THE INTEREST RATE TERM STRUCTURE IN THE INDIAN MONEY MARKET

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ABSTRACT

Using five benchmark rates from the Indian Money Market, this paper tests the Expectation Hypothesis (EH) with constant term premium. The data analysis draws on Johansen's test for multivariate cointegration and the corresponding Error Correction Models approach. The empirical results are in favor of the EH holding in the Indian money market. The five interest rates are found to be completely integrated and the spreads are able to predict changes in the short term rates. The acceptance of the validity of the EH in the Indian money market implies that this market is an efficient vehicle for monetary policy implementation. For the sample period we examined, the Indian money market accomplished its role as a means of formulating market expectations in accordance with those of monetary policy makers.

Key words: Expectation Hypothesis, Cointegration, Money Market Rates, Term Structure

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I. INTRODUCTION

Characterizing the properties of the term structure in markets where a given asset is offered at different maturities is a central issue in financial economics. The complex relationship between time to maturity and yield on securities is of widespread interest to both economists and financial market participants. It provides useful information regarding the presence of inter-temporal arbitrage opportunities present in the market. At the macroeconomic level, it also gives the monetary authorities information regarding the extent to which the interest rate term structure can be altered to desirably affect short-term international capital flows, while simultaneously encouraging long-term local investment [Shen (1998)]. Apart from its relevance for monetary policy implementation, or from the possible ability of the term structure slope to predict future changes in economic activity, it has been discussed for a number of years that some characteristics of the term structure contain significant information on future interest rate changes. An efficient money market supports the bond market mainly through the process of liquidity. In addition to the importance of money market for financing positions, money market prices liquidity and anchors the short end of the yield curve [Reddy (2003)]. In the post-deregulated interest rate environment this study assumes significant importance

This paper aims to test the Expectation Hypothesis (EH) in the Indian money market. The EH has received a lot of attention in previous literature in addressing hypothesis that account for yield curve behaviour. The empirical results have often been contradictory and the ability of the EH to explain the behavior of interest rates over the term structure has been controversial for a long time. The initial evidence on US data [Shiller, Campbell and Schoenholtz (1983), Fama (1984), Fama and Bliss (1987) and Shiller (1990)] consistently rejected the restrictions implied by the EH. But Fama (1990) and Mishkin (1988) both found that the spread does contain information on short-term rates several periods into the future. Thus they obtained evidence on the existence of explanatory power in the short/long-term interest rate spread on future short-term rates. Mankiw and Summers (1984) and Mankiw and Miron (1986) analyzed 3- and 6-month US rates, concluding that the term structure had important explanatory power for future interest rates, although it seems to have faltered after the founding of the Federal Reserve System. Campbell and Shiller (1987,1991) found again that the restrictions of the EH do not hold, but that the US spread explains the direction of changes in short-term rates. However, the predicted changes are small, suggesting a possible time varying risk or term premium. A major evidence in favor of the EH was given by Hardouvelis (1994). He used quarterly data from the G-7 countries, and rates of return on three month and 10 year bonds, to conclude that the cumulative movements in future short term rates roughly agree with the implications of the theory, and strongly rejecting the hypothesis that the spread lacks any explanatory content. More recently, Gerlach and Smelts (1997) have obtained evidence in favor of both, the restrictions of the EH, and the explanatory power of the spread on future short-term rates. Studies on European data are generally in favor of the EH. Wolters and Hassler (2001) provide evidence on the holding of EH in Germany using 1, 3, 6 and 12 month rates of the German inter bank money market. Bredin and Cuthbertson (2000) found evidence in favor of EH in the Irish money market. MacDonald and Speight (1988, 1991), Engsted and Tanggard (1994), Engsted (1996) and da Fonseca (2002) found evidence generally supportive for the validity of the EH for the short-term, highly volatile interest rates. In studies on Asian markets, Shen (1998) investigated the EH on Taiwan money market by employing the 10 day short and 30, 90 and 180 day long commercial paper rates. He concluded that the theory is rejected for shorter maturities but cannot be rejected for longer maturities. The only comparable study we came across for the Indian money market is Verma (1997) where it is found that the Indian money market lacks a well defined yield curve.

This paper is organized as follows. Section II describes the conceptual foundations of the expectation hypothesis and its implications. Section III presents the methodology adopted in this study. Section IV describes the data used for the purpose of this study. Section V reports and analyses the empirical results obtained. Finally, Section VI summarizes and concludes the paper.

II. THE EXPECTATION HYPOTHESIS

Broadly speaking, the Expectations Hypothesis (EH) is the idea that financial market expectations determine the shape of the term structure of interest rates. In more specific terms, expectations hypothesis (EH) of the term structure hypothesizes that the yield spread between the long rate and short rate is an optimal predictor of future changes in short rates over the life of the long duration bond.

The testing of EH can be accomplished by testing the following two implicit hypotheses:

1. "There should be one unique stochastic trend driving the whole money market system". [Wolters and Hassler (1998)]
2. "Yield Spread should be an optimal prediction of future changes in short term rates over the life of the instrument." [Mylonidid and Nikolaidou (2003)]

When stated in the above form, *cointegration* and *equilibrium correction* techniques become a natural way of testing for EH of the term structure of interest rates.

In mathematical terms, the EH of the term structure posits that the return on an n-period bond $R_t^{(n)}$ is determined solely by expectations of (current and) future rates on a set of m-period short rates $r_t^{(m)}$ (where n > m). Using continuously compounded spot rates the "fundamental term structure" relationship is:

$$R_t^{(n)} = \frac{1}{k}\sum_{i=0}^{k-1} E_t r_{t+im}^{(m)} + C_{n,m} \quad \text{………………(1)}$$

where k = n/m is an integer and E_t is the expectations operator (with information up to and including time t) and $C_{n,m}$ is a time invariant term premium, which is constant for given (n,m).

The intuition behind (1) is easily seen by taking n=9 and m=3. If Rs.100 is invested at the 9-month spot rate, then the certain amount received after 9-months is Rs.100*(1+R_t*9/12). Alternatively at t=0, the investor can consider investing Rs. 100 at the three-month rate r_t and then reinvesting at the *three-month rates* in months three and six (i.e. rolling over the three-month investment). The latter is a risky strategy and results in *expected* "rupee" receipts of Rs.100*(1+r_t*3/12) (1+$E_t r_{t+1}$*3/12) (1+$E_t r_{t+2}$*3/12). The EH assumes investors are risk neutral and that the market is efficient, hence in equilibrium (1+R_t*9/12). = (1+r_t*3/12) (1+$E_t r_{t+1}$*3/12) (1+$E_t r_{t+2}$*3/12). Taking logarithms of both sides of the latter expression and noting that ln(1+r_t) is the continuously compounded interest rate, we obtain Equation (1) .

We can re-arrange (1) in terms of the spread and the change in interest rates (since below we find that these are stationary variables) and (1) can then be seen to imply that the "long-short" spread is an optimal predictor of future changes in short rates, rt(m) :

$$S_t^{(n,m)} = E_t \sum_{i=0}^{k-1} (1-\frac{i}{k})\Delta^m r_{t+im}^{(m)} = E_t[PFS_t^{(n,m)}] \quad \text{........(2)}$$

where $S_t^{(n,m)} = (R_t^{(n)} - r_t^{(m)})$ is the yield spread. Equation (2) implies that if future short rates are expected to rise, then this will be accompanied by an increase in the spread. To see the intuition behind (2), again consider the case n=9, m=3. Suppose at t=0, investors believe that economy shall be doing better in following months (than previously anticipated). Then they will revise upwards their forecasts of the three-month rates pertaining to months 3 and 6, that is $E_t r_{t+1}$ and $E_t r_{t+2}$, and hence E_t? r_{t+1} and E_t? r_{t+2} will also rise. Therefore, rolling over "one-period" investments will currently give a higher expected return than investing at the 9-month spot rate. Investors will therefore sell 9-month (zero coupon) instruments to invest in three-month instruments, and the price of 9-month instruments will consequently fall. But the latter implies that their yield R_t will rise, as will the spread S_t = (R_t – r_t). Arbitrage ensures that R_t increases until the higher spread just equals the (weighted average of) future expected increases in one-period rates, as summarised in (2). For our simple case, Equation (2) is S_t = (2/3) E_t? r_{t+1} + (1/3) E_t? r_{t+2}.

The *perfect foresight spread* PFS_t in (2) is simply the (weighted average) of actual future changes in short term rates (which agents are trying to forecast). However, in the literature it is referred to as the "perfect foresight spread" because under the EH, it can also be interpreted as the spread that would ensue if agents had perfect foresight about future movements in interest rates (i.e. made no forecast errors).

III. METHODOLOGY

To test for the co-movements in the yields of money market instruments of different maturities, the theory of cointegration is used. If spreads are mean-reverting, yields are tied together in the long term by a common stochastic trend, and we say that the yields are cointegrated [Gujarati (1995)]. A two step cointegration testing process is used. First, the existence of any long-run equilibrium between yields is established. Then an error correction model for dynamic correlation of yields is estimated to reveal the Granger Causalities present in the cointegr ated system.

If $R_t^{(m)}$ is an I(1) process, then eq. (2) implies that $R_t^{(n)}$ and $R_t^{(m)}$ are cointegrated with a cointegrating vector (1,-1) [Campbell and Schiller (1987)]. Given a set of r yield variables, eq. (2) suggests that each yield is cointegrated with all other yields, and hence there should be r-1 cointegration vectors. Then each of the r-1 linearly independent spread vectors (-1,1,0, … ,0), (-1,0,1, … ,0), etc. should span the cointegrating space. We employ the Johansen procedure (Johansen (1988)), Johansen and Juselius(1990)) to test the cointegration implications of EH.

a. The Johansen Methodology

Two methodologies of cointegration- Johansen's methodology and Engle Granger are popular in the econometric studies. Johansen's methodology for investigating cointegration in a multivariate system has been preferred over the Engle-Granger method as it employs a power function better than the latter. Moreover, it has less bias when the number of variables is greater than two. The Johansen tests are based on the Eigen values of a stochastic matrix and in fact reduce to canonical correlation problem similar to that of principal components.

The Johansen tests seek the linear combination which is most stationary whereas the Engle-Granger tests, being based on OLS, seek the linear combination having minimum variance.

The Johansen tests are a multivariate generalization of the unit root tests. An autoregressive AR(1) process can be written in the form:

$$\Delta y_t = c + (a - 1) y_{t-1} + e_t \ldots\ldots (3)$$

where c is a constant and e_t is i.i.d.$(0,s^2)$. Here the first difference ? y_t is regressed on the lagged level y_{t-1}. The test for a stochastic trend is based on the fact that the coefficient of the lagged term should be zero if the process has a unit root. Generalizing this argument for a VAR(1) process motivates the Johansen tests for a common stochastic trend, that is, for cointegration. The VAR(1) model can be written with **? $\mathbf{y_t}$** as the dependent variable in a regression on $\mathbf{y_{t-1}}$:

$$\Delta y_t = a_0 + (A - I) y_{t-1} + e_t \ldots\ldots (4)$$

Now if each variable in **y** is I(1) then each equation in (4) has a stationary variable on the left-hand side. The errors are stationary and therefore each term in **(A-I)** $\mathbf{y_{t-1}}$ must be stationary for the equation to be consistent. If **A-I** has rank zero it is equivalent to the zero matrix, this condition implies nothing about the relationship between the **y** variables. But if **A-I** has rank r>0, then there are r independent linear relations between the **y** variables that must be stationary. Therefore the I(1) variables in y will have a common stochastic trend. Hence, they shall be cointegrated, if the rank of **(A-I)** is non-zero. The number of cointegrating vectors is the rank of **A-I**. The rank of a matrix is given by the number of non-zero eigen values, so the Johansen procedure tests for the number of non-zero eigen values of **A-I**.

The model given in (4) may need to be modified depending on the nature of the data. It may contain a constant term if there is a drift in the stochastic trend, a time trend if the process also contains a deterministic trend, and it can be augmented with sufficient lagged dependent variables to remove autocorrelation in residuals. If a higher order VAR(p) model is used for Johansen tests, the first difference formulation becomes:

$$\Delta y_t = a_0 + (A_1 - I)\Delta y_{t-1} + (A_1 + A_2 - I)\Delta y_{t-1} + (A_1 + A_2 + ... + A_{p-1} - I)\Delta y_{t-1} + (A_1 + A_2 + ... + A_p - I) y_{t-1} + e_t \quad \text{.....(5)}$$

and the Johansen method is a test for the non-zero eigen values of the matrix

? = A1 + A2 + … + Ap – I

Johansen and Juselius(1990) recommend using the standard `trace' test for the number r of non-zero eigenvalues in the matrix **?**. The test statistic for

H0: r <= R against H1: r > R

is

$$Tr = -T \sum_{i=R+1}^{n} \ln(1 - \hat{l}_i) \quad \text{..... (6)}$$

where T is the sample size, n is the number of variables in the system and the eigen values of ? are real numbers ? such that 0 = ? < 1. In (6) the estimates of these eigen values are ordered so that $\hat{l}_i > \hat{l}_2 > \ldots > \hat{l}_n$. So the Tr statistic decreases as R increases. The Johansen method first computes the eigen values and then calculates the trace statistic for every R = 0 to n-1. Critical values of the trace statistic (6) are given in Johansen and Juselius (1990). They depend on the specification of the underlying model, whether or not it includes a constant or trend, and the number of lags in the VAR.

b. Error Correction and Causality

The mechanism which ties a cointegrated series together is `causality, not in the sense that if we make a structural change to one series the other will change too, but in the sense those turning points in one series precedes turning points in the other. This is the concept of `Granger Causality'. When time series are cointegrated there must be some Granger causal flow in the system.

The Granger representation theorem states that a vector autoregressive model on differences of I(1) variables will be misspecified if the variables are cointegrated [Engle and Granger (1987)]. Engle and Granger showed that an equilibrium specification is missing from a VAR specification but when lagged disequilibrium terms are included as explanatory variables the model becomes well specified. The model is called an *error correction model* because it has a self-regulating mechanism whereby deviation from the long-term equilibrium is automatically corrected.

The ECM is a dynamic model for first differences of the I(1) variables that were used in the cointegrating regression. Thus if the yields are cointegrated and the cointegrating vector is based on these, the ECM is a dynamic model of correlation in yields, and the t-statistics on its estimated coefficients give the lead-lag behaviour between yields.

For the case of two cointegrated yield rates x and y, the ECM takes the form:

$$\begin{aligned} \Delta x_t &= a_1 + \sum_{i-1}^{m_1} b_{1i} \Delta x_{t-i} + \sum_{i-1}^{m_2} b_{2i} \Delta y_{t-i} + g_1 z_{t-1} + e_{1t} \\ \Delta y_t &= a_2 + \sum_{i-1}^{m_3} b_{3i} \Delta x_{t-i} + \sum_{i-1}^{m_4} b_{4i} \Delta y_{t-i} + g_2 z_{t-1} + e_{2t} \end{aligned} \quad \ldots\ldots.(7)$$

where ? denotes the first difference operator, z = x – ay is the disequilibrium term and the lag lengths are determined by testing down OLS regressions. Now if a > 0, then (7) shall be an

ECM only if ?$_1$ < 0 and ?$_2$ > 0, for only then the last term in each equation constrain deviations from the long-run equilibrium so that errors will be corrected. For eg. if z is large and positive, then x will decrease because ?$_1$ < 0 and y will increase because ?$_2$ > 0. Both have the effect of reducing z. In this way errors are corrected. Similarly if a < 0, for an ECM, we must have ?$_1$ < 0 and ?$_2$ < 0. The magnitude of coefficients ?$_1$ and ?$_2$ determines the speed of adjustment.

For more than two variables, the ECM shall have one equation for each variable in the system. The dependent variable shall be the first difference and each equation shall have the same explanatory variables: lagged first difference terms up to some order p, and up to r lagged disequilibrium terms corresponding to the r cointegrating vectors. The full specification of the ECM in this form shall be:

$$\Delta y_t = a_0 + B_1 \Delta y_{t-1} + B_2 \Delta y_{t-2} + ... + B_p \Delta y_{t-p} + \Pi y_{t-1} + e_t \quad ....(8)$$

Each of the n equations in (8) has as regressors a constant, the lagged first differences of all variables in **y** up to order p, and all lagged disequilibrium terms because of the term Πy_{t-1}. OLS estimation of each equation separately indicates which variables should be included in each equation, since only some of them are significant in every equation.

IV. DATA

We have selected five rates from the Indian money market for this analysis - 90 day Commercial Paper rate, Overnight Call Money Rates, Overnight MIBOR, Secondary Markey yield of 90 Day Treasury Bill and Secondary Market Yield of One Year Treasury Bill. The full sample period consists of 524 daily observations of each rate from September 3, 2001 to June 30, 2003. The selection of the period has been determined primarily by the availability of data. The various sources of the data and the identifier used for them while reporting empirical results are given in the Table 1.

TABLE 1: DATA SOURCES

Money Market Rate	**Identifier used in reporting empirical results**	**Source**
90 day Commercial Paper Rate. We use the benchmark rate of Reuters.	CP	www.debtonnet.com
3 month Treasury Bill Secondary Market Yield	TB3MN	Money Line Telerate
1 Year Treasury Bill Secondary Market Yield	TB1YR	Money Line Telerate
Overnight MIBOR. We use the benchmark rate of NSE.	MIBOR	National Stock Exchange (NSE)
Overnight Call Money rates. We use the average rate from Money Line Telerate.	CALL	Money Line Telerate

Figure 1 gives the plot of the data used over the same. Table 2 gives the mean and standard deviations of the interest rates over the period of the sample. We can see that the figure clearly reflects the falling interest rate scenario prevailing in the Indian money and capital markets in the last few years. The benchmark money market rates have come down from the range of 7% - 8% during September 2001 to a range of 4% - 5% in June 2003. It is also observed that the 90 day Commercial Paper rate was consistently above the other regards till December 2002. But from there it seems to be at parity with the other rates. This could be due to the low volumes of Commercial Papers initially and the underdevelopment of its market leading to a higher risk premium, which might also include a illiquidity premium, being associated with it. The overnight MIBOR has the most spikes, primarily because it is a polled rate and not an actual traded rate. Treasury Bill rates are more stable compared to other rates as shown by their relatively low standard deviations.

FIGURE 1: PLOT OF RATES USED OVER THE SAMPLE PERIOD

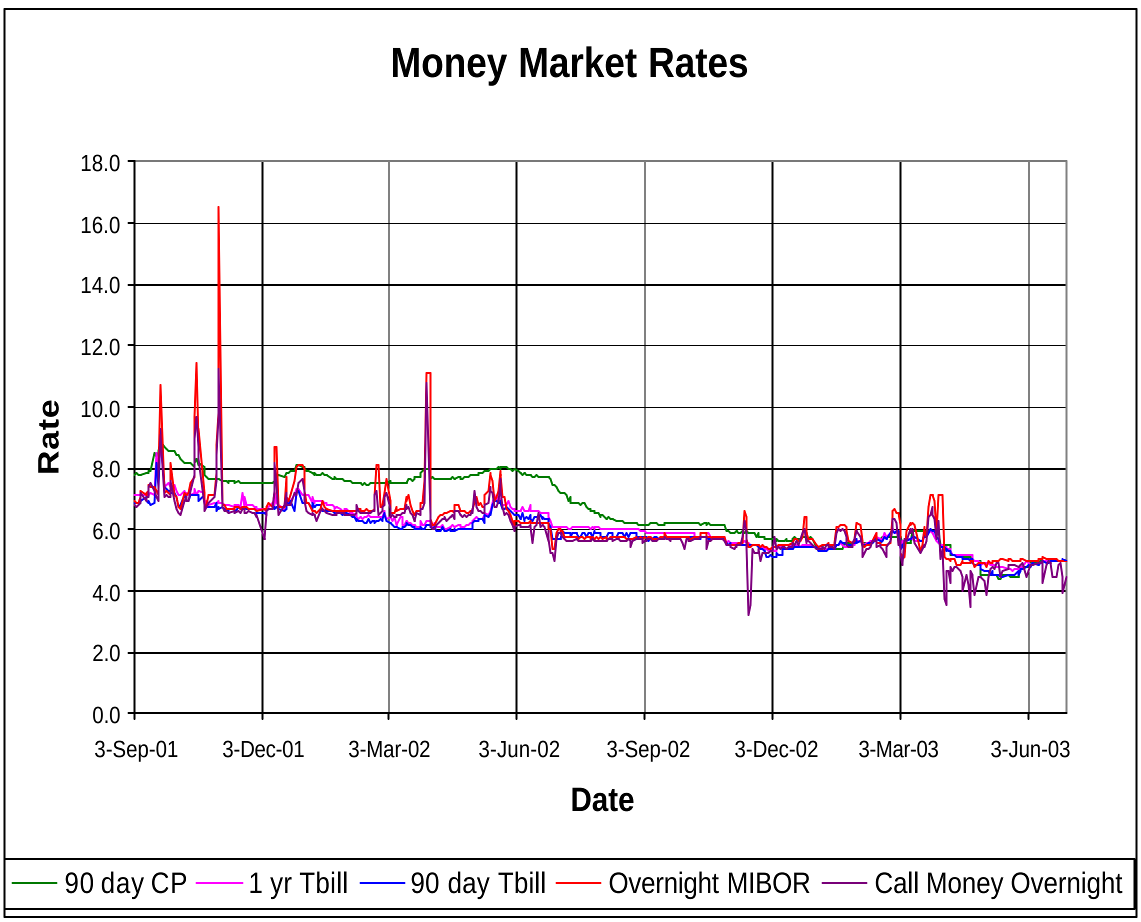

TABLE 2: MONEY MARKET RATES AND THEIR VOLATILITY

Money Market Rate	**Average Rate (%)**	**Standard deviation (%)**
90 day Commercial Paper Rate	6.6545	1.1164
Secondary Market Yield of One Year Treasury Bill	6.0527	0.6840
Secondary Market Yield of 3 month Treasury Bill	5.9391	0.6609
Overnight MIBOR	6.2147	1.0299
Call Money Rate	5.9752	0.9142

V. EMPIRICAL RESULTS

a. Testing for Unit Roots

To test for cointegration between the money market rates, we first establish that the selected money market rates are I (1) i.e. integrated of order 1. This is done by performing a unit root test on time series data on these rates. The unit root test identifies variables that are non stationary, meaning that they contain stochastic trend that leads them to wander randomly. The presence of unit root is tested using the Augmented Dickey-Fuller test suggested by Dickey and Fuller (Said 1991).To test whether a series, z_t, is stationary or not we model it as:

$$\Delta z_t = a + (r - 1) z_{t-1} + \sum_{j=1}^{n} r_j z_{t-j} + e_t \text{ ….(9)}$$

A drift factor has been taken in modeling the series, as the data series were observed to have a downward drift in Figure 1. The n lag terms have been taken to protect against the possibility that z_t follows a higher order autoregressive process. The truncation lag for the test is initial set as:

n = c * (Number of terms) ^ r….(10)

Where c = 5 and r = 0.25. Then the Akaike Information Criteria (Gujarati 1995) (AIC) has been used to find the optimal n.

The null hypothesis of H_0: ?=1 implies that there exists a unit root and, hence, the time series z_t is non-stationary. This is tested against the alternate hypothesis that H_1: ¦ ?¦ <1which implies that the unit root does not exist and the series z_t is stationary. The test statistic is a pseudo t-stat, called Dickey-Fuller (DF) statistic, whose critical values have been documented by MacKinnon (1991).

The results of the unit root test on the five data series are given in Table 3.

TABLE 3: AUGMENTED DUCKY-FULLER TEST RESULTS

Series	**n (No. of lags)**	**DF stat***	**Conclusion**
CP	23	-0.9112	H_0 accepted, the series is I(1)
TB3MN	22	-1.3959	H_0 accepted, the series is I(1)
TB1YR	23	-1.2671	H_0 accepted, the series is I(1)
CALL	15	-1.6102	H_0 accepted, the series is I(1)
MIBOR	15	-2.0605	H_0 accepted, the series is I(1)

*: *Critical Values of DF-stat are -2.86 (5% level of significance) and -2.56 (10% level of Significance) [Mackinnon 1991]*

As expected, we find that all the five money market rates are I (1). Therefore, we proceed with applying the cointegration analysis on them.

b. Johansen's Test

We now test the hypothesis that the money market rates are cointegrated with the spread vectors corresponding to cointegrating vectors. The optimal lag length is found to be 1 using the Schwarz criterion.

On the basis of the Johansen's maximum eigenvalue test ($?_{max}$), of the null hypothesis that there are r cointegrated vectors against the alternative that there are r + 1 cointegrated vectors, we obtain the following results:

TABLE 4: RESULTS OF JOHANSEN'S MAXIMUM EIGEN-VALUE TEST

r	Test Statistic	Critical Value*			Conclusion		
		20%	10%	5%	20%	10%	5%
0	336.7	28.0	30.8	33.3	reject	reject	reject
1	177.2	22.3	24.9	27.3	reject	reject	reject
2	112.3	16.5	19.0	21.3	reject	reject	reject
3	40.8	10.7	12.8	14.6	reject	reject	reject
4	0.1	4.9	6.7	8.1	accept	accept	accept

*: Given in Johansen and Juselius (1990)

On the basis of the Johansen's trace statistic ($?_{trace}$), of the null hypothesis that there are at most r cointegrated vectors against the alternative that there are 5 cointegrated vectors, we obtain the results given in Table 5.

TABLE 5: RESULTS OF JOHANSEN'S TRACE TEST

r	Test Statistic	Critical Value*			Conclusion		
		20%	10%	5%	20%	10%	5%
4	0.1	4.9	6.7	8.1	accept	accept	accept
3	40.8	13.0	15.6	17.8	reject	reject	reject
2	153.1	25.5	28.4	31.3	reject	reject	reject
1	330.3	41.6	45.3	48.4	reject	reject	reject
0	667.1	61.6	66.0	70.0	reject	reject	reject

*: Given in Johansen and Juselius (1990)

The above results show that the rank of the cointegration space is four. Hence, we conclude that the interest rates in the Indian money market are fully cointegrated.

The standardized cointegrating vectors obtained are:

TABLE 6: STANDARDIZED COINTEGRATING VECTORS

Vector	CP	TB3MN	TB1YR	MIBOR	CALL
l_1	-0.0746089	-0.2177542	0.1011592	-0.7956353	1
l_2	0.0902618	1	-0.9179672	-0.0552298	-0.1075432
l_3	0.0079625	-0.8632089	1	-0.0320496	-0.1419981
l_4	-0.6374818	0.1356365	1	-0.0253904	0.0215941

c. Error Correction Model

Having found clear evidence in favor of the money market rate being cointegrated, we now investigate the causal structure and the adjustment processes of the rates using an error correction model.

Let the error correction model equation be:

$$z(t)-z(t-1) = B.H'z(t-1) + c + u(t)....(11)$$

where:

1. z(t) is a 5-vector with components:

   z(1,t) = 90 day CP(t)
   z(2,t) = 90 day Tbill(t)
   z(3,t) = 1 yr Tbill(t)
   z(4,t) = Overnight MIBOR(t)
   z(5,t) = Call Money Overnight(t)

2. H'z(t-1) = e(t-1), say, is the 4-vector of error correction terms, with H the 5x4 matrix of cointegrating vectors,

$$H = \begin{bmatrix} -0.0746089 & +0.0902618 & +0.0079625 & -0.6374818 \\ -0.2177542 & +1.0000000 & -0.8632089 & +0.1356365 \\ +0.1011592 & -0.9179672 & +1.0000000 & +1.0000000 \\ -0.7956353 & -0.0552298 & -0.0320496 & -0.0253904 \\ +1.0000000 & -0.1075432 & -0.1419981 & +0.0215941 \end{bmatrix}$$

3. u(t) is the 5-vector of error terms.

4. t = 2,…,524.

5. B is a 5*4 matrix, where

   B(x,y) represents the coefficient of the yth error correction term for the error correction equation of the x^{th} interest rate.

   x can take values from 1 to 5, with

   1 = 90 day CP
   2 = 90 day T-Bill
   3 = 1 yr T-Bill
   4 = Overnight MIBOR
   5 = Call Money Overnight

   y can take values from 1 to 4, with

   1 = error correction term corresponding to cointegrating vector λ_1
   2 = error correction term corresponding to cointegrating vector λ_2
   3 = error correction term corresponding to cointegrating vector λ_3
   4 = error correction term corresponding to cointegrating vector λ_4

6. c is a 5-vector of constants, where

   c(x) represents the constant for the error correction equation of the x^{th} interest rate

   x can take values from 1 to 5 with

   1 = 90 day CP
   2 = 90 day T-Bill
   3 = 1 yr T-Bill
   4 = Overnight MIBOR
   5 = Call Money Overnight

The estimated value for B and c, with their significance values, are given in Annexure 1. The p-values in red are values that are statistically significant at 5% significance.

We get error correction equations in the following format:
For the rate z_t :

$$\Delta z_t = \sum_{i=1}^{4} b_{zi} EC_i + c_z$$

where,
EC_i is the i^{th} error term as follows:

TABLE 7: ERROR TERMS

Error Terms	**CP_{t-1}**	**$TB3MN_{t-1}$**	**$TB1YR_{t-1}$**	**$MIBOR_{t-1}$**	**$CALL_{t-1}$**
Error Term 1	-0.0746089	-0.2177542	+0.1011592	-0.7956353	1
Error Term 2	+0.0902618	1	-0.9179672	-0.0552298	-0.1075432
Error Term 3	+0.0079625	-0.8632089	1	-0.0320496	-0.1419981
Error Term 4	-0.6374818	+0.1356365	1	-0.0253904	+0.0215941

b_{zi} is the coefficient of the i^{th} error term in equation for z^{th} rate;

and c_z is the constant term in equation for z^{th} rate

The error correction equations obtained are given in Table 6 below.

TABLE 8: ERROR CORRECTION EQUATIONS

	S.No.	1	2	3	4	5
LHS	**Money Market Rate**	ΔCP_t	$\Delta TB3MN_t$	$\Delta TB1YR_t$	$\Delta MIBOR_t$	$\Delta CALL_t$
RHS	**Error Correction Term 1 (EC1)**	0.043327 (5.23)	0.072707 (3.68)	0.062647 (3.70)	1.187471 (16.95)	0.152968 (2.86)
	Error Correction Term 2 (EC2)	-0.050283 (-2.02)	-0.359652 (-6.04)	-0.02538 (-0.50)	1.081235 (5.13)	1.238951 (7.71)
	Error Correction Term 3 (EC3)	-0.009953 (-0.50)	0.155595 (3.28)	-0.02496 (-0.61)	0.952407 (5.67)	1.083716 (8.46)
	Error Correction Term 4 (EC4)	0.014395 (1.47)	-0.118037 (-5.05)	-0.1196 (-5.98)	-0.04527 (-0.55)	-0.05468 (-0.87)
	Constant	-0.037206 (-1.46)	0.322273 (5.29)	0.31279 (5.99)	0.355155 (1.65)	0.23676 (1.44)
	R-square	0.0608	0.1417	0.0873	0.3982	0.211

Figures in brackets give the t-stats

We find that the adjustments in the money market rates is in the right direction in each of the above cases, for example, in the error correction equation for CP above if the error correction term $_{is}$ positive then CP shall increase and since the coefficient of CP in the error correction term is negative, the error correction term shall decrease. Similarly, in every other case, we find that the direction of adjustments is right. This finding supports one of the central implications of the EH, namely that the spreads should be able to predict changes in the short term rates.

VI. CONCLUSION

The presence of well-developed money market instruments is a prerequisite for the proper functioning of the Indian capital market. In this paper, we investigated the structure of the Indian money market and assessed its operational efficiency by testing the validity of the EH.

We used five benchmark rates of the Indian money market: 90 day Commercial Paper rate, 90 day Treasury Bill rate, 1 year Treasury Bill rate, Overnight MIBOR and Overnight Call Money rate. All the rates were found to be non-stationary of order 1 i.e. I(1), a necessary condition for cointegration analysis.

The Johansen cointegration analysis and spread restrictions are consistent with the EH over the sample period. The five rates are found to be completely cointegrated with their cointegration space spanning four vectors. This means that the whole system is driven by one common stochastic trend. The validity of the EH in the Indian Money Market implies that that this market is an efficient vehicle for macroeconomic policy implementation. For the sample period we examined, the Indian money market accomplished its role as a means of formulating market expectations in accordance with those of monetary policy makers. For the investors, it shows that from a long term perspective, all the various money market instruments shall bear same returns.

The error correction model shows that the spreads are self-correcting, i.e., the changes in the rates in the short term take it in the direction of the long-run equilibrium between them. This is encouraging evidence for the market investors, since not only it helps them to predict the changes in the money market rates in the short term, but it also helps them choose between the various money market instruments. The instrument which is farthest from its long term alignment shall have the greatest correction in the near term. The error correction equations also identify the direction of this movement in the short term. Thus, an investor can choose the instrument that best suits his portfolio requirements.

But the speed of adjustment is found to be slow in general, given the many small coefficients in the error correcting equations. This shows that though the money market rates tend to move towards their long term equilibrium state, the movement is not a quick one. This should act as a caveat for the investors and the error correcting model should not be taken as the sole criterion of investment. It also reflects that the money markets in India are still in a transitory state. The ongoing reforms have definitely led to a greater integration in the financial markets. Yet there has to be better and faster information flow to investors, to ensure no unfair arbitration opportunities to a few players.

Direct benefits from money market developments include more efficient liquidity management, more effective risk management and a broadening in the range of investment and funding products. Indirect benefits include increased competition in the financial sector, more accurate financial pricing through benchmarking and a more rapid transmission of price changes across the spectrum of interest rates. Related to this, developed money markets facilitate the smooth implementation of monetary policy in liberalized financial systems. This includes greater flexibility in implementation and, also, the avoidance of measures, like selective credit lines, that distort the allocation of resources through the financial system. Thus, it is imperative that countries like India, that have worked hard to develop its financial markets, ensure that the financial sector reforms continue to make the markets as efficient and as integrated as those of the developed economies.

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ANNEXURE

ANNEXURE A			
90 day CP R-square = .0608			
Parameter	ML estimate	t-value	p-value
b(1,1)	0.043327	5.23	0.00000
b(1,2)	-0.050283	-2.02	0.04350
b(1,3)	-0.009953	-0.50	0.61627
b(1,4)	0.014395	1.47	0.14095
c(1)	-0.037206	-1.46	0.14480
3 Month T-Bill R-square = .1417			
Parameter	ML estimate	t-value	p-value
b(2,1)	0.072707	3.68	0.00024
b(2,2)	-0.359652	-6.04	0.00000
b(2,3)	0.155595	3.28	0.00104
b(2,4)	-0.118037	-5.05	0.00000
c(2)	0.322273	5.29	0.00000
One Year T-Bill R-square = .0873			
Parameter	ML estimate	t-value	p-value
b(3,1)	0.062647	3.70	0.00022
b(3,2)	-0.025376	-0.50	0.61867
b(3,3)	-0.024957	-0.61	0.53928
b(3,4)	-0.119600	-5.98	0.00000
c(3)	0.312790	5.99	0.00000

ANNEXURE A

Overnight MIBOR R-square = .3982			
Parameter	ML estimate	t-value	p-value
b(4,1)	1.187471	16.95	0.00000
b(4,2)	1.081235	5.13	0.00000
b(4,3)	0.952407	5.67	0.00000
b(4,4)	-0.045267	-0.55	0.58420
c(4)	0.355155	1.65	0.09991
Call Money Overnight R-square = .2110			
Parameter	ML estimate	t-value	p-value
b(5,1)	0.152968	2.86	0.00420
b(5,2)	1.238951	7.71	0.00000
b(5,3)	1.083716	8.46	0.00000
b(5,4)	-0.054676	-0.87	0.38619
c(5)	0.236760	1.44	0.15048