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Macroeconomic factors and yield curve for the emerging Indian economy

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This article investigates the dynamic linkages between the estimated parameters of a zero coupon yield curve and macroeconomic variables like inflation, gross domestic product growth in the presence of a monetary policy indicator in India for the period July 1997 to February 2004. The study finds that there exists strong causality from financial factors, defined by three parameters of the yield curves ('Level', 'Slope', 'Curvature') to macroeconomic factors; growth, inflation and monetary policy indicators (changes in the call money rate). However, the causality in the opposite direction is found to be weaker. It is found that the yield and macro factors do not cause each other before the launch of a liquidity adjustment facility, so the evidence of causality from financial to macroeconomic factors can be attributed to the introduction of a liquidity adjustment facility in June 2000. The causality from yield factors to macro factors is primarily driven by the fact that the 'changes in level' of yield curve brings an impact on inflation through the changes in monetary policy. This finding suggests that monetary policy plays a key role in driving the causality. This also implies that the indirect instrument of monetary policy mechanism is becoming increasingly important to influence the aggregate demand in the economy.

Keywords: term structure of interest rates; inflation, growth; monetary policy; financial reforms; LAF; VAR modelling; Granger causality; Impulse response

1. Introduction

The article aims at exploring the dynamics of the linkage, if any, between the term structure of interest rates and the macroeconomic factors in the Indian economy post the financial reforms. There has been large gap in the yield curve models developed by macroeconomists and financial economists. Macroeconomists focus more on the role of fundamentals of economy like expectations of inflation and future growth, unlike financial economists whose prime focus is interest rate forecasting or bond pricing or market surveillance. Parsimonious models like Nelson-Siegel or Svensson's fail to offer insight into the nature of the underlying economic forces that drive the movements of the yield curve. The changes in the yield curves or term structure of interest rates are often interpreted as 'Level', 'Slope' and 'Curvature' in the literature. However, a good economic interpretation of these factors causing the movements in the yield curve has always remained a challenge. Movements in

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the yield curves is an outcome of the expectations of the market which capture the changes in the key macroeconomic fundamentals; inflation, growth, monetary policy. So the shape of the yield curve can be used as a good predictor or reflector to effectively manage monetary policy, which would influence inflation and growth in an economy.

There has been a growing consensus for the last two decades regarding the relationship between the term structure of interest rates and the real activity in an economy, although establishing a theoretical rational between the real sectors of the economy and the financial sectors is a little complex as their connectivity cannot be ascertained only by a pair of simple equations as can be done in the case of inflation and the slope of the yield curve. Inflation has been a major concern of policymakers for many years. In the recent years, the prime focus of central banks of many countries has been the price stability in the economy. To meet this goal, central banks require tracking the degree of inflationary movements or at least some indicators of inflation in the country. Central banks pursuing the direct inflation targeting strategy or an intermediate-target strategy need to monitor the indicators of financial market expectations. These indicators could contribute to the central bank's own inflation forecasts. One of the common indicators used by most of the central banks in developed countries is the term structure of interest rates. A theoretical linkage of growth with term spread (defined as the difference between long-term rate and short-term rate) is supported by Bernanke (1990), Bernanke and Blinder (1992), and Lowe (1992).[1]

This study integrates macroeconomic factors and yield curves with two-fold objectives; first, to investigate the dynamic linkages between macro and yield factors, and second, to examine if the integrated macro-yield model improves the prediction of yield curve. To explore the possibility of a central bank's intervention in this dynamics, an indicator for monetary policy is also introduced. The dynamics of yield curve and macroeconomic factors cannot independently be determined without a monetary policy indicator as in most cases it is found that monetary policy plays a major role to these movements and the predictive content of the yield curve is primarily due to the conduct of monetary policy. Estimated parameters of the yield curve (representative of the financial factors), inflation, growth (representation of the macroeconomic factors), along with policy variable are combined in a vector auto regression (VAR) framework to study the linkage between 'yields-to-macro' and 'macro-to-yields'. The empirical analysis covers the post reform period July 1997 to February 2004 of Indian financial markets. In India the interest rates were not the true reflections of the market determined interest rates until the mid1990s, as the financial markets were heavily regulated until then. So one of the most important hurdles the study would face is the lack of large sample set.

The rest of the article is organized as follows: section 2 gives a review of the literature. Section 3 gives an overview of monetary policy in India with a specific focus to its transmission mechanism through money market instruments. Section 4 describes how the estimated parameters can be treated as Level, Slope and Curvature. It also highlights the association of Level, Slope and Curvature with macroeconomic factors. Section 5 describes the estimation methodology. Section 6 talks about the data. Section 7 describes the estimation results. Section 8 has concluding remarks with the interpretation of the results for the Indian scenario.

2. Literature survey

Factor models developed by Knez et al. (1994), Duffie and Kan (1996), and Dai and Singleton (2000) are often interpreted as Level, Slope and Curvature and do not have good macroeconomic interpretations. There has been a vast literature developed in the area of term structure of interest rates which focuses only on the yield-to-macro link or how yield curves can be used a predictor of fundamentals in the economy. Mishkin (1990), Estrella and Hardouvelis (1991) and Estrella and Mishkin (1998) have focused on the unidirectional predictive power of the yield curve for the key macroeconomic variables like inflation and real activity. Estrella and Hardouvelis (1991) formulated a probit model to predict the probabilities of US recessions one year ahead. Estrella et al. (2003) have examined the association of term spread and real activity for both US and German data using continuous and binary models. They found that the binary models are more stable than the continuous models. Kozicki and Tinsley (2001), Dewachter and Lyrio (2002) and Rudebusch and Wu (2003) allowed feedback from an implicit inflation target derived from the yield curve to help determine the dynamics of the yield curve. In the past few years, there has been a lot of work which combine the macroeconomic factors in the yield curve modelling. Ang and Piazzesi (2003), Hördahl et al. (2002), Wu (2002), and Evans and Marshall (1998, 2001) incorporate macroeconomic variables into multi-factor yield curve models. They considered unidirectional macro linkages as output and inflation are assumed to be determined independently of the shape of the yield curve, but not vice versa. Diebold et al. (2003, 2006) provide a macroeconomic interpretation of the Nelson-Siegel representation of the yield curve by combining it with VAR dynamics for the macroeconomy. In the dynamic interactions between macroeconomy and yield curve, they have found weak evidence of the effects of yield curves on future movements of the macroeconomic variables and a strong relationship is observed from macroeconomic variables to the yield curves.

In India there have been some studies to investigate the characteristics of the post-deregulated financial market. Joshi (1998) has shown that there is a linkage between the conduct of monetary policy and the movements in the interest rates of money market instruments in India. There have been similar studies by Bhoi and Dhal (1998) that provide evidence of the integration of financial markets in India. In the Indian scenario, the work by Kangasabapathy and Goyal (2002) closely resembles the study by Estrella and Mishkin (1998). Kangasabapathy and Goyal (2002) found yield spread, defined as the difference between long-term and short-term, to be a good predictor of real activity. This study is different from any of the previous studies in India as it incorporates both the macroeconomic fundamentals, inflation, growth, monetary policy and yield-curves, explained by Level, Slope and Curvature to understand their dynamics linkages.

3. Significance of money market in monetary policy transmission

Monetary policy in India aims at maintaining a judicious balance between price stability and economic growth. In view of the increasing openness of the Indian economy, macroeconomic and financial stability have attained great importance these days.

In India the conduct of monetary policy until 1997–98 was based on an intermediate target of broad money (M_3). The aim was to regulate money supply in line with the expected growth in real income and a projected level of inflation. In the phase of ongoing openness in financial sectors, the interest rate channel or exchange rate channel has gained much importance in transmission mechanism of monetary policy compared to quantity variables. In April 1998, the RBI has formally adopted a multiple indicator approach where interest rates or rates of return in different financial markets along with the data on currency, credit, trade, capital flows, fiscal position, inflation and exchange rates are juxtaposed with the output data for policy perspectives (Mohan 2007). In the increasing evidence of growing inter linkages in the financial markets there has been a shift in focus of monetary policy approach from direct to indirect instruments.

The success of a framework that relies on indirect instruments of monetary management such as interest rates is contingent upon the extent and speed with which changes in the central bank's policy rate are transmitted to the spectrum of market interest rates and exchange rate in the economy and to the real sector. The money market has a pivotal role in the transmission mechanism of monetary policy. The money market performs a crucial role in providing a channel to equilibrate short-term demand for and supply of funds, thereby facilitating the conduct of monetary policy. In India the money market mainly comprises of a call money market, the activities in other money market segments, the commercial bills market and the inter-corporate deposits market are limited. The call money market deals in funds for two to four days. In India, like many other developing countries, the evolution of the money market and its structure has been integrated into the overall deregulation process of the financial sector which started in the late 1980s. Given the importance of the money market as an indirect instrument in the monetary transmission mechanism, several reform initiatives were taken since the late 1980s. Among the several measures, most important was to turn the call money market into a pure inter-bank market and to develop repo market towards improving the monetary transmission mechanism to influence the aggregate demand in the economy in 1999. Introduction of a liquidity adjustment facility (LAF) in June 2000 gave a different dimension in the monetary policy operating procedure in India. In this approach, the Reserve Bank of India (RBI) decides its policy rates (repo and reverse report rates)[2] and executes repo and reverse repo operations which provide a corridor for overnight money market rates. The LAF was introduced primarily to develop a robust short-term operational model for better understanding the transmission mechanism of the monetary policy. In line with this, a liquidity assessment model is being structured, on the basis of available data, to assess both the mechanism and inter-linkages among different segments of the financial systems. The call money market is influenced by liquidity conditions in the economy mainly driven by capital flows, Reserve Bank's operations affecting banks' reserve requirements on the supply side and tax outflows, the government borrowing programme, seasonal fluctuations and non-food credit off-take on the demand side. At the time of easy liquidity, call rates tend to hover around the Reserve Bank's repo rate which helps to absorb short-term surplus fund from the system. During the periods of tight liquidity, call rates tend to move with the reverse repo rate and bank rate.

In the post-LAF period, the call money rate remained more stable as the RBI has been successful in managing the short-term liquidity under diverse market conditions more effectively through repo and reverse repo operations. So the LAF combined with other open market operations has emerged as an effective instrument to signal monetary policy stances in the economy. This also helped the central bank to adjust the supply of money in response to the movement of key macroeconomic indicators in a much faster way. The LAF avoids targeting a particular level of overnight money market rates in case of exogenous influences (for example, volatile government cash balances and unpredictable foreign exchange flows) impacting liquidity at the shorter end of term structure of interest rates. This has enabled the RBI to affect the demand for funds through policy rate channel. It enabled it to set a corridor for call money rates consistent with the policy objectives of the central bank.

4. Estimated parameters of yield curve: relationship with empirical proxies and macroeconomic factors

The section demonstrates the reasons of choosing estimated parameters of the term structure of interest rates as Level, Slope and Curvature. The term structure of interest rates is first estimated by the Nelson-Siegel method for the period July 1997 to February 2004, minimizing the ‘yield errors’. The algorithm to estimate the spot rates is provided in Figure 1.

4.1. Estimated parameters and factor loadings

The estimated parameters ($\beta 0$, $\beta 1$, $\beta 2$) of the Nelson-Sigel spot rate function r(m) (defined below):

$$\begin{aligned} r(m) = \beta 0 + \beta 1 [\{1 - \exp(-m/\tau 1)\}/(m/\tau 1)] \\ + \beta 2\,[\{1 - \exp(-m/\tau 1)\}/(m/\tau 1) - \exp(-m/\tau 1)](\beta 0, \tau 1, \tau 2 > 0) \quad (1) \end{aligned}$$

where m is the maturity and r(m) is the spot rate, can be interpreted as the latent dynamic factors. The loading on the first factor $\beta 0$ is 1, a constant, so in the limit, does not decay to 0. This is a long-term factor. The loading on the second factor $\beta 1$ is $\{1- \exp(-m/\tau 1)\}/(m/\tau 1)$, a function that starts at 1, but decays monotonically and approaches to 0, hence this is considered as a short-term factor. The loading on the third factor $\beta 2$ is $[\{1 - \exp(-m/\tau 1)\}/(m/\tau 1) - \exp(-m/\tau 1)]$, starts at 0 and then increases and approaches to 0 further. This factor is viewed as the medium term factor. The long-term, short-term and medium-term factors can also be interpreted as Level, Slope and Curvature of the yield curve. $\beta 0$ governs the level of the yield curve. An increase in the long-term factor ($\beta 0$) will lead to an increase in all yields equally as the loading is identical across all maturities. However, an increase in $\beta 1$ will change the short-end of the yield curve more than its long-end, as the short rates load heavily to $\beta 1$, thereby changing the slope of the yield curve. Hence, it can be interpreted that $\beta 1$ governs the slope of the yield curve. The medium-term factor $\beta 2$ is closely related to the curvature of the yield curve. Both the short rates and the long rates load insignificantly to $\beta 2$ as compared to the medium-term rates, which load heavily to the third factor. Hence an increase or decrease in $\beta 2$ will bring impact on the medium term maturities.

Figures 2 to 5 demonstrate the factor loadings of the estimated parameters $\beta 0$, $\beta 1$, and $\beta 2$ for January 1998, January 1999, December 2002 and December 2003.

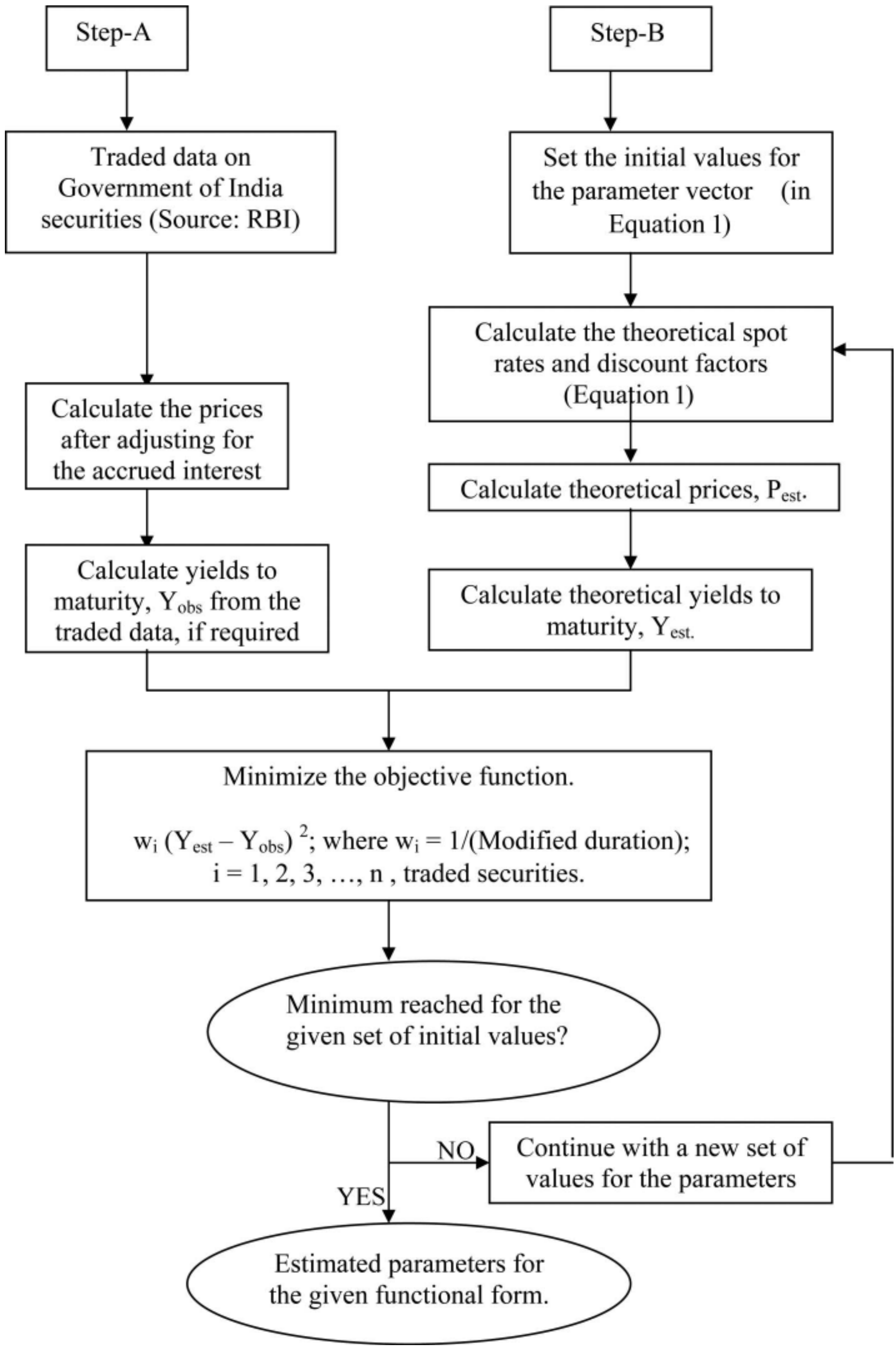

Figure 1. Yield error minimization estimation algorithm.

These represent that at yield curve can be described as ‘Level’ ($L_{t(est)}$), ‘Slope’ ($S_{t(est)}$), and ‘Curvature’ ($C_{t(est)}$), at any point in time. These four data points are randomly chosen. The finding however is similar for all other data months.

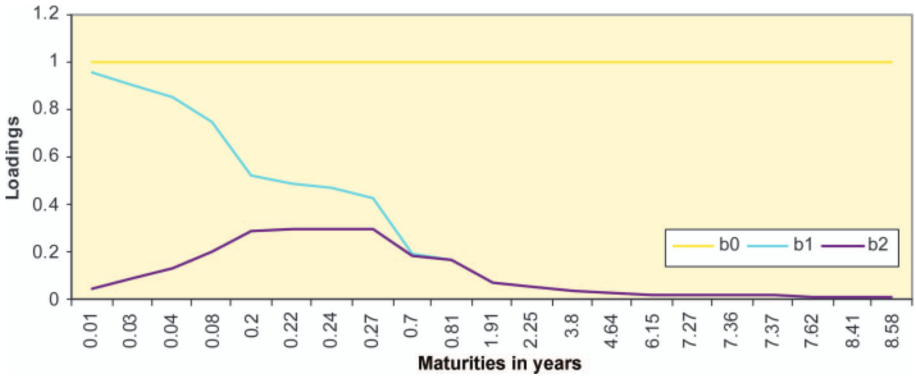

Figure 2. Nelson-Siegel factor loadings, January 1998.
Note: b0 = $\beta 0$, b1 = $\beta 1$ and b2 = $\beta 2$.

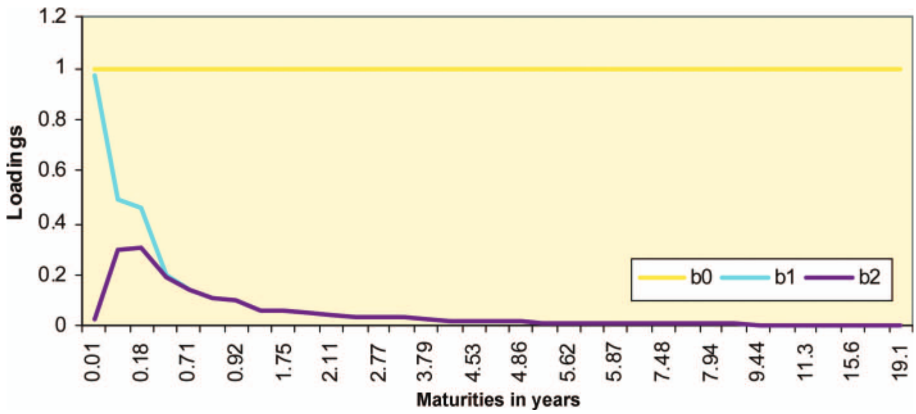

Figure 3. Nelson-Siegel factor loadings, January 1999.
Note: b0 = $\beta 0$, b1 = $\beta 1$ and b2 = $\beta 2$.

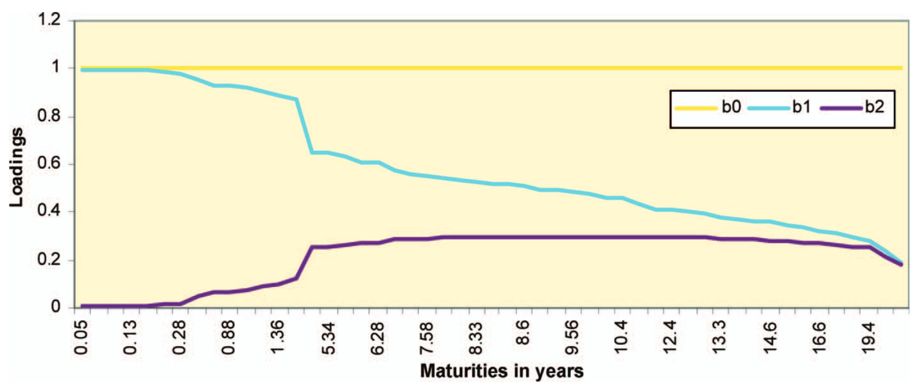

Figure 4. Nelson-Siegel factor loadings, December 2002.
Note: b0 = $\beta 0$, b1 = $\beta 1$ and b2 = $\beta 2$.

4.2. Estimated parameters, empirical proxies and macroeconomic factors

The empirical proxies for the three factors are crucial in order to understand the gap between the estimated parameters and the actual yields. Several empirical proxies for the Level, Slope and Curvature factors have been tested for the Indian scenario with no significant difference in the original findings. A common empirical proxy for level is an average of short-term (3 months yield), medium-term (24 months yield) and long-term (120 months) yields. Diebold (2003) has also used the same empirical approximation for the Level factor. $(y_t\ (3) + y_t\ (24) + y_t\ (120))/3$ is taken as the proxy for level. A proxy for empirical estimation of slope is taken as $(y_t\ (5) - y_t\ (144))$. A standard proxy for curvature is considered as $(2^*\ y_t\ (24) - y_t\ (5) - y_t\ (144))$. Figures 6, 7 and 8 plot the empirical proxies along with the $L_{t(est)}$, $S_{t(est)}$ and $C_{t(est)}$.

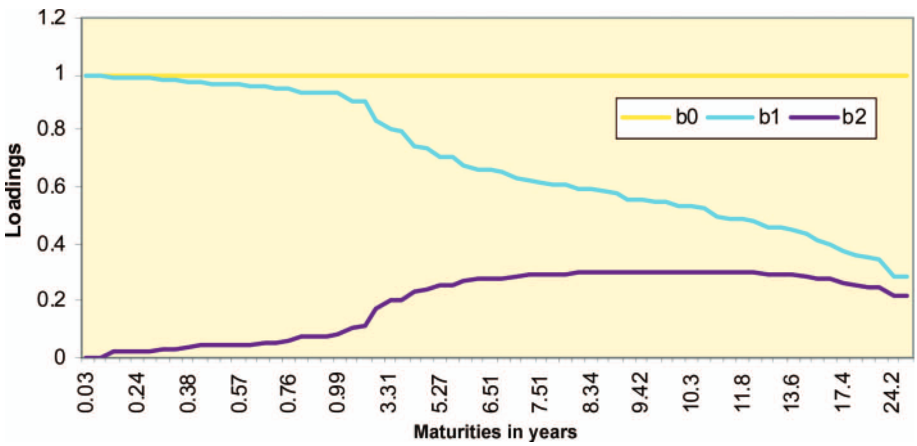

Figure 5. Nelson-Siegel factor loadings, December 2003.
Note: b0 = $\beta0$, b1 = $\beta1$ and b2 = $\beta2$.

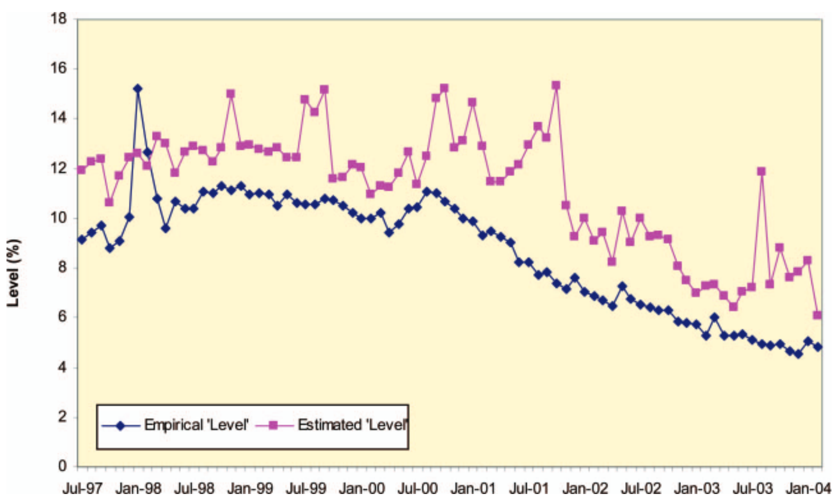

Figure 6. Correlation between empirical and estimated level.

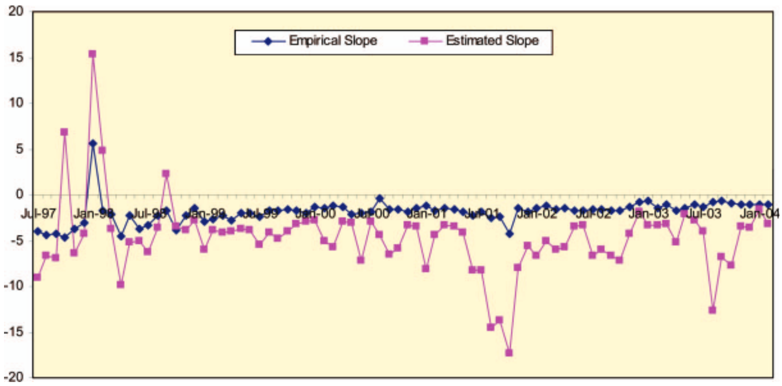

Figure 7. Correlation between empirical and estimated slope.

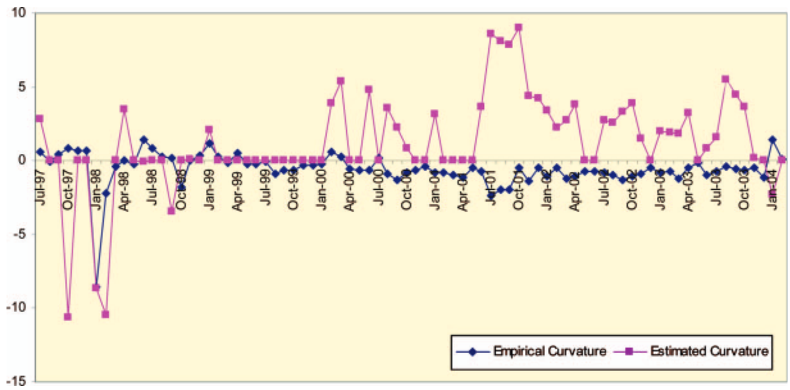

Figure 8. Correlation between empirical and estimated curvature.

The correlation between $L_{t(est)}$ and empirical level factor $(y_t\ (3) + y_t\ (24) + y_t\ (120))/3$ is 80%. However, the degree of association between the empirical slope factor and $S_{t(est)}$ is 47%. The correlation between the empirical curvature ($C_{t(est)}$) and is 8%. The degree of correlation varies between the pre-LAF and post-LAF periods. For the period July 2000 through to February 2004, a high degree of correlation is observed for the estimated Level (82%), Slope (60%) and Curvature (58%) with the empirical proxies defined above. The high degree of correlation between the $L_{t(est)}$, $S_{t(est)}$ and $C_{t(est)}$, and their empirical proxies lend credibility to the interpretation of $\beta 1$, $\beta 2$ and $\beta 3$ as Level, Slope and Curvature factors in the post-LAF period. The lower degree of association between the estimated slope and curvature with their empirical proxies reflects the regulated nature of the market in the pre-LAF period. In the initial period of the data span, very few debt instruments were regularly traded in the market. The spread between the long-term and short-term instruments shows a declining trend for India in the entire data span considered. This should indicate that the Level of the yield curve almost explains the entire span of the yield curve. This also implies a relatively flattening yield curve trend for India during the period considered.

Diebold et al. (2003) investigated the association between $L_{t(est)}$ with inflation and $S_{t(est)}$ with capacity utilization for the US economy. The correlation between $L_{t(est)}$ with inflation and $S_{t(est)}$ with capacity utilization were approximately 40%. In this case, the degree of correlation between $L_{t(est)}$, $S_{t(est)}$ and $C_{t(est)}$ with inflation or growth is in the range of 10% to 15%. However, the correlation between $L_{t(est)}$ and the call money rate (CMR) is around 50%. The finding is consistent with the fact that monetary policy in general will bring most impact to the level of the yield curve as the transmission of monetary policy runs from short term interest rates to longer term influencing aggregate demand in the economy.

5. Estimation methodology

This section attempts to give an overview of the interactions of yield curves with inflation, growth and the role of central bank before explaining the estimation methodology to understand the 'macro-to-yield' and 'yield-to-macro' link in an economy.

In general, the transmission of monetary policy happens through short-term to long-term rates. In the case where the central bank wants to adopt a tight monetary policy, it will sell government bonds/instruments, reducing the liquidity in the system. The central bank can infuse the liquidity in the economy buying back government bonds/instruments. When the market expects the central bank to cut rates the shorter term instruments become expensive as they continue to offer higher interest or coupon rates. As a consequence, the yield declines, adjusting to the lower interest rate environment and the yield curve becomes steeper. On the contrary, when the market expectation is that the central bank will increase interest rates, the price of the debt instruments fall causing the yield to increase, and the yield curve flattens. The central bank's decision to increase or decrease interest rates depend on the economic scenario in the country. If there is growth prospect in the economy, investment activity will be buoyant, resulting in increasing demand for money. This might lead to constant inflationary pressures. In such cases the central bank adjusts the fast rise in demand to the slower growth in supply, increasing the cost of money. Economic growth and inflation affect the yield curve as the monetary policy is largely influenced by the health of the economy.

5.1. Estimation methodology: VAR and Granger's causality

The estimated Level ($L_{t(est)}$), Slope ($S_{t(est)}$), Curvature ($C_{t(est)}$), growth (changes in the industrial index of production (IIP)), along with inflation (changes in the wholesale price index (WPI)) and the call money rate (CMR) are used in a VAR framework to understand the dynamics of financial and macroeconomic variables for the period July 1997 to February 2004. The policy variable, CMR, helps to identify the response of macroeconomic and financial factors to the changes in monetary policy. $L_{t(est)}$, $S_{t(est)}$ and $C_{t(est)}$ are taken as financial factors and growth (GWT_t), inflation (INF_t) and CMR_t are taken as macro variables.

As a first step, the existence of a non-stationary feature of each variable is examined. In case the series is non-stationary in nature, the first difference of the series is taken to make it stationary. In the next step the VAR model is estimated incorporating the appropriate lagged terms of the variables. The estimated model is then used for an in-sample forecast of the yields. Next, the direction of individual and block Granger causality among the variables is investigated. In case of significant existence of structural break, a dummy or exogenous variable is incorporated in the VAR estimation. Finally, sensitivity analysis or impulse response function is carried out to identify the dynamics of macro variables with respect to financial variables and vice versa. This analysis is repeated for the pre-LAF and post-LAF periods to see if the difference in findings are due to the introduction of liquidity adjustment facility by the central bank (LAF) in the month of June 2000.

5.1.1. *VAR estimation methodology*

Let us consider an unrestricted VAR of order p represented by

$$y_t = a_0 + a_1 t + \sum_{i=1}^{p} \Phi_i y_{t-i} + \Psi w_t + u_t \tag{2}$$

where y_t is a $(n \times 1)$ vector of endogenous I(0) variables, t is the linear time trend, a_0 and a_1 are $(n \times 1)$ vectors, w_t is a $(q \times 1)$ vector of exogenous variables and u_t is a $(n \times 1)$ vector of unobserved disturbances where $u_t \sim N(0, \Omega)$, t = 1 2 .....T.

VAR can be constructed either in terms of the level of the data or in terms of their first differences, i.e. I(0) variables. If the series are non-stationary, the Granger causality test may give misleading results unless the data are transformed to induce stationarity.

5.1.2. *Augmented Dickey Fuller Test (ADF) test for stationarity*

ADF test is conducted with the following model:

$$\Delta X_t = \alpha_0 + (1-k)\beta_t - (1-k)X_t - 1 + \sum_{1}^{p} \gamma_j \Delta X_{t-j} + \varepsilon_t \tag{3}$$

where X_t is the underlying variable at time t, ε_t- is the error term and α_0, β, k and γ_j are the parameters to be estimated. The lagged terms are introduced in order to justify that errors are uncorrelated with them. For the above-specified model the hypothesis, which would be of our interest, is:

$$\mathrm{H}_0: \quad (1-k) = 0$$

5.1.3. *Block Granger causality test*

$$\Delta X_t = \alpha + \sum_{i=1}^{m} \beta_i \Delta X_{t-i} + \sum_{j=1}^{n} \gamma_j \Delta Y_{t-j} + u_t \tag{4}$$

$$\Delta Y_t = a + \sum_{i=1}^{q} b_i \Delta Y_{t-i} + \sum_{j=1}^{r} c_j \Delta X_{t-j} + v_t \tag{5}$$

The optimum lag length m, n, q and r are determined on the basis of Akaike's (AIC) and/or Schwarz Bayesian (SBC) and/or log-likelihood ratio test (LR) criterion. ΔY Granger causes ΔX if,

H_0: $\gamma_1 = \gamma_2 = \ldots = \gamma_n = 0$ is rejected.

Against H_A: = at least one $\gamma_j \neq 0$, j = 1 ... n,
and ΔX Granger causes ΔY if,
H_0: $c_1 = c_2 = \ldots = c_n = 0$ is rejected.
Against H_A: = at least one $c_j \neq 0$, j = 1 ... r.

5.1.4. Pair-wise Granger causality tests/block exogeneity Wald test

Pair-wise Granger causality tests whether an endogenous variable can be treated as exogenous. For each equation in the VAR, CHSQ (Wald) statistics test for the joint significance of each of the other lagged endogenous variables in that equation.

6. Data

The analysis covers the data from July 1997 through to February 2004. The time series of estimated parameters of the yield curve Level, Slope and Curvature are taken as financial factors. Annualized monthly changes in WPI and IIP are used as inflation and real economic activity respectively. CMR is the main component of the money market. The money market has always played a pivotal role in the monetary policy transmission mechanism in the Indian context, like many other developing economies. Hence, the CMR is considered as a proxy for monetary policy indicator. Inflation, real activity and CMR represent macro factors. To understand the regime-shift effect of LAF, which was introduced in June 2000 as part of the monetary and credit policy, the analysis is also carried out for the pre-LAF (July 1997 to May 2000) and post-LAF periods (July 2000 to February 2004) separately.

7. Empirical results

As a first step the stationarity of the series is carried out using an ADF test.

The Table 1 below displays the ADF tests for all variables under consideration, Level ($L_{t(est)}$), Slope ($S_{t(est)}$), Curvature ($C_{t(est)}$), GWT_t, INF_t, $DCMR_t$. $L_{t(est)}$ and CMR_t possess unit root at 5% level of significance. However, both the series become stationary in its first difference. No significant structural break is observed in any variables for the period under study July 1997 to February 2004.

7.1. Results: overall sample

We estimate VAR with six variables $DL_{t(est)}$, $S_{t(est)}$, $C_{t(est)}$, GWT_t, INF_t, $DCMR_t$. VAR of order one is selected based on Akaike and SBC criteria. In this case, the estimated VAR model is,

$$Y_t = \text{Constant} + A(\text{est})Y_{t-1} \tag{6}$$

Table 1. Augmented Dicky Fuller (ADF) unit foot tests.

Variable	t-Statistic	Test critical values at 5%	Probability
$L_{t(est)}$	−2.940249	−3.469235	0.1561
$DL_{t(est)}$	−5.162545	−3.475305	0.0004
$S_{t(est)}$	−5.973453	−3.468459	0
$C_{t(est)}$	−5.376175	−3.468459	0.0001
GWT_t	−11.21877	−3.478305	0
INF_t	−5.558771	−3.470032	0.0001
CMR_t	−2.209611	−3.478305	0.4764
$DCMR_t$	−5.505683	−3.478305	0.0001

Notes: Null hypothesis: the variable has a unit root. Exogeneous: constant, linear trend. Optimal lag length is decided based on AIC criteria.

where $Y_t = (DL_{t(est)}, S_{t(est)}, C_{t(est)}, GWT_t, INF_t, DCMR_t)$ is a (5×1) vector of endogenously determined variable. In this case, W_t (in Equation 7) does not contain any exogenous variables as no significant structural break is found in the data span considered.

The estimated VAR model is shown in Table 2 where each of the variable at time point ‘t’ is regressed on its own lagged value and the lagged values of other five variables at time ‘t-1’. Inflation with a lag of one period is significant at the 5% level in the equation of changes in level and changes in CMR. This estimated VAR model is then used for in-sample forecasts of the parameters level ($\beta 0$), slope ($\beta 1$) and curvature ($\beta 2$) of the Nelson-Siegel model for the five months; October 2003 to February 2004. The estimated yield parameters Level, Slope and Curvature obtained from the VAR model of macro and yield factors are used to estimate the yield curve for October 2003 to February 2004 using the Nelson-Siegel model. The objective is to verify if the goodness of fit[3] of the yield curve improves with the estimated yield parameters obtained from the multivariate VAR model of macro and financial variables. Table 3 shows the root mean square errors (RMSEs) of estimated spot rates or term structure of interest rates by the Nelson-Siegel method (shown as ‘Actual’) and the multivariate VAR estimates of macro and financial variables (shown as ‘Predicted’) for the period October 2003 to February 2004.

The actual and forecasted RMSEs do not differ at all. This suggests that in the Indian context, inclusion of macro variables does not seem to improve ‘in-sample’ prediction of the yield curve significantly. This finding is different from Diebold et al. (2003), who proved that for the US economy the yield curve model along with key macro economic variables improve the prediction of spot rates. The liquidity adjustment facility which was launched in June 2000 through repo and reverse repo operations enabled the central bank to manage the liquidity conditions in response to the movement of key macroeconomic indicators in a much faster way. After the launch of the LAF the interest rates in the money market and government securities market have become more consistent with policy objectives of central banks which vary under diverse macroeconomic conditions. There has been a significant development in the government securities market over the past five years in terms of its participants, turnover, and liquidity following a series of reform measures adopted by the RBI which would lead to better integration of the government securities market with other financial sectors and macroeconomic factors in the

Table 2. Vector autoregression estimates.

Variables	$DL_{t(est)}$	$S_{t(est)}$	$C_{t(est)}$	GWT_t	INF_t	$DCMR_t$
$DL_{t(est)-1}$	−0.3732	0.024821	−0.02311	−0.050405	0.012289	0.132528
	[−3.83976]	[0.89027]	[−0.96582]	[−1.36536]	[3.21990]	[0.57732]
$S_{t(est)-1}$	1.828912	0.256048	−0.05585	−0.395878	0.023119	1.62653
	[2.74108]	[1.33776]	[−0.34007]	[−1.56208]	[0.88240]	[1.03213]
$C_{t(est)-1}$	1.520739	−0.22421	0.473581	−0.500128	0.032319	−1.6653
	[1.88195]	[−0.96724]	[2.38082]	[−1.62947]	[1.01856]	[−0.87255]
GWT_{t-1}	−0.53695	−0.00709	0.003441	−0.467099	−0.00466	−0.71797
	[−1.84825]	[−0.08509]	[0.04811]	[−4.23296]	[−0.40876]	[−1.04634]
INF_{t-1}	**−2.21155**	0.699156	−0.86264	−1.806333	0.314601	**−17.1228**
	[−1.00137]	[1.10357]	[−1.58674]	[−2.15331]	[3.62770]	**[−3.28260]**
$DCMR_{t-1}$	0.069506	−0.0036	0.01043	−0.000978	0.003548	−0.46576
	[2.26731]	[−0.40890]	[1.38214]	[−0.08399]	[2.94734]	[−6.43267]
Constant	0.059334	−0.0349	0.006932	0.001239	0.002915	0.17874
	[2.11630]	[−4.33961]	[1.00439]	[0.11635]	[2.64767]	[2.69922]

Notes: t-statistics in [ ]. VAR of order one is selected based on AIC criterion.

Table 3. In-sample forecasts of term structure of interest rates, root mean square error (RMSE).

Months	Actual	Predicted
October 2003	0.52071	0.52081
November 2003	0.75204	0.75165
December 2003	0.73701	0.73702
January 2004	1.79016	1.79012
February 2004	2.80090	2.80088

Table 4. Likelihood ratio (LR) test of block Granger causality.

	Entire sample period		Pre-LAF		Post-LAF	
	July 1997–February 2004		July 1997–May 2000		July 2000–February 2004	
Block of variables	CHSQ (9)	Probability	CHSQ (9)	Probability	CHSQ (9)	Probability
Financial to macro	29.9956	0*	14.2364	0.114	19.5841	0.021*
Macro to financial	20.9976	0.103	10.8071	0.289	14.5437	0.104

Notes: * implies hypothesis of non-causality is rejected. Financial factors: $DL_{t\ (est)}$ $S_{t\ (est)}$ $C_{t\ (est)}$. Macro factors: GWT_t, INF_t and $DCMR_t$.

economy. So the finding that the inclusion of macro factors (inflation, growth) do not appear to improve the yield curve estimates could be attributed to the sample period considered in this study.

As a next step, both block and individual Granger causality tests of the financial and macro variables are carried out for the entire sample period. Table 4 shows the block Granger causality both from financial factors ($DL_{t(est)}$, $S_{t(est)}$, $C_{t(est)}$) to macro factors (GWT_t, INF_t, $DCMR_t$) and macro to financial factors.

The probability value of 0 associated with the LR test of block non-causality (in Table 4) suggests that the financial factors represented by the estimated level, slope, curvature do influence the movements of macroeconomic factors with a weaker feedback effect from macroeconomic factors to financial factors, where the associated probability value that macro factors Granger cause the financial factors is 10%. One of the possible reasons could be that the yields in the government securities markets for the sample period considered are market related. They do not reflect the true market determined rates. Hence, changes in the macroeconomic factors do not have significant reflections on the changes in the financial factors. However, we could possibly find the reverse trend; macro factors driving the financial factors in more recent data given the significant development in the government securities market.

To obtain a clear picture of the dynamics of each variable and understand the intervention of the central bank in the macro-to-yield and yield-to-macro link the individual Granger causality among the variables is examined for the entire sample period July 1997 to February 2004. The results are shown in Table 5.

The variables listed in each row are regressed on the variables across the columns. For example, in Table 5, $DL_{(est)}$ is regressed on $S_{(est)}$, $C_{(est)}$, growth (GWT), inflation

Table 5. VAR Granger causality/block exogeneity Wald tests, entire sample period (July 1997 to February 2004).

Dependent variables	$DL_{(est)}$	$S_{(est)}$	$C_{(est)}$	GWT	INF	DCMR
$DL_{(est)}$		**7.513518**	3.541724	3.416019	1.002737	**5.140688**
		[0.0061]	[0.0598]	[0.0646]	[0.3166]	[0.0234]
$S_{(est)}$	0.792573		0.935558	0.00724	1.217865	0.167198
	[0.3733]		[0.3334]	[0.9322]	[0.2698]	[0.6826]
$C_{(est)}$	0.932807	0.115647		0.002315	2.51773	1.910304
	[0.3341]	[0.7338]		[0.9616]	[0.1126]	[0.1669]
GWT	1.864208	2.440084	2.655168		**4.636739**	0.007055
	[0.1721]	[0.1183]	[0.1032]		[0.0313]	[0.9331]
INF	**10.36775**	0.778633	1.037465	0.167083		**8.686785**
	[0.0013]	[0.3776]	[0.3084]	[0.6827]		[0.0032]
DCMR	0.333299	1.065301	0.761347	1.09482	**10.77545**	
	[0.5637]	[0.302]	[0.3829]	[0.2954]	[0.001]	

Notes: Probability values are in [ ]. Highlighted cells imply existence of causality.

(INF) and changes in CMR (DCMR). The probability values in excess of 5% associated with the null hypothesis of non-causality will not be considered to have any strong impact on the dependent variable. We observe that the dynamics of yield and macro factors start with the inflation change. For example, in the equation of changes in CMR, inflation is the significant variable. So inflation in the first place brings an impact on CMR. The changes in CMR have an impact on inflation. In the equation of inflation, we see that changes in CMR is statistically significant, so as the level of yield curve. So changes in CMR influences the movements (increase/decrease) of inflation and also brings an impact on the level of yield curve.[4] Thus, the changes in CMR influences the estimated level of the yield curve causing an impact on the overall movements of yield curve. Changes in level, in turn, brings an impact on inflation; finally inflation causes an impact to the overall growth of the economy. And growth has a weaker impact on the changes in the level of the yield curve. So it is observed that the policy variable CMR has a very important role in bringing an impact on inflation, growth and overall yield curve movements. This finding is consistent with the fundamental macroeconomic movements in an economy. The indirect instruments of monetary policy are becoming an important tool in influencing the aggregate demand or growth in the economy. Hence, it is observed that in the Indian scenario, the central bank does play a vital role in establishing the linkage between macroeconomic and financial factors through the changes in monetary policies. The result also suggests that the Level of the yield curve can be used as indicator for inflation. The introduction of the LAF in June 2000 has significant role in revamping the liquidity factor in government securities market in India. So the section below divides the entire sample into two periods: pre- and post-LAF and examines the causality for the two sample periods July 1997 to May 2000 and July 2000 to February 2004 separately.

7.2. Results: pre-LAF and post-LAF periods

The Reserve Bank of India has introduced a liquidity adjustment facility in June 2000 as part of the monetary and credit policy. The LAF was introduced primarily to develop a robust short-term operational model for better understanding of the transmission mechanism of the monetary policy. In line with this, a liquidity assessment model is being structured, on the basis of available data, to assess both the mechanism and inter-linkages among different segments of the financial systems. Repo auctions to absorb the liquidity and reverse repo-auctions to inject liquidity in the economy started on a daily basis after June 2000. This helped the central bank to adjust the supply of money in response to the movement of key macroeconomic indicators in a much faster way. This is indeed one of the major achievements for the sovereign market in India.

To understand whether introduction of LAF has changed the dynamic linkages between the macro and the financial factors we separate out the pre- and post-LAF period. Table 4 shows block Granger causality tests for the pre- and post-LAF period separately. In the pre-LAF period no causality is found from any direction. So neither financial factors nor macro factors has any linkages in the movements of each other. But the result in the post-LAF period suggests that the causality exists in both the directions. However, causality running from macro to financial factor is found to be weaker compared to the financial factors to macro link. This is consistent with the finding of the entire sample period. So the causality from the financial to the macro factors in the Indian scenario evolves post the introduction of liquidity adjustment facility.

A pair-wise Granger causality tests are also shown in Tables 6 and 7 for the pre- and post-LAF periods respectively.

In the pre-LAF period none of the variables are found to have a strong causal impact. It is found that inflation causes the changes in CMR with a feedback effect to inflation. However, the evidence of causality is found to be weaker in this period. This could be due to the fact that the use of indirect instruments of monetary policy was in the process of making for the sample period under study. The result for the post-LAF period as shown in Table 7 is similar to the overall sample. Inflation causes the changes in CMR, which in turn influences the movements in the level of the yield curve. And we find causality runs from changes in level to inflation and growth. But the causality from the changes in level to growth is weaker. Also, we see a weaker causality running from inflation to

Table 6. VAR Granger causality/block exogeneity Wald tests, pre-LAF (July 1997 to May 2000).

Dependent variables	$DL_{(est)}$	$S_{(est)}$	$C_{(est)}$	GWT	INF	DCMR
$DL_{(est)}$		0.26113	3.68E-06	0.344906	0.021596	1.024626
		[0.6093]	[0.9985]	[0.557]	[0.8832]	[0.3114]
$S_{(est)}$	0.491535		0.015293	0.537953	0.371391	0.005193
	[0.4832]		[0.9016]	[0.4633]	[0.5422]	[0.9426]
$C_{(est)}$	0.900265	0.023089		1.097081	2.061459	1.298125
	[0.3427]	[0.8792]		[0.2949]	[0.1511]	[0.2546]
GWT	0.002108	0.278977	0.454625		1.638465	0.132496
	[0.9634]	[0.5974]	[0.5001]		[0.2005]	[0.7159]
INF	0.728759	0.504135	2.189808	0.11106		3.279767
	[0.3933]	[0.4777]	[0.1389]	[0.7389]		[0.0701]
DCMR	0.008784	2.597045	0.591171	3.809058	3.538602	
	[0.9253]	[0.1071]	[0.442]	[0.051]	[0.06]	

Note: Probability values are in [ ].

growth. This leads us to infer that the Level of the yield curve can be used as an indicator for the movements of the inflation. So it is clear that the role of the central bank (RBI) or the indirect instrument of monetary policy has become much stronger in influencing the aggregate growth in India after the introduction of the liquidity adjustment facility.

7.3. *Sensitivity analysis*

In order to see the responses of individual variables while there is a shock in the system, impulse response functions are analysed for the entire sample and the post-LAF period.[5] The results should further validate the previous findings. Figures 9 to 14 show results of impulse response functions for the entire sample period.

Each of the graphs shows the response of all variables while there is one unit standard error shock in one specific variable. For example, Figure 9 shows the

Table 7. VAR Granger causality/block exogeneity Wald tests, post-LAF (July 2000 to February 2004).

Dependent variables	$DL_{t(est)}$	$S_{t(est)}$	$C_{t(est)}$	GWT_t	INF_t	$DCMR_t$
$DL_{t(est)}$		**8.036065**	**4.712088**	1.902009	0.729316	**4.215012**
		[0.0046]	[0.03]	[0.1679]	[0.3931]	[0.0401]
$S_{t(est)}$	0.016905		4.279774	0.00724	1.217865	0.167198
	[0.8966]		[0.0386]	[0.9322]	[0.2698]	[0.6826]
$C_{t(est)}$	0.932807	0.115647		0.939653	0.001122	0.164592
	[0.3341]	[0.7338]		[0.3324]	[0.9733]	[0.685]
GWT_t	2.976206	1.326795	1.099969		2.355619	0.037513
	[0.0845]	[0.2494]	[0.2943]		[0.1248]	[0.8464]
INF_t	**12.49285**	1.81068	0.383457	0.061256		1.225752
	[0.0004]	[0.1784]	[0.5358]	[0.8045]		[0.2682]
$DCMR_t$	0.837949	0.374026	0.91438	0.010439	**5.404851**	
	[0.36]	[0.5408]	[0.339]	[0.9186]	[0.0201]	

Notes: Probability values are in [ ]. Highlighted cells imply existence of causality.

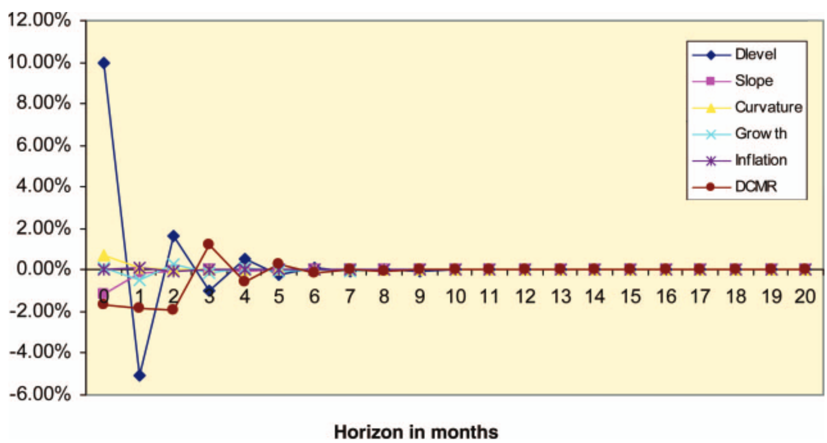

Figure 9. Impulse response to one unit SE shock of Dlevel (entire sample period July 1997 to February 2004).

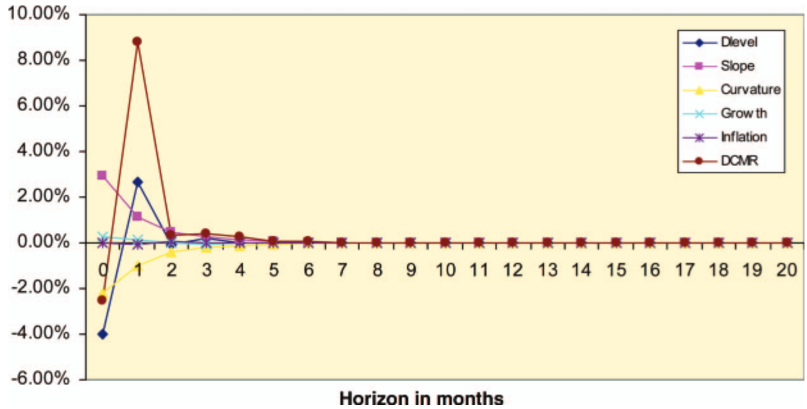

Figure 10. Impulse response to one unit SE shock of Slope (entire sample period July 1997 to February 2004).

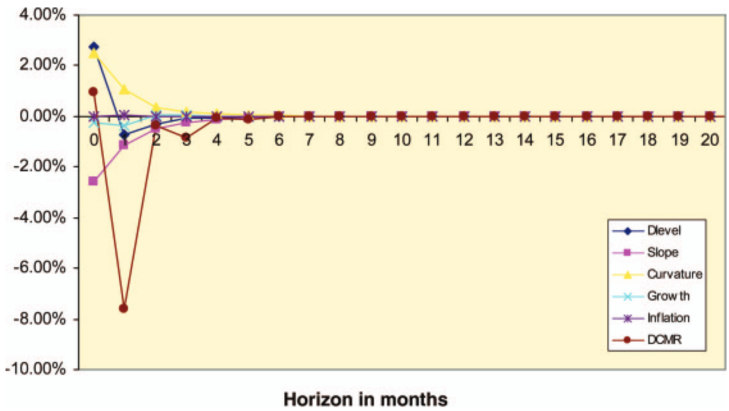

Figure 11. Impulse response to one unit SE shock of Curvature (entire sample period July 1997 to February 2004).

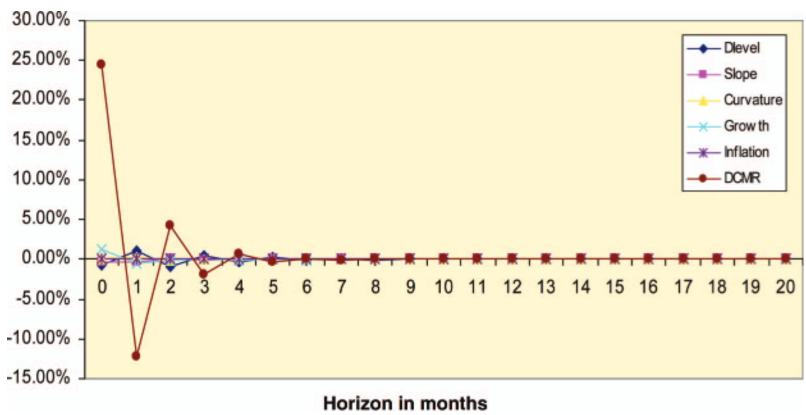

Figure 12. Impulse response to one unit SE shock of Growth (entire sample period July 1997 to February 2004).

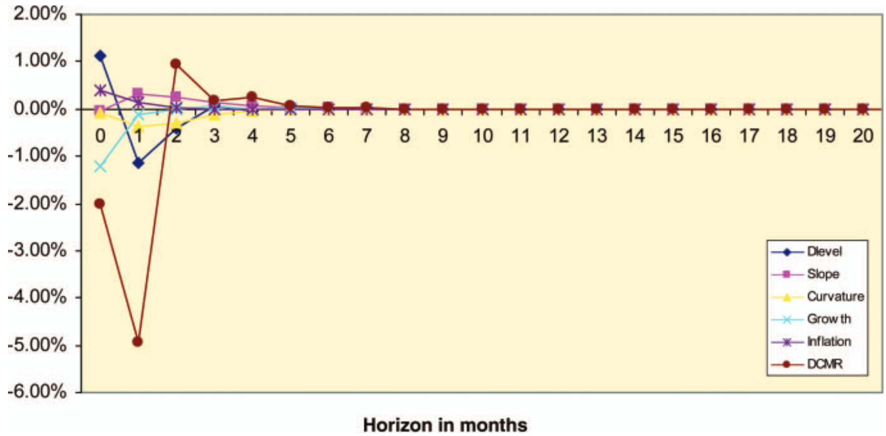

Figure 13. Impulse response to one unit SE shock of inflation (entire sample period July 1997 to February 2004).

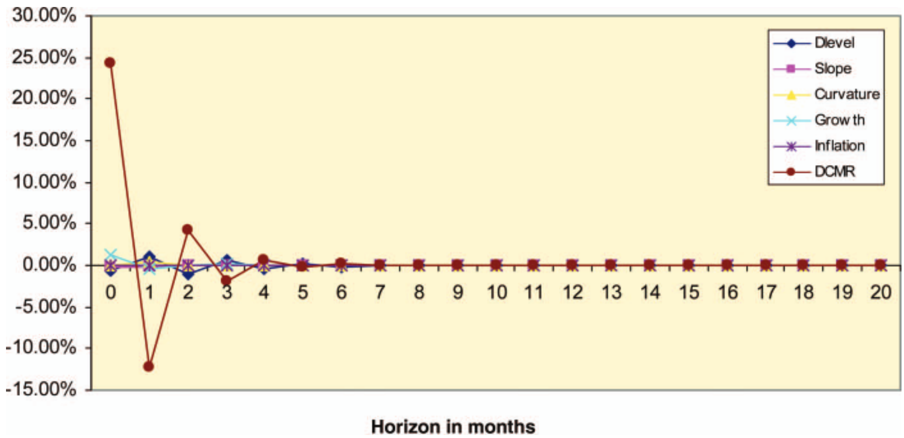

Figure 14. Impulse response to one unit SE shock of DCMR (entire sample period July 1997 to February 2004).

response of slope (est), curvature (est), growth, inflation and changes in the CMR (DCMR) when there is one unit standard error shock to changes in Level of yield curve. The shock in changes in level (Dlevel) brings a significant impact to the changes in the monetary policy variable, DCMR, with no significant deviations in other variables in the system. Figures 9 to 14 suggest that while the system receives a shock in any variables either inflation or growth or slope, it is the changes in CMR that deviates most in the short-term. Figure 13 shows the responses of financial and macro variables while there is an external shock in inflation. This needs further discussion given the dynamic linkages observed between macro and financial factors in the above section. The response or deviation of changes in CMR is the highest followed by the changes in level of yield curve with one unit standard error shock in inflation. Changes in CMR and changes in level take almost five to six months to come back to the normal level after an inflation shock in the system. The shock in inflation also brings a deviation in growth. Thus, we observe that the response of monetary policy is very prompt or immediate while there is an inflation shock in the system. This also suggests that the indirect instrument of monetary policy is becoming important to stabilize the economy while there is an external macroeconomic shock.

Figures 15 to 20 show similar findings for the post-LAF period July 2000 to February 2004.

In the post-LAF period it is observed that the changes in level of yield curve reacts most followed by the changes in CMR while there is a shock in inflation. The shock in inflation also brings significant impact in growth. The changes in

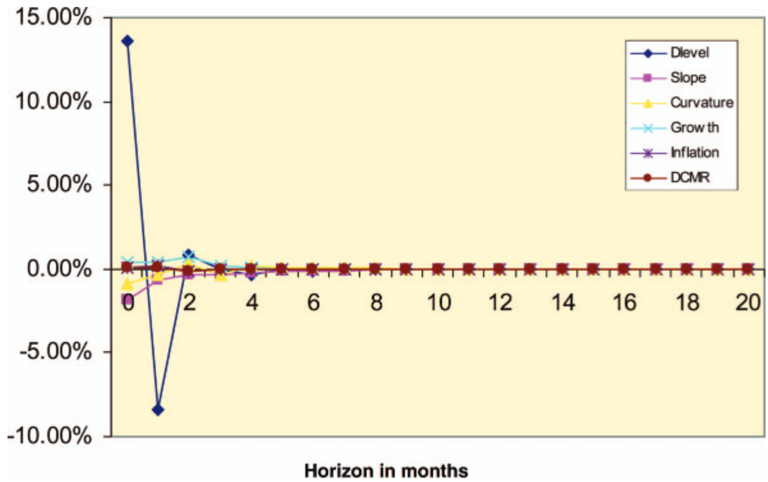

Figure 15. Impulse response to one unit SE shock of Dlevel (post-LAF period July 2000 to February 2004).

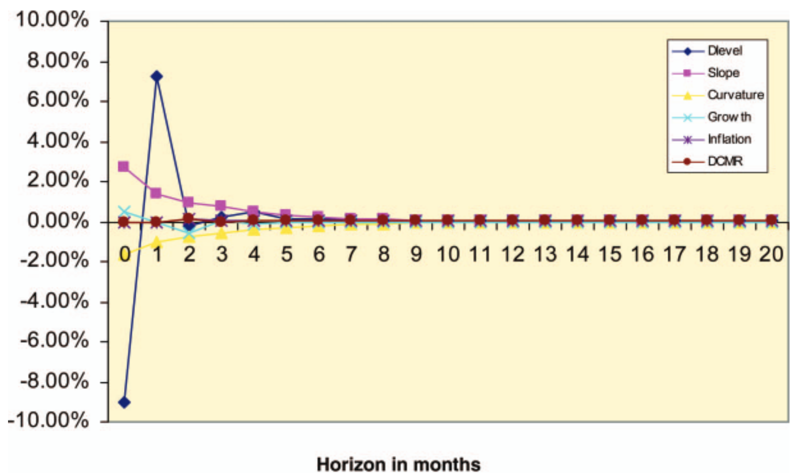

Figure 16. Impulse response to one unit SE shock of Slope (post-LAF period July 2000 to February 2004).

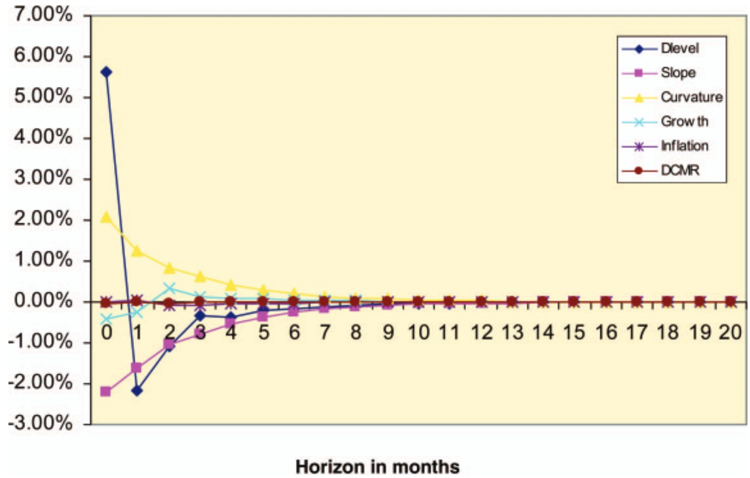

Figure 17. Impulse response to one unit SE shock of Curvature (post-LAF period July 2000 to February 2004).

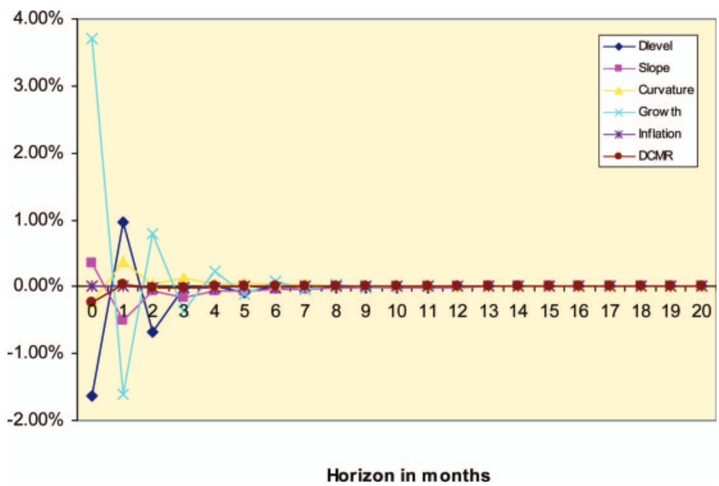

Figure 18. Impulse response to one unit SE shock of Growth (post-LAF period July 2000 to February 2004).

level of yield curve takes three to four months, on average, to come back to the normal state. This finding implies that the level of the yield curve responds most with the external shock in the economy. The result also suggests that with the constant endeavour of the RBI to develop the government securities market in India, the yield rates are becoming more market related and the term structure of interest rates can be used as one of the important indicators to predict future behaviour of inflation or growth.

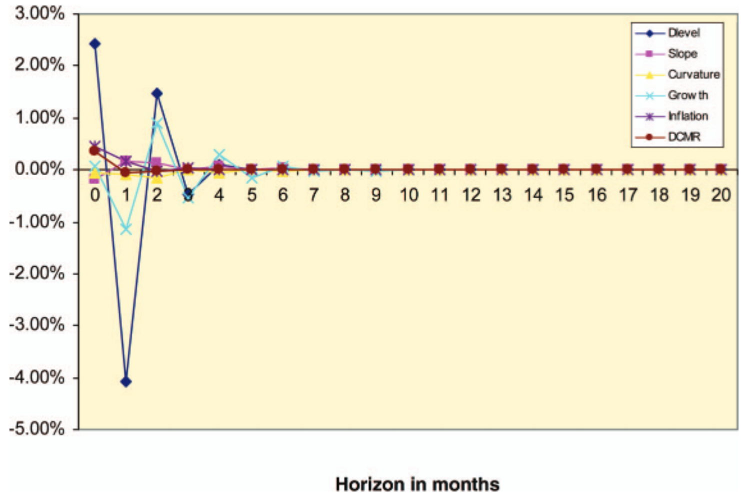

Figure 19. Impulse response to one unit SE shock of inflation (post-LAF period July 2000 to February 2004).

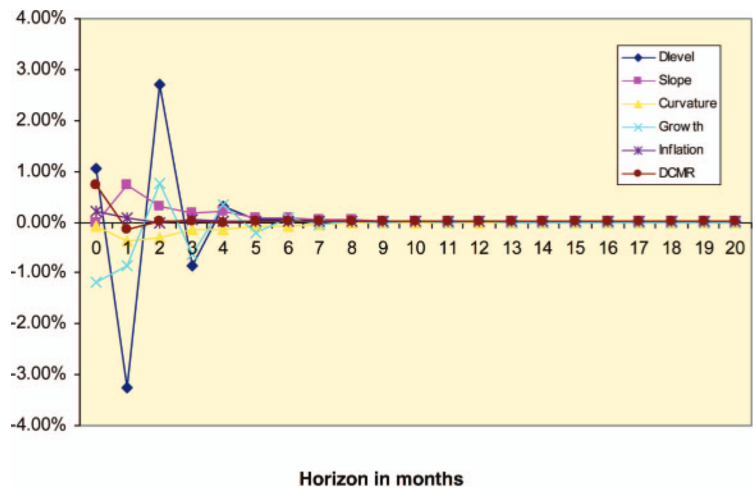

Figure 20. Impulse response to one unit SE shock of DCMR (post-LAF period July 2000 to February 2004).

8. Conclusion

The study aims at understanding the dynamics of the linkage, if any, between the term structure of interest rates and the macroeconomic factors of the deregulated Indian economy. Movements in the yield curves is nothing but an outcome of the changes in the key macroeconomic fundamentals; inflation, growth, and monetary policy. So shape of the yield curve can be used as a good predictor or reflector to effectively manage monetary policy, which would influence inflation and growth in an economy. This study integrates macroeconomic factors and yield curves with two-fold objectives: first, to investigate the dynamic linkages between macro and yield factors, and second to see if the integrated macro-yield model improves the prediction of yield curve. To explore the possibility of the Reserve Bank of India's intervention in this dynamic relationship an indicator for monetary policy is also introduced. The dynamics of yield curve and macroeconomic factors cannot independently be determined without a monetary policy indicator as in most cases, it is found that monetary policy plays a major role in these movements and the predictive content of the yield curve is primarily due to the conduct of monetary policy. The validity of the rational expectation hypothesis for the government security markets in India provides a strong basis to test the bidirectional linkages between the debt instruments and the key macroeconomic indicators in the intervention of monetary policy.[6]

It is shown that the factor loadings of the parameters ($\beta 0$, $\beta 1$, $\beta 2$) estimated by the Nelson-Siegel model can be explained as Level, Slope and Curvature for a zero-coupon yield curve at any point in time. A time-series of Level, Slope and Curvature along with inflation (annualized monthly changes in WPI), GDP growth (annualized monthly changes in IIP) and a policy variable call money rate (CMR) are used to understand the long-run dynamics between financial and macroeconomic factors for the period July 1997 to February 2004 in a multivariate VAR framework. The in-sample predictions of term structure of interest rates show that the inclusion of macro factors does not improve the prediction of yield curve. The result differs from Diebold (2003) where he found that the inclusion of macro factors improved the yield curve fit.

Block Granger causality between macro and financial factor shows that there is strong causality from financial factors, defined by the three parameters of the yield curves (level, slope and curvature) and to macroeconomic factors (growth, inflation and changes in CMR) for the entire sample period. However, the causality in the opposite direction is found to be much weaker. The study also finds that in the pre-LAF period (July 1997 to May 2000), yield and macro factors do not cause each other. The finding in the post-LAF period (Jul 2000 to February 2004) is similar to the one for entire sample period. Pair-wise Granger causality shows the dynamics of causality starts from inflation. Inflation causes the changes in CMR, which in turn influences the movements in the level of the yield curve. The causality runs from changes in level to inflation and growth. However, the causality from level to growth is found to be weaker. Thus, CMR responds to inflation and changes in the CMR drives the change in the level of the yield curve which in turn smoothens or tightens inflation and finally brings an impact on the aggregate demand in the economy. The finding is consistent with the fundamental macroeconomic movements in an economy. The result implies that the indirect instruments of monetary policy are becoming an important tool in influencing the aggregate demand or growth in the economy. Hence, it is observed that in the Indian scenario, the RBI does play a vital role in establishing the linkage between macroeconomic and financial factors through the changes in monetary policies. The finding also suggests that the Level of the yield curve can be used as indicator for inflation. The introduction of the LAF in June 2000 has had a significant role in revamping the liquidity factor in the government securities market in India.

Sensitivity analysis for the overall sample and for the post-LAF period show that changes in CMR or monetary policy variable and changes in the level of the term structure of interest rates deviate most once there is a shock in the system. This implies that the indirect instrument of monetary policies are becoming increasingly important to stabilize the aggregate demand in the economy. Also, with the continuous development of the government security market in India, yield rates are becoming more and more market related and have started reflecting the market behaviours. Thus, with the ongoing reform measures in the financial market in India, and especially in the government securities market in India, term structure of interest rates can be used as one of the main indicators to predict future behaviour of inflation or growth in the near future.

The study falls in the initial phase of reforms and hence is constrained by the smaller sample, so to prove that term structure of interest rate plays a leading role to predict the future macroeconomic behaviours, this study can be extended or replicated with more recent data starting from the post-LAF period, June 2000. The finding in this case can be expected to be more robust for a couple of reasons. Firstly, the sample size will be larger. Secondly, the developments in the government securities market have been immense in terms of its liquidity and market turnover post the launch of the liquidity adjustment facility in June 2000 to date. Government securities markets are progressively becoming more integrated with financial markets. Yield rates are becoming more market oriented which should reflect the expectations of the economy.

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Notes

1. Lowe (1992) asserts that the predictive power of the slope of the yield curve is primarily due to the liquidity effect in the economy, which is basically the negative relationship between the interest rates and money supply. Movements in the short-term interest rates as a result of the monetary policy changes underlie the predictive power of the yield curve for future real activity as because real activity responds to the movements in short-term interest rates with a lag. The fact that the transmission mechanism of monetary policies affect the slope of the yield curve is established by Bernanke (1990), Bernanke and Blinder (1992). The second view concerning the predictive capability of the term spread about business cycle of the economy stems from the 'consumption-based asset-pricing model'. Harvey (1988, 1989) has shown a systematic relationship between the stage of the business cycle and the shape of the yield curve. The theory says that the forecasting power of the yield spread for future real activity originates from the economic agents' expectations about the future state of the economy and intertemporal utility maximizing behaviour. This view has been supported by Hu (1993), Plosser and Rouwenhorst (1994), and Kim (1998).
2. Repo auctions, which are to absorb the liquidity, and reverse repo-auctions, which are to inject liquidity in the economy, started on a daily basis after June 2000.
3. Goodness of fit criterion is decided based on root mean square error of the yields.
4. In the equation of changes in level, changes in CMR is statistically significant.
5. The results for the pre-LAF period are not discussed as the linkage between macro-to-yield and yield-to-macro is found only for the post-LAF period.
6. The underlying assumption of this framework is based on the fact that the rational expectations theory holds true for the government securities market in India. The study is a chapter of the PhD thesis 'Term Structure of Interest Rates: Indian Macroeconomic

Issues'. One of the chapters explores the validity of rational expectation hypothesis (REH) for the government securities markets in India. The finding goes in favour of the theory for the market.

Notes on contributor

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