CDE
June 2010

DETERMINANTS OF WEEKLY YIELDS ON GOVERNMENT SECURITIES IN INDIA

Pami Dua
Email: dua@econdse.org
Department of Economics
Delhi School of Economics
University of Delhi

Nishita Raje
Email: nbraje@rbi.org.in
Reserve Bank of India
Mumbai

Working Paper No. 187

Centre for Development Economics
Department of Economics, Delhi School of Economics

Determinants of Weekly Yields on Government Securities in India

Pami Dua*

Department of Economics, Delhi School of Economics
University of Delhi, Delhi, India
e-mail: dua@econdse.org

and

Nishita Raje*

Reserve Bank of India, Mumbai 400001, India
e-mail: nbraje@rbi.org.in

May 2010

Abstract

This paper examines the determinants of the Government yields in India using weekly data from April 2001 through March 2009. The analysis covers Treasury Bills with residual maturity of 15-91 days and Government securities of residual maturity one, five and ten years respectively. The empirical estimates show that a long-run relationship exists between each of these interest rates and the policy rate, rate of growth of money supply, inflation, interest rate spread, foreign interest rate and forward premium. At the same time, the empirical results also show that the relative importance of the determinants varies across the maturity spectrum. The normalized generalized variance decompositions suggest that the policy rate and the rate of growth of high powered money are less important in explaining the proportion of variation in longer term interest rates. The weight of the forward premium also diminishes as we move towards higher maturity interest rates. The inflation rate is also relatively less important in explaining variations in the 10-year rate. The yield spread, on the other hand, is more important in explaining the longer term rates. The results also show that a large proportion of the variation in the rates on the 5-year and 10-year government securities is attributed to the interest rate itself suggesting that the unexplained variation may be a result of cyclical factors that are relatively more important for longer term rates but are not captured by the yield spread and are omitted from the estimations due to the high frequency of data employed.

JEL: C 22, E 43
Keywords: interest rate determination; government yields; cointegration and generalized variance decompositions

Acknowledgments

The authors gratefully acknowledge a research grant from the Centre for Development Economics, Delhi School of Economics and competent research assistance from Naveen Kumar. The authors also acknowledge suggestions from participants of the International Conference on Quantitative Methods in Money, Banking, Finance and Insurance where the paper was presented in March 2010 at the Indian Business School, Hyderabad.

*The views expressed in the paper belong to the authors and not to the organization they belong to. The errors, if any, are solely their responsibility.

I. Introduction

Tracking interest rates and understanding their determinants is crucial for both financial market participants and policymakers. This is especially true in the case of an economy such as India with an evolving financial sector and increasing integration with the global economy. After almost two decades of financial liberalisation, the financial markets in India are now fairly developed and its monetary policy is also comparable to some extent to that of developed countries. In this scenario, the objective of the study is to examine the impact of domestic market forces and external factors on interest rate determination in India across the maturity spectrum. The importance of such a study can hardly be over-emphasized given the fact that prior to economic reforms in India, not only was the capital account closed, but most of the interest rates were also administered. As a result, the interest rates were to a great extent immune to both domestic market forces and external factors. In the post-reform period, however, Indian financial markets are more integrated and the movement of various rates of interest is generally concerted and responsive to market forces. With the onset of financial liberalisation in 1991, various segments of the financial market were gradually deregulated and Government securities started paying market determined interest rates. The development of the financial markets has also improved the transmission of monetary policy and the fixed income Government securities market has matured a great deal over the years.[1]

The focus of this study is on the secondary market yields on Government securities on a residual maturity basis. Limiting the analysis to zero-default risk Government paper enables us to examine a uniform set of securities across the maturity spectrum. The existence of a large secondary market for Government securities assures the market players of liquidity as the securities can be easily traded. Yet there is a differential in the yields of these securities across the maturity spectrum. This paper thus examines the relative influence of various monetary and financial factors on the short- and long-term weekly interest rates on Government Securities from April 2001 through March 2009[2]. The determinants that are considered include the policy rate (repo rate), money supply growth, inflation rate, interest rate spread, liquidity, forward premium and foreign interest rates.

The rest of the paper proceeds as follows Section 2 describes the salient features of the Indian economy with respect to interest rate determination. Section 3 outlines the model

[1] See Kanagasabapathy and Goyal(2004)

[2] The starting period allows sufficient time for the Liquidity Adjustment Facility (LAF) to stabilise after it was introduced on June 5, 2000.

for interest rate determination. Section 4 covers the data and methodology and the following section reports the empirical results. Section 6 provides the conclusions.

2. Interest Rates and Monetary Policy in India: Some Stylized Facts

The Indian financial system till the early 1990s was characterized by an administered structure of interest rates and restrictions on various market players, *viz.* banks, financial institutions, mutual funds, corporate entities. Under the erstwhile administered interest rate regime, the Reserve Bank of India fixed interest rates both on the assets and liability side (of the commercial banks) to ensure that the commercial banks had a reasonable spread. Government securities had a captive market resulting from the SLR requirement applicable to banks and similar statutory provisions governing investment of funds by financial institutions and insurance companies facilitated the floatation of debt at relatively low interest rates. Since lending and borrowing operations did not involve any interest rate risk, there was no real incentive for the market players to actively manage their assets and liabilities. Moreover, in this era the public sector banks were not driven by the profit motive. There were also restrictions on the portfolio allocation in the form of specified targets. All these factors culminated in the lack of adequate volumes as a result of which the market lacked depth and liquidity.

It may be mentioned here that alongside the developments in the Government securities market, the banking sector was also evolving to a significant extent in response to financial sector reforms initiated as a part of structural reforms encompassing trade, industry, investment and external sector, launched by the Central Government in the early 1990s in. A high-powered Committee on the Financial System (CFS) was constituted by the Government of India in August 1991 to examine all aspects relating to the structure, organisation, functions and procedures of the financial system (Chairman: Mr. M. Narasimham). Financial sector reforms were initiated as part of overall structural reforms to impart efficiency and dynamism to the financial sector. It was highlighted that one of the major factors that affected banks' profitability was high pre-emption of their resources. Accordingly, a phased reduction in the SLR and the CRR was undertaken beginning January 1993 and April 1993, respectively. There was a sharp reduction in the Central Government's fiscal deficit in the initial years of reforms. Accordingly, there was less of a need to use the banking sector as a captive source of funds. Interest rates on Government securities were also made more or less market determined in 1992.

In this context the operationalisation of the landmark historic agreements between the Reserve Bank and the Central Government in September 1994 that phased out automatic monetisation of fiscal deficits through *ad hoc* Treasury Bills turned out to be valuable in many respects. It brought about a shift from the administered interest rate to market-determined interest rates and made the Government more conscious of the true costs of its borrowing programme imparting fiscal discipline. The move towards bond financing induced conditions for increased private capital formation. It freed monetary policy from the fiscal deficit's straitjacket and allowed the interest rate to reflect the opportunity cost of holding money among financial and other assets so as to improve its allocative efficiency (Jalan, 2002)[3].

In conjunction with these developments the commercial banks were also given freedom to fix their own deposit and lending rates depending on commercial judgment, subject to the approval of their boards. The process of deregulation of interest rates - that took place over the period 1994 to 1997- enhanced the prominence of interest rates in monetary policy. It ushered in a greater role to market forces and enabled a shift from direct to indirect instruments of monetary policy. The prominence of the interest rate channel increased after financial sector liberalization, a greater role assigned to the policy rates, the Bank rate and later to the repo rate. The Reserve Bank's Working Group on Money Supply (1998) underscored the significance of the interest rate channel of monetary transmission in a deregulated environment. This was, in fact, the underlying principle of the multiple indicator approach that was adopted by the Reserve Bank during 1998-99, whereby a set of economic variables (including interest rates) were to be monitored along with the growth in broad money, for monetary policy purposes. Monetary Policy Statements of the Reserve Bank in recent years have also emphasized the preference for a soft and flexible interest rate environment within the framework of macroeconomic stability.[4]

Interest rates across various financial markets have been progressively rationalized and deregulated during the reform period. The reforms have aimed towards the easing of quantitative restrictions, removal of barriers to entry, wider participation, and increase in the number of instruments and improvements in trading, clearing and settlement practices as well as informational flows. Besides, the elimination of automatic monetization of Government budget deficit, the progressive reduction in statutory reserve requirements and the shift from direct to indirect instruments of monetary control, have impacted upon the structure of financial markets and the enhanced role of interest rates in the system.

Financial liberalization has made it possible for the monetary authority to shift to the indirect instruments for conduct of monetary policy. The process on monetary policy making

---

[3] Also see Report on Currency and Finance , 2006.

[4] Along with these developments the external sector dynamics was changing fast, the exchange rates were first made flexible and then left to the market forces increasing the role of the exchange rate channel with increasing global integration.

also underwent a change; see Nachane and Raje (2007) for details of how monetary policy changed in India with liberalisation.

Since April 1992, the Central Government borrowing programme has been conducted largely through auctions enabling market based price discovery. As a result of the institutions of market related interest rates on Government borrowing, OMOs, hitherto ineffective, gained considerable momentum. There has been a gradual shift in emphasis from direct to indirect instruments of policy - OMOs and repos have been actively used to influence the level of reserves available with banks. To augment the effectiveness of this instrument, greater efforts are being made to widen and deepen the money, foreign exchange and gilts markets and strengthen the banking system. Along the maturity continuum, the Government Securities market has also become very active and today there are various influences that drive the interest rates. Once the Government security market was freed, the dynamics changed with respect to public sector banks that were the major holders of Government bonds. Now in the freer environment, the public sector banks were required to handle interest rate risk, market risk by managing their assets and liabilities appropriately. This fostered a greater emphasis on the treasury management in banks across the board. Consequently, an element of competitive pricing and substitutability in response to interest rate movements gradually entered into the operations of banks and institutions leading to market integration.

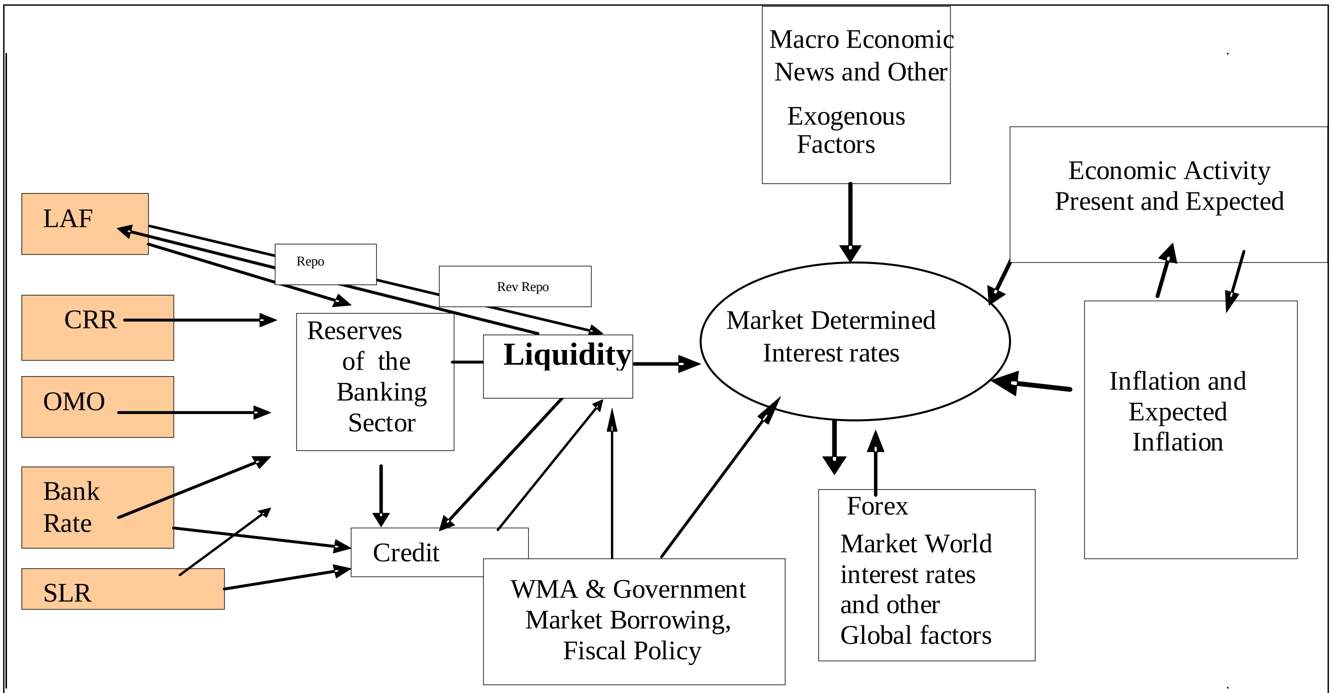
The Government Securities market gathered depth and breadth with a number of institutional and technological measures introduced by the Reserve Bank of India. The foremost of these were the setting up of Discount and Finance House of India (DFHI), Securities Trading Corporation of India (STCI) and the introduction of Primary Dealers system in 1996. These measures enhanced the liquidity and depth in the markets. The Primary Dealers ensured maximum participation in the primary auctions and provided two-way quotes. Another significant step was the introduction of the scheme of Ways and Means Advances after the phasing out of *ad-hoc* treasury bills. Apart from these reform measures, markets were gradually opened to the non-bank participants since the shift from the administered interest rates to a market based pricing of securities attracted larger participation including the non-banks. Computerization of Statutory General Ledger (SGL) operations and dissemination of information on secondary market trading imparted considerable transparency in the trading and settlement system for Government securities markets. Recognizing the importance of the payment systems, a number of initiatives were undertaken for bringing about efficiency in the payment and settlement systems. These include the implementation of the real time gross settlement (RTGS) and introduction of the Negotiated

Dealing System (NDS) in February 2002 to facilitate electronic bidding, secondary market trading and settlement and to disseminate information on trades on a real time basis. These developments enabled the Government Securities market to leap frog on technology. Both in terms of volume and value, the transactions in the Government Securities market have increased significantly in recent years. In India, the spread of the RTGS system was very rapid in comparison with other countries. Effective funds movements through the RTGS platform also greatly helped the cash management by banks and the Government Securities market.

Today the Government Securities market is vibrant and has acquired significant depth and liquidity that has resulted in growing volumes. Significant activity level in the secondary market has helped the development of the yield curve and the term structure of interest rates. With the opening up of the economy, the international developments and the international interest rates have come to bear upon the domestic rates. Collateralised Borrowing and Lending Obligations (CBLOs) were operationalised as a money market instrument through the Clearing Corporation of India Limited (CCIL) in January 2003. With a view to developing the market for this instrument, the Reserve Bank introduced automated value-free transfer of securities between market participants and the CCIL during 2004-05. Now a significant repo market outside the LAF has been assiduously developed by the Reserve Bank to provide an avenue for bank and non-bank participants to trade funds after the conversion of the call/notice money market into a pure inter-bank market. With the initiation of the process of financial liberalisation, the financial markets have become progressively integrated as is evident from the closer alignment of interest rates. Market integration has also implied that the interest rate channel of monetary transmission has gained some strength in recent years. Now the market repo and the interbank market have both geared to take care of the short term liquidity in the system. There is a correspondence between changes in monetary policy stance and the movement in yields of money market securities, Treasury bills and Government dated securities.

There are various factors that influence the movement of interest rates in India. Determinants of interest rates can be looked at as market forces of demand and supply of liquidity that are key determinants of the market determined rates. The RBI conducts its day-to-day operations by maintaining adequate liquidity in the system. The Reserve Bank has put in place a liquidity management framework to manage daily liquidity, taking into account the country-specific features. The market interest rates are affected by a series of factors, like the RBI's decisions to alter the quantum of liquidity in the system; or changes that it may make in the required reserve ratios; changes in the level of Government balances with RBI and its use of the WMA facility. The LAF window is used to modulate liquidity through judicious fixing of the repo-reverse repo informal corridor. The other route is open market operations where the RBI operates through purchase and sale of securities through the auction route. The Market Stabilization Scheme (MSS) was introduced in early 2004 to absorb excess liquidity generated on account of the accretion of the foreign exchange assets of the Bank to neutralise the monetary impact of capital flows. The MSS is an arrangement between the Government of India and the Reserve Bank to mop up excess liquidity. Under the scheme, the Reserve Bank issues treasury bills/dated Government securities by way of auctions (and the cost of sterilisation is borne by the Government) on behalf of the Government and the money raised is impounded in a separate account with the RBI. The MSS has provided the Reserve Bank with an additional instrument of liquidity management and to relieve the LAF from the burden of sterilisation operations. The unwinding of the MSS or what is known as de-sequestering is also used as a key instrument of liquidity management. The FII investment in the G-Sec market is capped at US $ 5billion limiting the direct impact of foreign money. Summing up, the RBI has a multipronged impact on the market through the repo rate/reverse repo rate, the mechanism of LAF auctions, open market operations and direct changes in CRR all of which impact on the market interest rates through the liquidity in the system as illustrated through all the boxes on the left hand side in Chart 1.

Chart I: Determinant of Interest Rates



CRR refers to the Cash Reserve Ratio; OMO are the open market operations, the WMA refers to Ways and Means Advances.

The present paper focuses on the yield rates on Government Securities in the secondary market on residual maturity basis so as to eliminate the differential impact of various risks, liquidity or convertibility. As far as the Government Bond market is concerned the shorter rates are again influenced by similar near term factors while the longer rates are driven by fundamentals. In the Indian context we use the Repo rate as the policy rate. In recent years the repo rate has emerged as a reference rate as also a signaling mechanism for monetary policy actions while the LAF has been effective both as a tool for liquidity management as well as a signal for interest rates in the overnight market.

The liquidity in the system is also influenced by ‘autonomous’ factors like the Ways and Means Advances (WMA) to the Government. The interest rates are also affected by developments in the foreign exchange markets, macroeconomic activity, actual and expected inflation and ‘news’.

3. Determinants of Interest Rates

Interest rates are determined by a number of macroeconomic variables. Furthermore, their impacts may differ depending upon the maturity spectrum of the interest rates. For instance, for short-term/medium-term rates, factors that might impact interest rates include monetary policy, liquidity, demand and supply of credit, actual and expected inflation, and external factors such as foreign interest rates. For long-term interest rates, demand and supply of funds, economic activity and expectations about government policy might be relatively more important.

Some of these factors also emerge from the stylised model developed by Dua and Pandit (2002) under covered interest parity condition. The equation for the real interest rate derived from their model can be expressed as a function of expected inflation, foreign interest rate, forward premium, and variables to denote fiscal and monetary effects as given below:

$$r = \mathrm{f}\,(g, m, \pi^e, i^*, fp)$$

where r denotes the real rate of interest; g is real government expenditure; m denotes real money supply; π^e is expected inflation; i^* is the foreign interest rate; and fp is forward premium.

Dua and Pandit (2002) estimate the cointegrating relationship using monthly data for India from March 1993 to May 2000 for three interest rates, viz., 3-month and 12-month Treasury bill rates and the commercial paper rate. The cointegrating relationship for each of the interest rates suggests that while real money supply is negatively related to the real interest rate, real government. expenditure, forward premium and the foreign interest rate have positive signs. Furthermore, real money supply, real government expenditure, foreign interest rate, forward premium and the domestic inflation rate Granger cause the domestic real interest rate.

Dua et al. (2008) develop vector autoregressive (VAR), vector error correction (VEC) and Bayesian vector autoregressive (BVAR) models to forecast Indian short-term and long-term rates, viz. call money rate, 15-91 days Treasury bill rate and rates on 1-year, 5-years and 10-years government securities. Since weekly data is used to estimate the multivariate models over the period April 1997 to December 2001 (with out-of-sample forecast period as January 2002 to June 2004), financial and monetary factors available at this high frequency such as inflation rate, policy rate, yield spread, liquidity, foreign interest rates and forward premium are considered. The study reports that all the variables significantly Granger cause the various interest rates, thus justifying their inclusion in the model.

The use of weekly data obviously restricted the selection of variables for inclusion in the models. Variables such as measures of current and future economic activity and fiscal policy could not be included due to unavailability of data at the weekly frequency.

Nevertheless, some of these effects can be captured in financial spreads that are measured by differences in the yields on financial assets. These spreads exist due to differences in liquidity, risk and maturity that can also be influenced by factors such as taxes and portfolio regulations. Cyclical changes in any of these factors can arise from monetary policy shifts leading to changes in financial spreads. The most commonly used financial spread is the yield spread whose role in predicting future changes in interest rates is documented in several articles including Campbell and Shiller (1991), Froot (1989), and Sarantis and Lin (1999).

The slope of the yield curve – the difference between the long-term interest rate and the short-term interest rate, measures the yield spread. According to the expectations hypothesis of the term structure, this yield differential provides an indication of the expected future inflation rate (Mishkin, 1989). It also provides a signal about growth in future output. For instance, tight monetary policy and high short-term interest rates can imply a declining yield curve and thus a slowdown in future output growth. Thus the inclusion of the yield spread in the forecasting models in Dua et al. served as a proxy for the expected inflation rate and the economic activity. The specification employed in Dua et al. is applied in this study.

Following Dua *et al*, the variables of interest are as below:

$$i = f\,(\textit{policy rate, liquidity, } \pi, \textit{ yield spread, } i^*, fp)$$

In the above specification, the policy rate and the quantum of liquidity capture the impact of monetary policy. Monetary policy plays an important role in the determination of interest rates although the extent of influence and the transmission effect depends on whether interest rates are regulated or market determined and on the degree of development of the financial markets. The operating procedures of monetary policy vary a great deal across countries. Nevertheless, one common feature across countries in recent years is that the shorter term interest rates have emerged as key indicators of the monetary policy stance across the globe. Central banks can influence interest rates either directly through a policy rate change or indirectly by changing the quantum of liquidity in the system, through various other instruments, such open market operations. It is expected that the more developed the financial market, the greater is the adjustment by the market in response to a cue from the central bank. In the case of developed countries, the mere announcements of the monetary authority are adequate to align the markets. Thornton (2000) has discussed how by just announcing the desired level of the interest rate, central banks can align the market players to new levels of interest rates. In this scenario, "open mouth operations" may be enough and open market operations may not be required[5]. Central banks of developing countries may, however, face some constraints on the transmission of their monetary policy impulses. This often occurs due to the existence of segmentation in markets and/or administered interest rates.

In an attempt to gauge the impact of a change in the policy rate on the market interest rate, Cook and Hahn (1989) show that the changes in the federal funds rate target influences the shorter term rates more than the longer term rates. These results are reinforced by a recent study by Piazzesi (2005) that demonstrates that as monetary-policy shocks affect short rates more than long ones, they change the slope of the yield curve. Nevertheless, while there may be a differential in the extent of impact on the short vs long rates, the sign of the policy rate is expected to be positive.

The liquidity aspect of monetary policy can be captured by money supply growth[6]. It is noteworthy, however, that besides the liquidity effect of money growth on interest rates whereby a rise in money growth is expected to cause a decline in interest rates, money supply growth also has an inflation expectation effect wherein an increase in money supply growth impacts interest rates upwards through inflation expectations. The sign on the money supply growth thus depends on the relative strength of the two effects. According to Cochrane (1989) the "anticipated inflation effect dominates if money growth is a good predictor of future money growth if the lag from money growth to inflation is short, and if changes in money growth are largely anticipated." He indicated that the liquidity effect should dominate if "short-term changes in money growth are typically not interpreted as signals that long-term policy has changed, if the lag from money to inflation is long, and if changes in money growth are largely unanticipated. Furthermore, the existence of a liquidity effect implies that (expected) real returns vary over time." [7]

The inflation rate is another important determinant of interest rates. This has been incorporated in various studies in different ways. For example, Rudebusch and Wu (2008) as

[5] The extent of intervention that is required is purely a reaction to the kind of channels of transmission in the system as illustrated by Bernanke and Blinder (1992). In recent times communication or merely talking about monetary policy has become very important in the transmission process of monetary policy and in this context, Blinder (2008) has illustrated the virtues (and vices) of central bank communication.

[6] Dua et al. (2008) construct a measure of liquidity based on bank reserves. Money supply growth, however, gave a better fit in the current study and is therefore used here.

[7] Cochrane (1989), p. 75.

well as Bekaert, Cho and Moreno (2005), show that the inflation rate targeted by the monetary authority, or the long run equilibrium inflation rate is a crucial determinant of the term structure. Rudebusch and Wu (2008) show that the level of the interest rate is affected by the market participants' views about the underlying or medium- term inflation target of the central bank.

The importance of the yield spread in predicting interest rates and serving as a proxy for economic activity and future inflation has already been discussed earlier in the text. To elaborate, a rise in short-term rates induced by tight monetary policy is likely to result in a slowdown in real economic activity and thus the demand for credit. This reduction in demand is likely to reduce short rates and since long-term rates can be defined as the average of the expected short-term rates, this causes them to fall. Thus the yield spread defined as the differential between the long-term and short-term rate also decreases resulting in a flatter yield curve. Changes in the slope of the yield curve are therefore predictors of economic activity with a flattening of the curve accompanied by reduced inflation expectations. In the equation for the interest rate, the yield spread as defined above therefore enters with a positive sign.

The foreign interest rate and the forward premium reflect the integration between domestic and global markets and the fact that the Indian money and foreign exchange markets have become intrinsically linked to each other, especially in view of the commercial banks having a dominant presence in both these markets. The world interest rate and the domestic rate are expected to be positively related since a rise in the foreign interest rate would lead to an outflow of capital implying a fall in the demand for domestic bonds and a rise in the domestic rate of interest. Finally, an increase in the forward premium is likely to result in an expectation of depreciation of the domestic currency raising the demand for foreign bonds relative to domestic bonds. This would result in lower domestic bond prices and a higher domestic rate of interest. Thus, the forward premium is expected to bear a positive coefficient.

The expected signs of the variables are therefore as follows:

Expected Signs of Independent Variables

Variables	Expected Sign
Policy rate	+
Liquidity (dm)	+/-
π	+
yield spread	+
i*	+
fp	+

It is expected that monetary policy variables would have a larger impact on shorter term rates while variables that denote economic activity, such as the yield spread would have a bigger effect on longer term rates.

4. Data and Empirical Model

The interest rates in this study are weekly observations on yields to maturity on riskless Government securities. The interest rates examined are Treasury bills 15 to 91 days, and Government securities with residual maturity of 1, 5 and 10 years. The term spread or the variation in rates across these securities is due to their term to maturity only as these Government securities do not differ in default risk, liquidity, marketability risk, tax effects and convertibility.

The rates are based on the secondary market outright transactions in Government securities as reported in the Subsidiary Government Ledger (SGL) accounts at the Reserve Bank of India, Mumbai. The data are taken from the Handbook of Statistics on the Indian Economy and are described in the annexure. The period of analysis is from April 2001 to March 2009.

The variables included in the models used in the present study are based on the analysis in the previous section and are as follows: policy rate (repo rate[8]); inflation - π (calculated from wholesale price index); yield spread (10 years Government security rate minus Treasury Bill rate of residual maturity 15-91 days); liquidity in the system (rate of growth of high powered money); foreign interest rates - i^*_1 and i^*_2 respectively (Libor 3 months and 6 months); and forward premium on exchange rate of US dollar for 3 and 6 months respectively - fp_1 and fp_2 .

The specific variables included in the various models are given below:

Model A: Treasury Bill rate (15-91 days)

$i_{(TB15\text{-}91)} = f(Repo\ rate,\ dm,\ \pi,\ Spread,\ i^*_1,\ fp_1)$

Model B: Government Security 1 year

$i_{(GSec1)} = f(Repo\ rate,\ dm,\ \pi,\ Spread,\ i^*_2,\ fp_2)$

Model C: Government Security 5 years

$i_{(GSec5)} = f(Repo\ rate,\ dm,\ \pi,\ Spread,\ i^*_2,\ fp_2)$

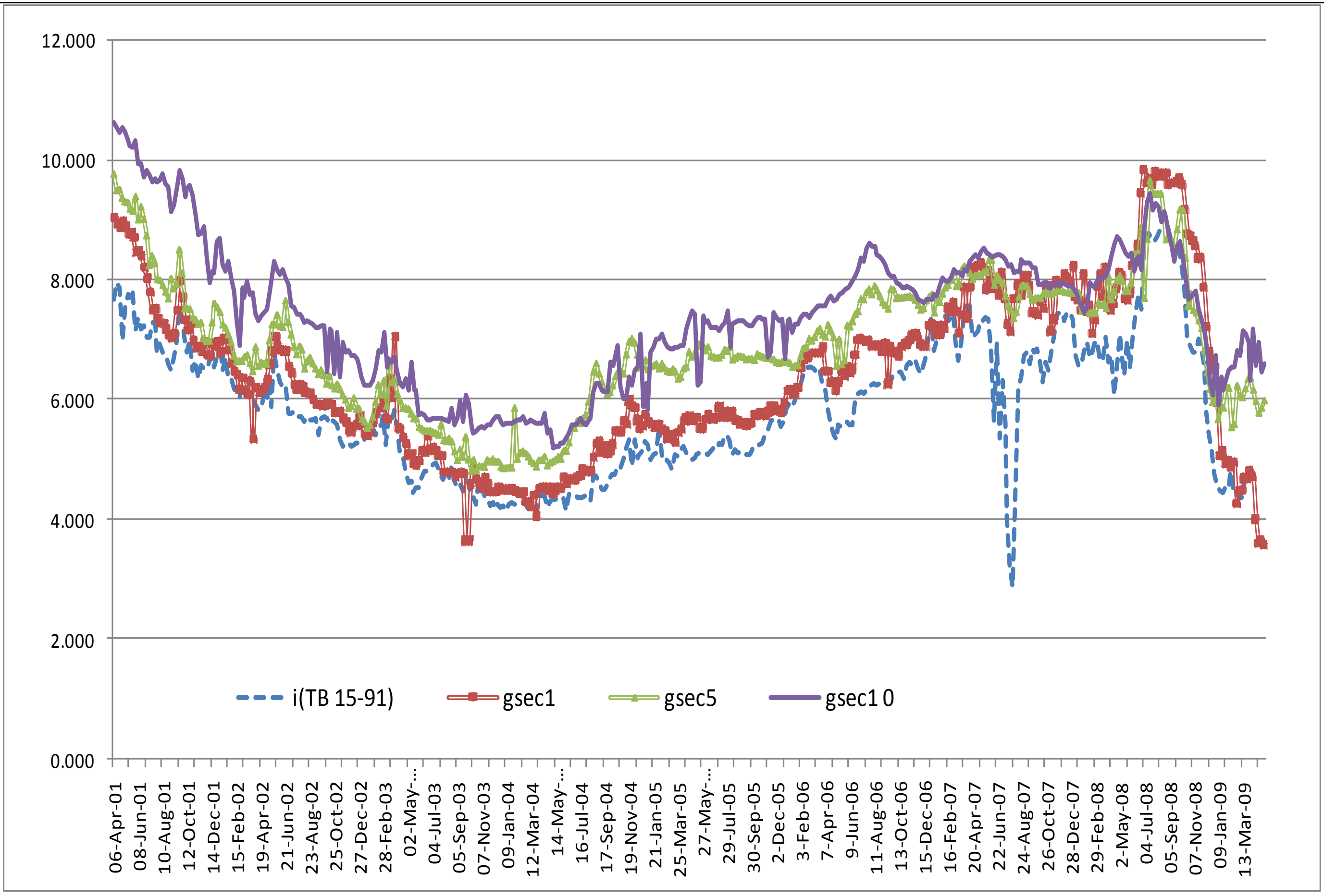
[8] In the Indian context we use the repo rate that has emerged as a reference rate as also a signaling mechanism for monetary policy actions

Model D: Government Security 10 years

$i_{(GSec10)} = f(\text{Repo rate}, dm, \pi, \text{Spread}, i^*_2, fp_2)$

The model specifications are essentially the same apart from the use of the 3 months Libor and forward premium employed in the specification of the Treasury bill rate compared to the 6 months rates in other models[9].

Chart 2: Secondary Market Yields on Government Securities (Residual Maturity)



A preliminary analysis of the data employed in the study is presented in Tables 1, 2A and 2B and Chart 2. Summary statistics for the interest rates given in Table 1 show that the mean value increases with term to maturity. Chart 2 as well as the correlation matrix reported in Table 2A shows that there is significant co-movement in the interest rates across

[9] This specification was confirmed by the empirical estimations.

the maturity spectrum. The data also show that the policy rate is highly correlated with the other interest rates. The strength of the correlation between the growth rate of high powered money and the interest rates declines as we move towards higher maturity interest rates; the direction of correlation remains positive throughout. Furthermore, the inflation rate is correlated to a larger extent to the shorter term interest rates than to those of longer maturity. The correlation matrix also shows that the foreign interest rate and the forward premia are positively related to the interest rates. The interest rate spread is positively related to the longer term interest rates with the magnitude being higher for the 10-year Government security compared to the 5-year security.

The correlation matrix between the independent variables also displays interesting trends. The correlations between 3- and 6-month Libor is 3- and 6-month forward premia respectively are close to one. The repo rate is reasonably correlated with the foreign interest rate and forward premia (correlation coefficient around 0.5) and the rate of growth of high powered money is also reasonably correlated with the inflation rate and the foreign interest rate. A caveat here is that the correlation analysis given above is merely indicative since the correlation coefficients are not tested for statistical significance and that the relationships between variables are best tested in a multivariate framework. A detailed econometric analysis is therefore necessary.

5. Econometric Methodology

This paper analyses the relationship between the various interest rates examined in this study and their determinants in a cointegration framework. The interest rates are as follows: Treasury bill 15-91 days rate and Government securities with residual maturity of 1, 5 and 10 years rates. The determinants include the repo rate, rate of growth of high powered money, inflation rate, interest rate spread, foreign interest rate and forward premium.

A test for nonstationarity is first conducted followed by tests for cointegration and Granger causality. Generalized variance decompositions are then examined.

Tests for Nonstationarity

The classical regression model requires that the dependent and independent variables in a regression be stationary in order to avoid the problem of what Granger and Newbold (1974) called 'spurious regression' characterized by a high R^2, significant t-statistics but results that are without economic meaning. A stationary series exhibits mean reversion, has a finite, time invariant variance and a finite covariance between two values that depends only on their distance apart in time, not on their absolute location in time. If the characteristics of the stochastic process that generated a time series change overtime, i.e. if the series is nonstationary, it becomes difficult to represent it over past and future intervals of time by a simple algebraic model. Thus the first econometric exercise is to test if all the series are nonstationary or have a unit root.

A battery of unit root tests now exists to discern whether a time series exhibits I (1) (unit root) or I (0) (stationary) behaviour. In this study, we employ the augmented Dickey-Fuller (1979, 1981) ADF test and its more powerful variant, the Dickey-Fuller generalized least squares (DF-GLS) test proposed by Elliot, Rothenberg and Stock (1996). These two tests share the same null hypothesis of a unit root.

To test if a sequence y_t contains a unit root using the ADF procedure, three different regression equations are considered.

$$\Delta y_t = \alpha + \gamma y_{t-1} + \theta t + \sum_{i=2} \beta_i \Delta y_{t-i+1} + \varepsilon_t \qquad (1)$$

$$\Delta y_t = \alpha + \gamma y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t \qquad (2)$$

$$\Delta y_t = \gamma y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t \qquad (3)$$

The most general form of the D-F test (equation 1) allows for both a drift term and a deterministic trend; the second excludes the deterministic trend; and the third does not contain an intercept or a trend term. In all three equations, the parameter of interest is γ. If $\gamma=0$, the y_t sequence has a unit root. The null is therefore $\gamma=0$ against the alternative $\gamma\neq 0$. The estimated t-statistic is compared with the appropriate critical value in the Dickey-Fuller tables to determine if the null hypothesis is valid. The critical values are denoted by τ_τ, τ_μ and τ for equations (1), (2) and (3) respectively. The D-F test presumes the existence of white noise errors in the regression; hence lags of the dependent variable are added to the regressions to whiten the errors.

Following Doldado, Jenkinson and Sosvilla-Rivero (1990), a sequential procedure is used to test for the presence of a unit root when the form of the data-generating process is unknown. This involves testing the most general model (equation 1) first and following various tests, moving to the most parsimonious model (equation 3). Such a procedure is necessary since including the intercept and trend term reduces the degrees of freedom and the power of the test implying that we may conclude that a unit root is present when, in fact, this is not true. Further, additional regressors increase the absolute value of the critical value making it harder to reject the null hypothesis. On the other hand, inappropriately omitting the deterministic terms can cause the power of the test to go to zero (Campbell and Perron, 1991).

Compared to the ADF test, the DF-GLS test has substantially improved power when an unknown mean or trend is present (Elliot et al., 1996). The DF-GLS procedure relies on demeaning and/or detrending a series prior to the implementation of the auxiliary ADF regression as follows:

$$y^d_t = y_t - \varphi' z_t \qquad (4)$$

For detrending, $z_t=(1,t)'$ and φ_0 and φ_1 are estimated by regressing $[y_1,(1-\overline{\rho}L)y_2,.......(1-\overline{\rho}L)y_T]$ on $[z_1,(1-\overline{\rho}L)z_2,.......(1-\overline{\rho}L)z_T]$ where $\overline{\rho}=1+(\overline{c}/T)$ with $\overline{c}$ = -13.5, and L is the lag operator. For demeaning, $z_t=(1)'$ and the same regression is run with $\overline{c}$ = -7.0. (see Elliott et al., 1996 for details). The augmented Dickey-Fuller regression is then computed using the y^d_t series:

$$\Delta y^d_t = \alpha + \gamma y^d_{t-1} + \theta t + \sum_{i=2}^{p} \beta_i \Delta y^d_{t-i+1} + \varepsilon_t \qquad (5)$$

Critical values for the GLS detrended test are taken from Elliott et al. (1996). Critical values for the GLS demeaned test are the same as those applicable to the no-constant, no-trend ADF test.

Cointegration and Granger Causality

Cointegration refers to a long-run equilibrium relationship between nonstationary variables that together yield a stationary linear combination. Although the variables may drift away from the equilibrium for a while, economic forces act in such a way so as to restore equilibrium. The possibility of a cointegrating relationship between the variables is tested using the Johansen and Juselius (1990, 1992) methodology which is described below.

Consider the p-dimensional vector autoregressive model with Gaussian errors:

$$y_t = A_1 y_{t-1} + ...+ A_p y_{t-p} + A_0 + \varepsilon_t$$

where y_t is an $m\times 1$ vector of I(1) jointly determined variables. The Johansen test assumes that the variables in y_t are I (1). For testing the hypothesis of co integration the model is reformulated in the vector error-correction form (VECM):

$$\Delta y_t = -\Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + A_0 + \varepsilon_t$$

$$\text{where, } \Pi = I_m - \sum_{i=1}^{p} A_i, \quad \Gamma_i = -\sum_{j=i+1}^{p} A_j, \quad i = 1,....., p-1.$$

Here the rank of Π is equal to the number of independent co integrating vectors. If the vector y_t is I(0), Π will be a full rank $m \times m$ matrix. If the elements of vector y_t are I(1) and co integrated with rank (Π) = r, then $\Pi = \alpha\beta'$, where α and β are $m \times r$ full column rank matrices and there are $r < m$ linear combinations of y_t. Then β' is the matrix of coefficients of the co integrating vectors and α is the matrix of speed of adjustment coefficients.

Under co-integration, the VECM can then be represented as:

$$\Delta y_t = -\alpha\beta' y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + A_0 + \varepsilon_t$$

If there are non-zero co-integrating vectors, then some of the elements of α must also be non zero to keep the elements of y_t from diverging from equilibrium. The model can easily be extended to include a vector of exogenous I(1) variables.

Johansen and Juselius (1990, 1992) suggest the likelihood ratio test based on the maximum eigenvalue and trace statistics to determine the number of the cointegrating vectors. Since the eigenvalue test has a sharper alternative hypothesis as compared to the trace test, it is used to select the number of cointegrating vectors in this paper.

If the variables are indeed cointegrated, an error correction model can be estimated with the lagged value of the residual from the cointegrating relationship as one of the independent variables (in addition to lagged values of other variables described above), the left-hand side variable being as above. The error correction model captures the short-term dynamics of the variables in the system. These dynamics represent the movements of at least some of the variables in the system in response to a deviation from long-run equilibrium. Movements in these variables ensure that the system returns to the long-run equilibrium.

Granger Causality

The concept of Granger causality can be tested in the framework of the error correction model. The Granger causality approach analyses how much of the current variable y_t can be explained by its own past values and tests whether adding lagged values of other variables can improve its forecasting performance. If adding lagged values of another variable, x_t does not improve the predictive ability of y_t, we say that x_t does not Granger cause y_t. In the error correction framework, Granger-causality can be tested by a joint χ^2 test of the error correction term and the lags of x_t.

While cointegration gives the long-run relationship between variables and Granger-causality throws light on the predictive ability of other variables, innovation accounting methods that include impulse responses and variance decompositions capture the dynamic relationships between the variables. We next examine the variance decompositions.

Variance Decomposition Analysis

Variance decomposition breaks down the variance of the forecast error into components that can be attributed to each of the endogenous variables. Specifically, it provides a break down of the variance of the n-step ahead forecast errors of variable i which is accounted for by the innovations in variable j in the VAR. As in the case of the orthogonalized impulse response functions, the orthogonalized forecast error variance decompositions are also not invariant to the ordering of the variables in the VAR. Thus, we use the generalized variance decomposition which considers the proportion of the n-step ahead forecast errors of x_t which is explained by conditioning on the non-orthogonalized shocks but explicitly allows for the contemporaneous correlation between these shocks and the shocks to the other equations in the system.

As opposed to the orthogonalized decompositions, the generalized error variance decompositions can add up to more or less than 100 percent depending on the strength of the covariances between the different errors.

6. Empirical Results

Nonstationarity, Cointegration and Granger causality

We first test for nonstationarity of all the variables. The results summarized in Table 3 shows that all the variables can be treated as nonstationary. Testing for differences of each variable confirms that all the variables are integrated of order one.

Since the variables are integrated of order one, cointegration analysis is applied to examine the relationships between these non-mean reverting series. We use Johansen's FIML technique to test for cointegration between each of the interest rates, repo rate, rate of growth of high powered money, inflation, interest rate spread, foreign interest rate and forward premium. For all interest rates, the maximum eigenvalue test statistic strongly rejects the null hypothesis that there is no cointegration between the variables but does not reject the hypothesis that there is one cointegrating relationship between the variables for each interest rate. As reported in Table 4, the cointegrating vector for each interest rate suggests that each interest rate is positively related with the repo rate, rate of growth of high powered money, inflation rate, interest rate spread, foreign interest rate and forward premium. The signs are therefore theoretically plausible and conform with the discussion in Section 3. The positive sign on the rate of growth of money supply suggests that the expected inflation effect outweighs the liquidity effect.

The next step is to test whether the variables individually Granger cause each of the interest rates. The results reported in Table 5 indicate that the null hypothesis of no Granger causality is strongly rejected in Models A through D, thus justifying the inclusion of the right hand side variables in the model.

To gauge the relative importance of the influences on interest rates we analyse the impact of each of these variables further. We investigate the dynamic interaction of various shocks using the variance decomposition function. Instead of the orthogonalized impulse responses, we use the generalized impulse responses and variance decompositions. The advantage of using the generalized impulse responses is that orthogonalized impulse response and variance decompositions depend on the ordering of the variables. If the shocks to the respective equations in VAR are contemporaneously correlated, then the orthogonalized and generalized impulse responses may be quite different. On the other hand, if shocks are not contemporaneously correlated, then the two types of impulse responses may not be that different and also orthogonalized impulse responses may not be sensitive to a re-ordering of the variables.

Generalized variance decompositions

Variance decompositions give the proportion of the h-periods-ahead forecast error variance of a variable that can be attributed to another variable. These therefore measure the proportion of the forecast error variance in the interest rates that can be explained by shocks given to its determinants. Results reported in Tables 6A-6D provide variance decompositions for up to the 24-week forecast horizon for each interest rate.

Table 7 gives the prorated percentage decompositions for the 24-week forecast horizon. This therefore allows us to analyse the relative importance of the determinants of interest rates for each interest rate as well as across interest rates. For instance, for the 15-91 days Treasury bill rate, important determinants in descending order of importance include the forward premium, inflation rate, and the rate of growth of high powered money. In the case of 1-year Government securities, the importance of the inflation rate and the forward premium are switched and the remaining ordering for the three most important variables is the same as that of the 15-91 Treasury bill rate. As we move towards longer maturity rates, the weight of the repo rate and the forward premium diminishes while the weight of the interest rate spread and the own variable increases substantially. The inflation rate is also relatively less important in explaining variations in the 10-year rate. The results also show that a large proportion of the variation in the rates on the 5-year and 10-year government securities is attributed to the interest rate itself suggesting that the unexplained variation may be a result of cyclical factors that are important for longer term rates and are not captured in the interest rate spread but are omitted from the estimations due to the high frequency of data employed.

7. Conclusions

This paper examines the determinants of the term structure of interest rates in India using weekly data from April 2001 through March 2009. The analysis covers Treasury Bills with residual maturity of 15-91 days and Government securities of residual maturity one, five and ten years respectively. The empirical estimates show that a long-run relationship exists between each of these interest rates and repo rate (policy rate), rate of growth of high powered money, inflation, interest rate spread, foreign interest rate and forward premium. These variables Granger cause each of the interest rates. Furthermore, the normalized generalized variance decompositions suggest that the policy rate is more important in explaining the proportion of variation in short to medium term interest rates. The weight of the forward premium also diminishes as we move towards higher maturity interest rates. The inflation rate and the rate of growth of high powered money are also relatively less important in explaining variations in the 10-year rate. The results also show that a large proportion of the variation in the rates on the 5-year and 10-year government securities is attributed to the interest rate itself suggesting that the unexplained variation may be a result of cyclical factors that are important for longer term rates but are omitted from the estimations due to the high frequency of data employed. These are cyclical factors that are not captured in the interest rate spread.

The paper thus highlights the differential response of the short and the longer rates to the various determinants including monetary policy. Interest rates at the shorter end of the maturity spectrum are more responsive to changes in monetary policy measured by policy rates and the rate of growth of high powered money. This impact peters-out as the maturity increases, showing that the longer term rates are influenced by an additional set of factors like current and future economic activity, output gap, fiscal policy and the global environment.

References

Bekaert, G., S. Cho and A. Moreno (2005), "New-Keynesian Macroeconomics and the Term Structure," NBER Working Paper No. W11340.

Bernanke, B. and A. Blinder (1992), "The Federal Funds Rate and the Channels of Monetary Transmission," *American Economic Review,* 82, 901-921.

Blinder, A. (2008), "Talking about Monetary Policy: The Virtues (and Vices?) of Central Bank Communication," BIS Annual Conference, Lucerne, June.

Campbell, J. Y. and P. Perron (1991), "Pitfalls and Opportunities: What Macroeconomists Should Know About Unit Root", *Technical Working Paper 100, NBER Working Paper Series,* April.

Campbell, J.Y. and R.J. Shiller (1991), "Yield Spreads and Interest Rate Movements: A Bird's Eye View," *Review of Economic Studies,* 58, 495-514.

Cochrane, John H. (1989),"The Return of the Liquidity Effect: A Study of the Short-Run Relation between Money Growth and Interest Rates" *Journal of Business & Economic Statistics,* 7, 75-83.

Cook, T. and T. Hahn (1989), "The Effect of Changes in the Federal Funds Rate Target on Market Interest Rates in the 1970s," *Journal of Monetary Economics,* 24, 331–51.

Dickey, D. A. and W. A. Fuller (1979). "Distribution of the Estimators for Autoregressive Time Series with a Unit Root." *Journal of the American Statistical Association,* 74, 427-31.

______________ (1981). "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root." *Econometrica,* 49, 1057-72.

Doldado, J., T. Jenkinson, and S. Sosvilla-Rivero (1990), "Cointegration and Unit Roots" *Journal of Economic Surveys,* 4, 249-73.

Dua, P. and B.L. Pandit (2002), "Interest Rate Determination in India: Domestic and

External Factors," *Journal of Policy Modeling*, 24, 853-875.

Dua, P., N. Raje, S. Sahoo (2008), "Forecasting Interest Rates in India" Margin: The Journal of Applied Economic Research, 2, 1-41.

Elliott, Graham and Rothenberg, Thomas J and Stock, James H. (1996), Efficient Tests for an Autoregressive Unit Root," *Econometrica*, 64, 813-36.

Froot, K.A. (1989), "New Hope for the Expectations Hypothesis of the Term Structure of Interest Rates," *Journal Of Finance*, 44, 283-305.

Granger, C. W. J. and Newbold P. (1974). "Spurious Regressions in Econometrics, " *Journal of Econometrics*, 35, 143-159.

Jalan, Bimal. 2002. "Research and Policy Developments in Money, Finance and External Sector in India", in Macroeconomics and Monetary Policy – Issues for a Reforming Economy (eds.) Montek S.Ahluwalia, Y. V. Reddy and S.S. Tarapore : 162-182.

Johansen, S. and K. Juselius (1990). "Maximum Likelihood Estimation and Inference on Cointegration with Applications to the Demand for Money." *Oxford Bulletin of Economics and Statistics*, 52, 169-209.

_____________ (1992). "Testing Structural Hypothesis in a Multivariate Cointegration Analysis of PPP and the UIP for UK." *Journal of Econometrics*, 53, 211-44.

Kanagasabapathy K. and Rajan Goyal (2002), "Yield Spread as a Leading Indicator of Real Economic Activity: An Empirical Exercise on the Indian Economy, IMF Working Paper WP/02/91, May 2002.

Mishkin, F.S. (1989), "The Information in the Longer Maturity Term Structure about Future Inflation," *NBER Working Paper No. 3126.*

Nachane, D.M. and Nishita Raje (2007), "Financial Liberalisation and Monetary Policy," Margin: The Journal of Applied Economic Research, 1, 47-83.

Piazzesi, M. (2005), "Bond Yields and the Federal Reserve," *Journal of Political Economy*, 113, 311-344.

Rudebusch, G. and T. Wu (2008), "A Macro-Finance Model of the Term Structure, Monetary Policy and the Economy," *Economic Journal*, 118, 906-926.

Sarantis, N. and S.X. Lin (1999), "The Role of Financial Spreads in Macroeconomic Forecasting: Evidence for the UK," *Manchester School*, 67, 89-110.

Table 1: Interest Rates – Summary Statistics: 6th April '01 to 27th March '09

Interest Rates	*Mean*	*Maximum*	*Minimum*	*Standard Deviation*
$i(TB_{15\text{-}91})$	5.89	9.09 (22nd Aug '08)	2.88 (3rd Aug '07)	1.14
$i(GSec_1)$	6.48	9.85 (4th July '08)	3.66 (26th Sep '03)	1.35
$i(GSec_5)$	6.93	9.78 (6th April '01)	4.81 (10th Oct '03)	1.11
$i(GSec_{10})$	7.42	10.64 (6th April'01)	5.18 (7th May '04)	1.19

Table 2A: Correlation-Matrix: 6th April '01 to 27th March '09

Variables	*$i(TB_{15\text{-}91})$*	*$i(GSec_1)$*	*$i(GSec_5)$*	*$i(GSec_{10})$*
$i(TB_{15\text{-}91})$	1.000			
$i(GSec_1)$	0.917	1.000		
$i(GSec_5)$	0.877	0.926	1.000	
$i(GSec_{10})$	0.818	0.844	0.919	1.000
π	0.389	0.466	0.360	0.136
Spread	-0.234	-0.057	0.134	0.367
Repo Rate	0.807	0.808	0.791	0.851
dm	0.402	0.497	0.458	0.275
i^*_1	0.508	0.567	0.673	0.587
i^*_2	0.496	0.556	0.668	0.577
fp_1	0.492	0.421	0.413	0.496
fp_2	0.474	0.400	0.412	0.534

Note: π denotes inflation(y-o-y); dm denotes growth rate of high powered money (y-o-y); i^*_1 and i^*_2 denote libor 3-months and 6-months respectively; fp_1 and fp_2 denote 3-months and 6-months forward premia respectively.

Table 2B: Correlation-Matrix: 6th April '01 to 27th March '09

Variables	*Π*	*Spread*	*Repo rate*	*dm*	*$libor_1$*	*fp_1*	*$libor_2$*	*fp_2*
π	1.0000							
spread	-0.3978	1.0000						
Repo Rate	0.0524	0.1338	1.0000					
dm	0.4969	-0.1846	0.2468	1.0000				
$libor_1$	0.1148	0.1699	0.5001	0.5150	1.0000			
fp_1	-0.0851	0.0419	0.5328	-0.2128	-0.0780	1.0000		
$libor_2$	0.1306	0.1727	0.4663	0.5052	0.9957	-0.0751	1.0000	
fp_2	-0.1900	0.1359	0.5890	-0.2394	-0.0809	0.9748	-0.0877	1.0000

Table 3: ADF and DF-GLS Tests (constant and trend): 6th April '01 to 27th March '09

Variables	***ADF(4)***	***DF-GLS(4)***	***Inference***
$i(TB_{15\text{-}91})$	-2.53	-1.62	I(1)
$i(GSec_1)$	-2.35	-1.14	I(1)
$i(GSec_5)$	-2.87	-0.98	I(1)
$i(GSec_{10})$	-2.84	-0.79	I(1)
π	-2.23	-2.22	I(1)
Spread	-3.75*	-2.61	I(1)
Repo Rate	-0.86	-0.99	I(1)
dm	-2.00	-2.15	I(1)
i^*_1	-0.888	-0.68	I(1)
i^*_2	-1.05	-0.75	I(1)
fp_1	-3.34	-3.30*	I(1)
fp_2	-2.84	-2.72	I(1)
Critical Values			
1%	-3.98(ADF)	-3.48(DF-GLS)	
5%	-3.42(ADF)	-2.87(DF-GLS)	

Note: π denotes inflation(y-o-y); dm denotes growth rate of high powered money (y-o-y); i^*_1 and i^*_2 denote libor 3-months and 6-months respectively; fp_1 and fp_2 denote 3-months and 6-months forward premia respectively. * denotes significance at 1% but not at 5%.

Table 4: Cointegrating Vectors (Normalised Values)

Interest Rates/ Variables	***Π***	***Spread***	***Repo rate***	***dm***	***i^*_1***	***i^*_2***	***fp_1***	***fp_2***
$i(TB_{15\text{-}91})$	0.067	0.357	0.449	0.068	0.099		0.276	
$i(GSec_1)$	0.069	0.038	0.446	0.111		0.185		0.310
$i(GSec_5)$	0.052	0.685	0.451	0.109		0.128		0.251
$i(GSec_{10})$	0.034	1.420	0.302	0.131		0.057		0.315

Table 5: Granger Causality Tests

Null Hypothesis	*Number of Lags*	*χ^2 (calculated)*	*Conclusion*
Model A: i(TB15-91)=f(π, Spread, Repo Rate, dm, i^*_1, fp_1)			
i($TB_{15\text{-}91}$) is not Granger caused by Inflation	4	42.99(0.000)	Reject Null Hypothesis
i($TB_{15\text{-}91}$) is not Granger caused by Spread	4	39.58(0.000)	Reject Null Hypothesis
i($TB_{15\text{-}91}$) is not Granger caused by Repo Rate	4	39.47(0.000)	Reject Null Hypothesis
i($TB_{15\text{-}91}$) is not Granger caused by dm	4	39.47(0.000)	Reject Null Hypothesis
i($TB_{15\text{-}91}$) is not Granger caused by $libor_1$	4	53.62(0.000)	Reject Null Hypothesis
i($TB_{15\text{-}91}$) is not Granger caused by fp_1	4	72.96(0.000)	Reject Null Hypothesis
Model B: i($GSec_1$)=f(π, Spread, Repo Rate, dm, i^*_2, fp_2)			
i($GSec_1$) is not Granger caused by Inflation	4	55.49(0.000)	Reject Null Hypothesis
i($GSec_1$) is not Granger caused by Spread	4	45.44(0.000)	Reject Null Hypothesis
i($GSec_1$) is not Granger caused by Repo Rate	4	53.08(0.000)	Reject Null Hypothesis
i($GSec_1$) is not Granger caused by dm	4	46.03(0.000)	Reject Null Hypothesis
i($GSec_1$) is not Granger caused by $libor_2$	4	60.35(0.000)	Reject Null Hypothesis
i($GSec_1$) is not Granger caused by fp_2	4	80.44(0.000)	Reject Null Hypothesis
Model C: i($GSec_5$)=f(π, Spread, Repo Rate, dm, i^*_2, fp_2)			
i($GSec_5$) is not Granger caused by Inflation	4	38.41(0.000)	Reject Null Hypothesis
i($GSec_5$) is not Granger caused by Spread	4	28.85(0.000)	Reject Null Hypothesis
i($GSec_5$) is not Granger caused by Repo Rate	4	32.54(0.000)	Reject Null Hypothesis
i($GSec_5$) is not Granger caused by dm	4	32.62(0.000)	Reject Null Hypothesis
i($GSec_5$) is not Granger caused by $libor_2$	4	40.06(0.000)	Reject Null Hypothesis
i($GSec_5$) is not Granger caused by fp_2	4	39.22(0.000)	Reject Null Hypothesis
Model D: i($GSec_{10}$)=f(π, Spread, Repo Rate, dm, i^*_2, fp_2)			
i($GSec_{10}$) is not Granger caused by Inflation	5	10.42(0.064)	Reject Null Hypothesis**
i($GSec_{10}$) is not Granger caused by Spread	5	12.16(0.033)	Reject Null Hypothesis
i($GSec_{10}$) is not Granger caused by Repo Rate	5	14.83(0.011)	Reject Null Hypothesis
i($GSec_{10}$) is not Granger caused by dm	5	30.09(0.000)	Reject Null Hypothesis
i($GSec_{10}$) is not Granger caused by $libor_2$	5	13.84(0.017)	Reject Null Hypothesis
i($GSec_{10}$) is not Granger caused by fp_2	5	15.29(0.009)	Reject Null Hypothesis

Note: π denotes inflation(y-o-y); dm denotes growth rate of high powered money (y-o-y); i^*_1 and i^*_2 denote libor 3-months and 6-months respectively; fp_1 and fp_2 denote 3-months and 6-months forward premia respectively. ** denotes significance at 10%.

Table 6A: Generalized Variance Decompositions – Model A

Horizon/Variables (Weeks)	$TB_{15\text{-}91}$	π	*Spread*	*Repo*	*dm*	i^*_1	fp_1
1	0.95659	0.0023519	0.49338	0.0097892	0.0056826	0.022104	0.024017
6	0.66097	0.045252	0.29212	0.030913	0.040763	0.019646	0.20995
12	0.42943	0.13221	0.17655	0.048194	0.091149	0.026702	0.25439
18	0.30783	0.19282	0.12667	0.054301	0.11897	0.028781	0.26277
24	0.24011	0.22917	0.10018	0.057298	0.13446	0.029727	0.26516

Table 6B: Generalized Variance Decompositions – Model B

Horizon/Variables (Weeks)	$GSec_1$	π	*Spread*	*Repo*	*dm*	i^*_2	fp_2
1	0.95483	0.0067428	0.042988	0.031366	0.027126	0.0020619	0.038903
6	0.58171	0.082798	0.030437	0.049748	0.17347	0.033567	0.18976
12	0.32889	0.17896	0.013824	0.052816	0.31447	0.039118	0.19823
18	0.20642	0.23394	0.0081925	0.049643	0.38384	0.035027	0.18850
24	0.14437	0.26449	0.0065186	0.046616	0.41858	0.031283	0.17911

Table 6C: Generalized Variance Decompositions – Model C

Horizon/Variables (Weeks)	$GSec_5$	π	*Spread*	*Repo*	*dm*	i^*_2	fp_2
1	0.98199	0.0019240	0.5660E-3	0.0078502	0.015337	0.046571	0.0033079
6	0.75714	0.047156	0.037837	0.010030	0.084495	0.11294	0.056630
12	0.55675	0.11426	0.10208	0.014719	0.15789	0.10128	0.068138
18	0.44312	0.15722	0.14335	0.016826	0.19485	0.087393	0.069564
24	0.37912	0.18249	0.16746	0.017854	0.21449	0.078211	0.069411

Table 6D: Generalized Variance Decompositions – Model D

Horizon/Variables (Weeks)	$GSec_{10}$	π	*Spread*	*Repo*	*dm*	i^*_2	fp_2
1	0.98770	0.0037243	0.30969	0.0066390	0.0025501	0.032108	0.0012957
6	0.88666	0.0050950	0.27773	0.0097539	0.015775	0.054363	0.067526
12	0.83765	0.016690	0.33523	0.0083551	0.026091	0.068839	0.079243
18	0.79438	0.030938	0.37598	0.0075495	0.040897	0.068585	0.081038
24	0.76117	0.042917	0.40291	0.0069474	0.052893	0.065937	0.080252

Note: a) π denotes inflation(y-o-y); dm denotes growth rate of high powered money (y-o-y); i^*_1 and i^*_2 denote libor 3-months and 6-months respectively; fp_1 and fp_2 denote 3-months and 6-months forward premia respectively.
b): Entries in each row are the percentages of the variances of the forecast error in the respective interest rate that can be attributed to each of the variables indicated in the column headings. The decompositions are reported for one-, six-, twelve-, eighteen- and twenty four-week horizons. The extent to which the generalized error variance decompositions add up to more or less than 100 percent depends on the strength of the covariances between the different errors.

Table 7: Generalized Variance Decompositions (Pro-rated in Percentage Terms)

Horizon (Weeks)		*Interest Rates*	π	*Spread*	*Repo*	*dm*	i^*_1	i^*_2	fp_1	fp_2
24	Model A:i($TB_{15\text{-}91}$)	21.78	18.49	8.45	3.88	17.05	4.22		26.10	
	Model B:i($GSec_1$)	11.39	33.25	1.09	1.78	32.92		2.42		17.12
	Model C:i($GSec_5$)	32.62	22.91	7.91	1.34	21.82		7.74		5.63
	Model D:i($GSec_{10}$)	53.86	3.03	28.51	0.49	3.74		4.66		5.67

Annexure 1

DATA DEFINITIONS AND SOURCES

Variable	Definition	Source
Bank rate	Rate at which the RBI lends to the commercial banks	Handbook of Statistics on the Indian Economy and RBI Bulletin
CRR	Cash reserve Ratio (CRR) is the amount of funds that the banks have to keep with RBI. If RBI decides to increase the percent of this, the available amount with the banks comes down. RBI is using this method (increase of CRR rate), to drain out the excessive money from the banks.	-do-
TB 15-91	Government of India Treasury Bills of residual maturity of 15-91 days based on the secondary market outright transactions in Government securities (face value) as reported in Subsidiary Government Ledger (SGL) accounts at RBI, Mumbai.	-do-
GSEC1	Government of India dated securities of residual maturity of one-year based on the secondary market outright transactions in Government securities (face value) as reported in Subsidiary Government Ledger (SGL) accounts at RBI, Mumbai.	-do-
GSEC5	Government of India dated securities of residual maturity of five-years based on the secondary market outright transactions in Government securities (face value) as reported in Subsidiary Government Ledger (SGL) accounts at RBI, Mumbai.	-do-
GSEC10	Government of India dated securities of residual maturity of ten-years and above based on the secondary market outright transactions in Government securities (face value) as reported in Subsidiary Government Ledger (SGL) accounts at RBI, Mumbai.	-do-
LIBOR 3-months	Three-month LIBOR on USD deposits	IFS
LIBOR 6-months	Six-month LIBOR on USD deposits	IFS
Repo	Repo rate is the rate at which the central bank lends to the commercial banks against their parking of Government and other approved securities for meeting their day to day liquidity requirements or to fill short-term gaps.	Handbook of Statistics on the Indian Economy and RBI Bulletin
Reverse Repo	Reverse Repo rate is the rate which the central bank offers to the commercial banks when they park their excess funds with it by purchase of Government and other approved securities which they sell off after the stipulated period.	-do-
SLR	The Statutory Liquidity Ratio is the amount a commercial bank needs to maintain in the form of liquid assets for prudential reasons and safety of depositors. It can be in cash, or gold or Govt. approved securities (Bonds) before providing credit to its customers. SLR rate is determined and maintained by the RBI (Reserve Bank of India) in order to control the expansion of bank credit.	-do-
fp 3-months	Three-month forward premium	-do-
fp 6-months	Six-month forward premium	-do-
INFLATION	Both week-to-week and year-on-year inflation rate have been used.	Weekly Statistical Supplement
dm	Growth in high powered money year on year	-do-
SPREAD	The yield spread is defined as the difference between the Government of India dated securities on residual maturity of ten-years and above and the 15-91-days Treasury bills rate	-do-