reverse repo* rate and it does reflect the monetary policy stance of the central bank.

The monetary policy framework of BB requires reliance on monetary targeting focused on the reserve money as the operating target. Therefore, BB follows a quantitative approach in monetary programming to routinely (indeed on a daily basis) monitor and influence the position of excess liquidity in the banking system. In this backdrop, quantity accepted in the *repo* and *reverse repo* operations seems to have direct impact on the stability of the overnight money market. Accordingly, we included the *repo* and *reverse repo* in volumes in the model to investigate the effectiveness of monetary policy operations to overnight money market stability. Other explanatory variables in the second model, among others include, excess liquidity in the banking system and exchange rate in terms of US dollar. In order to capture the effects of two Eid festivals, we use a seasonal dummy in the model. We also try to incorporate the end-days effects of the reserve maintenance period to the volatility of the money market by incorporating dummy variables. All variables except the dummy variables are in natural log form. After experimenting with a number of variables, the final variables for the empirical study are as follows:

cr *weekly average call money rate*
tr *28 day* T-bill *rate on weekly basis*
re *log of weekly average excess reserve in the banking system in taka million*
rei *log of weekly average repo volume in taka million*
rrei *log of weekly average reverse repo volume in taka million*
xe *weekly average exchange rate*
SD *seasonal dummy*
RD *dummy for reserve maintenance period*

5.1 Unit Root Test

At the first stage, we investigate the time series properties of the data. We begin this by looking at the line graph and autocorrelation (called as correlogram) for the weekly call money rate, the principal variable of the study. Figure 1 and Appendix Table 1 present the line graph of weekly call rate (*cr*) and the correlogram function respectively. The mean value declines sharply in 2004 before going up in 2005 and 2006 (Table 1). In Figure 2, even though the series seems generally mean reverting, a deeper look reveals that the mean actually does not remain constant over time. In addition, the call money rate exhibits an upward bias so that the mean is not constant over time. The autocorrelation function (Appendix 1) declines as the number of lags become large, but only very slowly. Furthermore, the partial autocorrelation (PAC) is as high as 0.67 at lag 1. We would therefore suspect that *cr* series is non-stationary. However, in order to decide formally whether the series is a I(0) or I(1) process, we follow the Augmented Dickey-Fuller (ADF) procedure (Dickey and Fuller 1979).

If ADF test statistics of the co-efficient is smaller (in absolute terms) than the corresponding critical value (in absolute terms), the null hypothesis of the existence of unit root cannot be rejected, and thus the conclusion is that the series is not stationary. Then the series is tested whether it is I (1) or (integrated of order one) or of a higher order. The lagged structure of this study is decided by using Akaike information criterion. Table 2 reports the result of unit root tests for each variable under study using ADF.

The lag length for the test is determined by the Akaike information criterion (AIC). The ADF test results indicate that we are unable to reject the call money rate (cr) series at 1 percent level of significance, while the 28-day T-bill rate (*tr*) is not rejected at both 1 percent and 5 percent levels of significance.

Table 2: Augmented Dickey-Fuller (ADF) Unit Root Tests

		Lag length		
Model 1: Sample 1997-2007				
cr	Intercept	49	-1.27	1%- (-3.44)
Δcr	Intercept	49	-7.42	5%- (-2.87)
tr	Intercept	5	-2.01	1%- (-3.44)
Δ*tr*	Intercept	5	-11.07	5%- (-2.87)
Model 2: Sample 2002-2007				
cr	Intercept	12	-2.88	1%- (-3.46)
Δcr	Intercept	12	-5.72	5%- (-2.87)
tr	Intercept	5	-1.96	1%- (-3.46)
Δ*tr*	Intercept	5	-3.83	5%- (-2.87)
lre	Intercept	4	-1.99	1%- (-3.46)
Δlre	Intercept	4	-9.11	5%- (-2.87)
xr	Intercept and trend	1	-2.43	1%- (-4.0)
Δxr	Intercept and trend	1	-10.06	5%- (-3.43)
rei	None	3	-4.92	1%- (-2.57)
Δrei	None	3	-11.55	5%- (-1.94)
rrei	None	3	-1.64	1%- (-3.46)
Δrrei	None	3	-9.01	5%- (-2.87)

Note: Δ is the first difference operator.

5.2 Long Run Relationship

A general argument regarding the movement of money market interest rates is that they tend to move together. This can also be true if we consider two important short-term interest rates in the market-the call money rate and 28-day T-bill rate. Empirically, several empirical studies have tried to investigate the co-integrating or long run relationship between federal fund rate and T-bill rate in the US (see Sarno and Thornton 2002; Ruderbusch 1995).

As mentioned earlier, there is hardly any empirical evidence on the long-run relationship between call money rate and T-bill rate in Bangladesh. To explore the relationship, we go for co-integration analysis between *cr* and *tr*. In this case, following a common shock, co-integrated series gradually convergence to their long run relationship(s) (Johansen 1988, 1991).

Johansen developed two test statistics, namely the maximum *eigenvalue* test and *trace test,* to determine the number of cointegration vectors. The test results for the present study are presented in Table 3. In our case, both the trace statistics and Max-Eigenvalue statistics indicate that there is at least one co-integrating vector between *cr* and *tr* at 1 percent significance level. Therefore, there is a long run equilibrium relationship between the call money rate and 28-day T-bill rate. The co-integrating relationship by normalizing on *cr* is presented in Table 4. According to the above equation, the coefficient of *tr* is significant at 1 percent level. The adjustment coefficient of the equation is signed correctly. The coefficient is -0.47, which indicates that 47 percent of the deviation from long run equilibrium is corrected within one week.

Table 3: Johansen Co-integration Test Results

Trace Test

Hypothesized No. of CE(s)	Eigen value	Test statistic	5 percent critical value	1 percent critical value
None	0.064	40.1	19.96	24.60
At most 1	0.015	7.4	9.24	12.97

Trace test indicates 1 cointegrating equation(s) at both 5% and 1% levels

Max-Eigenvalue Test

Hypothesized No. of CE(s)	Eigenvalue	Test statistic	5 percent critical value	1 percent critical value
None	0.064	32.71	15.67	20.20
At most 1	0.015	7.39	9.24	12.97

Max-eigenvalue test indicates 1 cointegrating equation(s) at both 5% and 1% levels

Table 4: Cointegration Equation

CR	***TR***	**C**
1.00	-0.47	-1.22
	(0.15)	(0.27)

Note: Figures in parenthesis are standard errors.

5.2 Effectiveness of Monetary Policy Operations

The empirical evidence in the preceding section provides evidence that call money rate and T-bill rate co-move in the long- run. This type of finding provides an important step toward understanding the transmission of changes in central bank's policy rates to other interest rates in the market. However, this is also important to investigate how the day-to-day monetary policy operations by BB affect the volatility in the call money market in Bangladesh. In section 3, we discussed various factors that influence the volatility, e.g., excess liquidity position, *repo* and *reverse repo* operations, reserve maintenance period, seasonal factors, and exchange rate. Incorporating various explanatory variables, a general model is written as:

$$cr_t = \alpha + \sum_{i=1}^{n} \beta_i cr_{t-i} + \sum_{i=0}^{n} \delta_i tr_{t-i} + \sum_{i=0}^{n} \gamma_i repi_{t-i} + \sum_{i=0}^{n} \varphi_i rrepi_{t-i} + \sum_{t=0}^{n} \rho_i Z_{t-i} + \theta_i D_i + \varepsilon_t$$

Where i is the number of different lags, Z is a set of control variables like position of excess reserve and exchange rate, and D represents the set of dummy variables like effect of reserve maintenance period and effect of *Eid* festival(s).

The above model can be transformed into the following first difference form[11]:

$$\Delta cr_t = \alpha + \lambda_1 (cr_{t-1} - tr_{t-1}) + \lambda_2 tr_{t-1} + \delta_0 \Delta tr_t + \sum_{i=2}^{n} \beta_i cr_{t-i} + \sum_{i=1}^{n} \delta_i tr_{t-i} + \sum_{i=0}^{n} \gamma_i repi_{t-i} + \sum_{i=0}^{n} \varphi_i rrepi_{t-i} + \sum_{t=0}^{n} \rho_i Z_{t-i} + \theta_i D_i + \varepsilon_t \text{ .... (1)}$$

Where,

$$\lambda_1 = \beta_1 - 1, \qquad and \qquad \lambda_2 = \delta_0 + \delta_1 + \beta_1 - 1$$

[11] See Appendix 2 for detailed derivation.

Equation 1 separates the short run from long run effects and models the change in *cr* as an autoregressive process. This kind of transformation helps to identify the effects of several policy measures. It includes the error correction term, which captures the adjustment of call money rate to its divergence from the policy rate. Because BB introduced *repo* and *reverse repo* arrangements in the recent past, our sample period is from November 2002 to June 2007 using weekly data.

Because of the high frequency weekly data, we tried different lags from 1 to 12. Then by sequentially eliminating insignificant terms or un-interpretable signs, the model was derived using the ordinary least square methodology (estimated equation 1). All the variables in equation 1 are highly significant having expected sign. However, since two explanatory variables, namely the exchange rate and dummy for reserve maintenance period, were not significant, they were dropped from the estimated equation. The reason behind the reserve maintenance period being not statistically significant is probably the use of weekly data, in which the day effects are averaged out. The adjusted R-square is 0.39, which is higher in the case of difference equation. The serial correlation LM test statistics reported in Table 5 do not reject the hypothesis of no serial correlation up to order twenty.

However, before proceeding further in interpreting the estimated coefficients and in describing the summary statistics, it is important to check whether any ARCH effect exists in the residual (as described in section 4). There may be the case where the variance of *cr* does not remain constant over the sample period, e.g. the presence of particular kind of heteroscedasticity in which the variance of the regression error depends on the volatility of the errors of the recent past. The ARCH test results, reported in Table 6, strongly suggest the presence of ARCH in the residuals. In such a situation, the regression coefficients under an ordinary least squares regression can give a false sense of precision (Engle 2001).

Estimated Equation 1: Using Ordinary Least Squares Method

Dependent Variable: DLCR
Method: Least Squares
Sample(adjusted): 12/07/2002 to 6/16/2007
Included observations: 237 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.132	0.098	-1.345	0.179
LCR(-1)-LTR(-1)	-0.288	0.051	-5.619	0.000
LCR(-2)	-0.127	0.068	-1.877	0.061
LCR(-3)	0.197	0.057	3.458	0.000
DLTR	1.994	0.753	2.647	0.009
LREPI	0.036	0.006	5.792	0.000
LREPI(-2)	-0.016	0.005	-3.396	0.000
LRREPI	-0.012	0.007	-1.715	0.088
LRREPI(-1)	0.015	0.007	2.079	0.038
DLRE	-0.158	0.044	-3.533	0.000
DLRE(-1)	-0.092	0.046	-2.002	0.046
SD	0.077	0.045	1.708	0.089

R-squared	0.418	Mean dependent var	-0.000
Adjusted R-squared	0.389	S.D. dependent var	0.279
S.E. of regression	0.218	Akaike info criterion	-0.159
Sum squared resid	10.69	Schwarz criterion	0.016
Log likelihood	30.84	F-statistic	14.68
Durbin-Watson stat	2.125	Prob(F-statistic)	0.000

Table 5: Breusch-Godfrey Serial Correlation LM Test

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	1.044	Probability	0.411
Obs*R-squared	32.810	Probability	0.331

Table 6: ARCH Test Result

ARCH Test:

F-statistic	9.993	Probability	0.002
Obs*R-squared	9.666	Probability	0.002

A widely used approach to handle this kind of problem is to follow the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model.[12] The GARCH model is an extension of original ARCH model introduced by Engle (1982). The central focus of the GARCH model is that the variances of the error terms are not equal in all points or ranges of the data. The ARCH/ GARCH model solves the problem by estimating a variance equation, which contains three components, a constant, last period volatility (the ARCH term), and the last period variance (the GARCH term). The autoregressive root, which governs the persistence of volatility shocks, is the sum of coefficients of ARCH (1) and GARCH (1); if the sum is very close to unity then the shocks die out rather slowly. With little modification of original OLS model, the GARCH (1, 1) estimation result is presented in estimated equation 2. In order to check if there exists any remaining ARCH effect in the residual, we perform the ARCH test again. The ARCH test result presented in Table 8 suggests that there is no remaining ARCH effect in the model.

Estimated equation 2 suggests that both the *repo* and *reverse repo* operations have useful implications for the movement of the call money rate. As mentioned earlier, Bangladesh Bank usually performs *repo* operations when the call money market becomes tight. This is reflected in the positive relation of call money rate and *repo* issue in present. However, the amount of *repo* operations helps to curb the upward trend of call money rate with a two-week lag. The same is true for the *reverse repo* operations. Bangladesh Bank performs *reverse repo* operations when the there is an easy liquidity situation and thus no evident pressure in the call money rate. However, as the operation is performed, it creates pressure on the call money rate. Both *repo* and *reverse repo* operations create their expected impact on the movement of the call money rate with *repo* operations having a two-week lag and *reverse repo* operations with a one-week lag. While both the *repo* and *reverse* operations place significant impact on the volatility in the overnight money market rate, the coefficient values suggest that *repo* operations have a greater impact on changes in the call money rate as compared with *reverse repo* operations.

The error correction term came with its expected sign, which once again supports the equilibrium relationship between the overnight money market rate and BB's policy rate. This is also supportive of estimating the equation in its transformed form (equation 1). While the seasonal dummy is significant at 10 percent level in OLS estimation, this is not significant in

[12] The GARCH model was introduced by Bollerslev (1986). See Palombini (2003) and Joshi (2004) for recent exposition on interest rate volatility using GARCH model.

the GARCH (1,1) estimation. An expected negative relationship with the excess reserve is found which is significant at 1 percent level.

Estimated Equation 2: Estimation using GARCH (1,1)

Dependent Variable: DLCR
Method: ML - ARCH (Marquardt)
Sample(adjusted): 12/07/2002 6/16/2007
Included observations: 237 after adjusting endpoints
Convergence achieved after 130 iterations
Variance backcast: ON

	Coefficient	Std. Error	z-Statistic	Prob.
C	0.083	0.053	1.578	0.114
LCR(-1)-LTR(-1)	-0.325	0.035	-9.291	0.000
LCR(-2)	-0.178	0.058	-3.098	0.002
LCR(-3)	0.219	0.057	3.865	0.000
DLTR	2.423	0.313	7.743	0.000
LREPI	0.014	0.002	6.064	0.000
LREPI(-2)	-0.011	0.003	-4.418	0.000
LRREPI	-0.024	0.003	-7.534	0.000
LRREPI(-1)	0.007	0.003	2.055	0.039
DLRE	-0.089	0.019	-4.708	0.000
DLRE(-1)	-0.069	0.026	-2.632	0.008
Variance Equation				
C	0.000	0.000	1.229	0.219
ARCH(1)	0.941	0.169	5.574	0.000
GARCH(1)	0.436	0.066	6.628	0.000

R-squared	0.331	Mean dependent var	-0.000
Adjusted R-squared	0.292	S.D. dependent var	0.279
S.E. of regression	0.235	Akaike info criterion	-0.615
Sum squared resid	12.290	Schwarz criterion	-0.410
Log likelihood	86.905	F-statistic	8.496
Durbin-Watson stat	1.858	Prob(F-statistic)	0.000

Table 8: ARCH Test Result

ARCH Test:

F-statistic	0.97	Probability	0.33
Obs*R-squared	0.974	Probability	0.32

6. Conclusions and Recommendations

This paper’s main objective has been to examine the effectiveness of central bank's operational policy in Bangladesh. Two important hypotheses, which have been widely addressed especially in the context of developed countries, are tested. One is that money market rates co-move in the long run and, therefore, are co-integrated. Secondly, the volatility in the overnight money market is linked with the monetary policy operations of BB. Our study results support both the views, and the results are important toward understanding the interest rate channel of monetary transmission, overnight money market behavior, and operational policy of BB.

Regarding the adoption of various indirect operational arrangements in recent years by BB namely, *repo* and *reverse repo,* the empirical evidence presented in this paper suggests that both the *repo* and *reverse repo operations* can significantly influence the movement in the market clearing rates. The model presented to analyze the efficacy of the operational policy of BB captures the time varying nature of volatility in the call money rate, which is the first of its kind in Bangladesh. The results suggest that market interest rates are linked with one another, so that disruptions in the demand for or supply of funds at one maturity can cause volatility spillovers to the markets for funds at other maturities. The results further suggest that BB can influence the call money rate both through its conduct of the monetary policy and through the market structure that it creates through setting reserve requirements.

Several important lessons emerge from the study for the market players, including the policy makers. The most important one is that the market-clearing rate would ultimately converge to the policy rate and there exists a long-run equilibrium relationship between the two. The available literature suggests that if this relationship exists in the market and there is a good perception about this among the market players, then market participants are likely to incorporate this belief into their demand and, therefore, the market interest rate is not likely to deviate much from the central bank's policy interest rate. The credibility of the central bank would be further enhanced if the market participants find that operational measures of the central bank can effectively influence the market-clearing rate. Therefore, if any divergence arises for some reason, it is expected that it would be corrected soon. If such credibility holds, going one-step further it can be suggested that central banks can use open mouth operations (signaling) rather than any actual interventions to keep the market rates at a target level.

References:

Akhtaruzzaman, M, Mahfuza, A., and Masuduzzaman, M. (2005), “ Recent Fluctuations in Call Money Rate and Its Impact on the Economy’’, *Bank Parikrama*, Vol. XXX, pp. 43-86

Bangladesh Bank (2006), *Monetary Policy Review,* Vol. 2, Nos.1 & 2.

Bangladesh Bank (2007), *Monetary Policy Review,* Vol. 3, No.1

Dickey, D. A. and Fuller, W. A. (1979), “ Distribution of the Estimators for Autoregressive Time Series with a Unit Root’’, *Journal of the American Statistical Association*, 74, pp. 427-431.

Engle, Robert (1982), “Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of U.K. Inflation,’’ *Econometrica*, Vol. 50, pp. 987-1008.

Engle, Robert (2001), “GARCH 101: The Use of ARCH/GARCH Models in Applied Econometrics, ’’ *Journal of Economic Perspectives,* Vol. 15, No. 4, fall 2001, pp157–161.

Guthrie and Wright, (2000), “Open Mouth Operations’’, *Journal of Monetary Economics*, Vol. 46, pp. 489-516.

Johansen, S. (1988), “Statistical Analysis of Cointegrating Vectors’’, *Journal of Economic Dynamics and Control*, 12, pp. 231-254.

Johansen, S. (1991), “Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector autoregressive Models’’, *Econometrica*, vol. 59, No. 6, 1551-1580.

Joshi, Himanshu (2004), “The Interbank Money Market in India: Evidence on Volatility, Efficacy of Regulatory Initiatives and Implications for Interest Rate Targeting, ’’ *Reserve Bank of India Occasional Papers*, Vol. 25, No. 1, 2 and 3.

Palombini, Edgardo (2003),“Volatility and Liquidity in the Italian Money Market,’’ Working Paper No. 6, Fondo Interbancario di Tutela dei Depositi.

Rudebusch, G. D., (1995), “Federal Reserve Interest Rate Targeting, Rational Expectations, and the Term Structure, ’’ *Journal of Monetary Economics*, 35, pp. 245-274.

Sarker, MD. Abdus Samad (1999), “Fluctuations in Inter Bank Call Money Market and Their Implications, ’’ *Bank Parikrama*, Vol. XXIV, No. 3 and 4, pp 25-38.

Sarno, Lucio and Thornton, Daniel L. (2002), “The Dynamic Relationship between the Federal Funds rate and the Treasury Bill rate: An Empirical Investigation’’, Working Paper 2000-032C, Federal Reserve Bank of St. Louis.

Shahiduzzaman, M. and Naser, M. S. (2007), *Volatility in the Overnight Money Market Rate in Bangladesh: Recent Experiences,* Policy Note 0707, Policy Analysis Unit, Bangladesh Bank.

Thornton, Daniel L. (2005), *Open Market Operations and the Federal Funds Rate,* Working Paper 2005-063A, Federal Reserve Bank of St. Louis.

Wetherilt, Anne Vila (2002*), Money Market Operation and Volatility of UK Money Market Rates,* Working Paper No.174, Bank of England.

Appendix 1: Correlogram of weekly call rate (*cr*): January 1997-June 2007

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
.|***** |	.|***** |	1	0.673	0.673	234.87	0.000
.|*** |	.|. |	2	0.431	-0.041	331.31	0.000
.|*** |	.|* |	3	0.380	0.193	406.30	0.000
.|*** |	.|* |	4	0.368	0.086	476.99	0.000
.|** |	.|. |	5	0.299	-0.018	523.68	0.000
.|** |	.|. |	6	0.253	0.047	557.15	0.000
.|** |	.|. |	7	0.226	0.006	583.85	0.000
.|** |	.|* |	8	0.257	0.119	618.41	0.000
.|** |	.|. |	9	0.276	0.056	658.55	0.000
.|** |	.|. |	10	0.259	0.024	693.89	0.000
.|** |	.|. |	11	0.205	-0.036	716.11	0.000
.|** |	.|. |	12	0.202	0.048	737.75	0.000
.|* |	*|. |	13	0.123	-0.152	745.73	0.000
.|* |	.|. |	14	0.087	0.032	749.76	0.000
.|* |	.|. |	15	0.103	0.032	755.39	0.000
.|* |	.|. |	16	0.096	-0.026	760.35	0.000
.|. |	*|. |	17	0.036	-0.066	761.04	0.000
.|. |	*|. |	18	-0.033	-0.114	761.64	0.000
*|. |	*|. |	19	-0.096	-0.107	766.56	0.000
*|. |	.|. |	20	-0.107	-0.032	772.75	0.000
*|. |	.|. |	21	-0.126	-0.055	781.31	0.000
*|. |	.|. |	22	-0.138	-0.001	791.63	0.000
*|. |	.|. |	23	-0.162	-0.039	805.76	0.000
*|. |	.|. |	24	-0.154	-0.024	818.70	0.000
*|. |	.|. |	25	-0.127	0.035	827.46	0.000
*|. |	*|. |	26	-0.143	-0.065	838.65	0.000
**|. |	*|. |	27	-0.196	-0.063	859.52	0.000
**|. |	.|. |	28	-0.221	-0.016	886.28	0.000
**|. |	.|. |	29	-0.216	0.009	911.74	0.000
**|. |	.|. |	30	-0.205	0.008	934.71	0.000
**|. |	.|. |	31	-0.201	0.013	956.85	0.000
*|. |	.|* |	32	-0.145	0.092	968.40	0.000
*|. |	.|* |	33	-0.086	0.077	972.51	0.000
.|. |	.|* |	34	-0.044	0.075	973.56	0.000
.|. |	.|* |	35	-0.015	0.078	973.69	0.000
.|. |	*|. |	36	-0.057	-0.071	975.49	0.000
*|. |	.|. |	37	-0.085	-0.014	979.47	0.000
.|. |	.|* |	38	-0.037	0.089	980.24	0.000
.|. |	.|. |	39	0.007	0.054	980.26	0.000
.|. |	.|. |	40	-0.013	-0.041	980.35	0.000
.|. |	.|. |	41	-0.008	0.015	980.39	0.000
.|. |	.|. |	42	0.018	-0.027	980.56	0.000
.|. |	.|. |	43	0.047	0.017	981.80	0.000
.|. |	.|. |	44	0.043	-0.056	982.83	0.000
.|. |	.|. |	45	0.033	-0.025	983.43	0.000
.|. |	.|. |	46	0.062	0.055	985.60	0.000
.|* |	.|. |	47	0.094	-0.030	990.62	0.000
.|* |	.|* |	48	0.153	0.111	1004.0	0.000
.|** |	.|. |	49	0.197	0.033	1026.1	0.000
.|** |	.|** |	50	0.316	0.221	1083.5	0.000
.|*** |	.|. |	51	0.352	0.031	1154.6	0.000
.|** |	*|. |	52	0.240	-0.109	1187.8	0.000
.|* |	.|. |	53	0.152	-0.051	1201.1	0.000

Appendix 2: Transformation of the Model in First Difference Form

$$cr_t - cr_{t-1} = \alpha + \beta_1 cr_{t-1} - cr_{t-1} + \sum_{i=2}^{n}\beta_i cr_{t-i} + \sum_{i=0}^{n}\delta_i tr_{t-i} + \sum_{i=0}^{n}\gamma_i repi_{t-i} + \sum_{i=0}^{n}\varphi_i rrepi_{t-i} + \sum_{t=0}^{n}\rho_i Z_{t-i} + \theta_i D_i + \varepsilon_t$$

or, $$\Delta cr_t = \alpha + (\beta_1 - 1)cr_{t-1} + \delta_0 tr_t + \delta_1 tr_{t-1} + \sum_{i=2}^{n}\beta_i cr_{t-i} + \sum_{i=2}^{n}\delta_i tr_{t-i} + \sum_{i=0}^{n}\gamma_i repi_{t-i} + \sum_{i=0}^{n}\varphi_i rrepi_{t-i} + \sum_{t=0}^{n}\rho_i Z_{t-i} + \theta_i D_i + \varepsilon_t$$

or, $$\Delta cr_t = \alpha + (\beta_1 - 1)cr_{t-1} + \delta_0 tr_t - \delta_0 tr_{t-1} + \delta_0 tr_{t-1} + \delta_1 tr_{t-1} + \sum_{i=2}^{n}\beta_i cr_{t-i} + \sum_{i=1}^{n}\delta_i tr_{t-i} + \sum_{i=0}^{n}\gamma_i repi_{t-i} + \sum_{i=0}^{n}\varphi_i rrepi_{t-i} + \sum_{t=0}^{n}\rho_i Z_{t-i} + \theta_i D_i + \varepsilon_t$$

or, $$\Delta cr_t = \alpha + (\beta_1 - 1)cr_{t-1} + \delta_0 \Delta tr_t + (\delta_0 + \delta_1)tr_{t-1} + \sum_{i=2}^{n}\beta_i cr_{t-i} + \sum_{i=1}^{n}\delta_i tr_{t-i} + \sum_{i=0}^{n}\gamma_i repi_{t-i} + \sum_{i=0}^{n}\varphi_i rrepi_{t-i} + \sum_{t=0}^{n}\rho_i Z_{t-i} + \theta_i D_i + \varepsilon_t$$

or,

$$\Delta cr_t = \alpha + (\beta_1 - 1)cr_{t-1} - (\beta_1 - 1)tr_{t-1} + (\beta_1 - 1)tr_{t-1} + \delta_0 \Delta tr_t + (\delta_0 + \delta_1)tr_{t-1} + \sum_{i=2}^{n}\beta_i cr_{t-i} + \sum_{i=1}^{n}\delta_i tr_{t-i} + \sum_{i=0}^{n}\gamma_i repi_{t-i} + \sum_{i=0}^{n}\varphi_i rrepi_{t-i} + \sum_{t=0}^{n}\rho_i Z_{t-i} + \theta_i D_i + \varepsilon_t$$

or,

$$\Delta cr_t = \alpha + (\beta_1 - 1)(cr_{t-1} - tr_{t-1}) + (\beta_1 - 1 + \delta_0 + \delta_1)tr_{t-1} + \delta_0 \Delta tr_t + \sum_{i=2}^{n}\beta_i cr_{t-i} + \sum_{i=1}^{n}\delta_i tr_{t-i} + \sum_{i=0}^{n}\gamma_i repi_{t-i} + \sum_{i=0}^{n}\varphi_i rrepi_{t-i} + \sum_{t=0}^{n}\rho_i Z_{t-i} + \theta_i D_i + \varepsilon_t$$

or, $$\Delta cr_t = \alpha + \lambda_1(cr_{t-1} - tr_{t-1}) + \lambda_2 tr_{t-1} + \delta_0 \Delta tr_t + \sum_{i=2}^{n}\beta_i cr_{t-i} + \sum_{i=1}^{n}\delta_i tr_{t-i} + \sum_{i=0}^{n}\gamma_i repi_{t-i} + \sum_{i=0}^{n}\varphi_i rrepi_{t-i} + \sum_{t=0}^{n}\rho_i Z_{t-i} + \theta_i D_i + \varepsilon_t \quad ....(1)$$

Where,

$\lambda_1 = \beta_1 - 1,$ *and* $\lambda_2 = \delta_0 + \delta_1 + \beta_1 - 1$