Interest-rate risk in the Indian banking system

Ila Patnaik*
ICRIER, New Delhi
and
NCAER, New Delhi
ila@icrier.res.in

Ajay Shah
Ministry of Finance, New Delhi
and
IGIDR, Bombay
ajayshah@mayin.org
http://www.mayin.org/~ajayshah

February 7, 2003

Abstract

Many observers have expressed concerns about the impact of a rise in interest rates upon banks in India. In this paper, we measure the interest rate risk of a sample of major banks in India, using two methodologies. The first consists of estimating the impact upon equity capital of certain interest rate shocks. The second consists of measuring the elasticity of bank stock prices to fluctuations in interest rates.

We find that as of 31 March 2002, many major banks had economically significant exposures. Using the first approach, we find that roughly two-thirds of the banks in the sample stood to gain or lose over 25% of equity capital in the event of a 320 bps move in interest rates. Using the second approach, we find that the stock prices of roughly one-third of the banks in the sample had significant sensitivities.

*We are grateful to CMIE and NSE for access to the data used in this paper. The views in this paper are those of the authors and not their respective employers. We benefited from discussions with Y. V. Reddy, Jammi Rao and Meghana Baji (ICICI), Rajendra P. Chitale, and Arvind Sethi.

Contents

Executive summary

From September 2000 to December 2002, the ten-year interest rate on government bonds fell by 500 basis points, from 11 percent to 6 percent. Many banks profited handsomely from this drop in interest rates. Since interest rates cannot continue to drop indefinitely, there is much interest in the question: What would happen to the balance sheets of banks if interest rates go up? Is the banking system adequately prepared for a scenario with higher interest rates?

The traditional focus in banking supervision in India has been on credit risk. In the Indian experience, bank fragility and bank failure has (in the past) been primarily caused by bad loans. The Basle Accord offers thumb rules through which equity capital requirements are specified, based on the *credit risk* adopted by banks. This has led to a focus, in banking policy, upon NPAs, rules for asset classification and provisioning.

In addition, changes in interest rates can also have major consequences for banks. When interest rates go up, every portfolio of bonds or loans suffers losses. A bond that has a duration of 10 years suffers a loss of roughly 10% when the long rate (which we consider to be the 10 year rate) goes up by 100 basis points. Banks as a whole have assets of roughly Rs.10 trillion. Even if the duration of the aggregate asset portfolio of banks was 3 years, a 100 bps rise in interest rates would give an enormous loss of Rs.30,000 crore.[1]

However, banks are able to lay off a substantial fraction of this interest rate risk to their liabilities. In the case of time deposits, banks directly have long dated liabilities. Current accounts and savings accounts can withdraw at a moments notice.[2] However, in practice it has been found that a significant fraction of current accounts and savings accounts tend to be stable, and can be treated as long dated liabilities. To the extent that demand deposits are stable, it enables banks to buy long dated assets, without bearing interest rate risk.

Interest rate risk measurement in banking can be done by simulating a scenario of higher interest rates, and putting together the losses on the assets side with gains on the liabilities. This approach focuses upon the NPV of assets and the NPV of liabilities, and the impact upon these of a shock to interest rates. To the extent that the change in NPV of assets and liabilities offset each other, the bank is hedged. If the change in NPV of assets and liabilities differs, this difference has to be absorbed by equity capital.

In this paper, we approach the measurement of the interest rate risk exposure of banks through two methods. The first method is based on accounting data that is released at an annual frequency by banks. We go through two steps. We make estimates of cashflows at all maturities for both assets and liabilities. We go on to compute the NPV impact of a rise in interest rates.

[1] A crore is 10 million.

[2] In India, current accounts are interest-free demand deposits. Savings accounts are checking accounts, which firms are prohibited from holding. The interest rate on savings accounts is set by the central bank, and is currently 3.5 percent.

Under existing regulations, banks are not required to disclose cashflows at all maturities for assets and liabilities. We resort to a detailed process of imputation of these cashflows using public domain information. The key difficulty in this imputation concerns the behavioural assumptions that are required about the stability of demand deposits. In an appendix, we engage in sensitivity analysis focusing on this issue. We create a 'baseline' set of plausible assumptions, and perturb it to create two additional 'optimistic' and 'pessimistic' sets of assumptions. We also make calculations for an 'RBI' set of assumptions, which uses existing RBI guidelines governing the treatment of demand deposits.

Once vectors of cashflows for both assets and liabilities are known, what is the scenario of higher interest rates that should be simulated? A proposal from the BIS offers a way in which we can look at past data on interest rate movements, and identify scenarios that should be evaluated. With Indian data, this works out to a 320 bps increase in the long rate over a one year horizon. Hence, we focus on analysing the impact of a scenario where the long rate rose by 320 bps.

We apply these methods to a sample of 42 major banks in India on 31 March 2002. We find that the two largest banks, SBI and ICICI Bank, carried relatively little interest rate risk. However, only 9 of the 42 banks were hedged, in the sense of standing to gain or lose less than 20% of equity capital in the event of a 320 bps shock. There were seven banks in the sample which have 'reverse' exposures, in the sense that they stood to *gain* between 21% and 59% of equity capital in this event. There were 25 banks which stood to lose between 25% and 105% of their equity capital. In the event, interest rates went down between 31/3/2002 and 31/12/2002, so these 25 banks profited from their exposure mismatch.

An alternative mechanism for judging the interest rate risk of banks consists of measuring the interest rate sensitivity of the stock price. Speculators on the stock market have good incentives to monitor banks, assess exposures, and move stock prices in response to fluctuations in interest rates. At the same time, there are concerns about stock market liquidity, and the extent to which stock market speculators are given adequate sound information in terms of disclosures.

We find that in a sample of 29 listed banks, roughly one-third seemed to have statistically significant coefficients in an 'augmented market model', which measures the elasticity of the stock price to movements in the long rate, after controlling for fluctuations of the stock market index. In the case of banks with highly liquid shares, such as SBI, ICICI Bank and HDFC Bank, the results obtained from this approach appear to broadly agree with those obtained using accounting data.

In summary, our results suggest that many important banks in the Indian banking system carried significant interest rate risk, as of 31 March 2002, in the sense of having an exposure of over 25% of their equity capital in the event of a 320 bps shock to the yield curve. We find that there was strong heterogeneity across banks in their interest rate risk exposure. We find that the stock market did seem to exhibit significant interest rate sensitivity in valuing bank stocks.

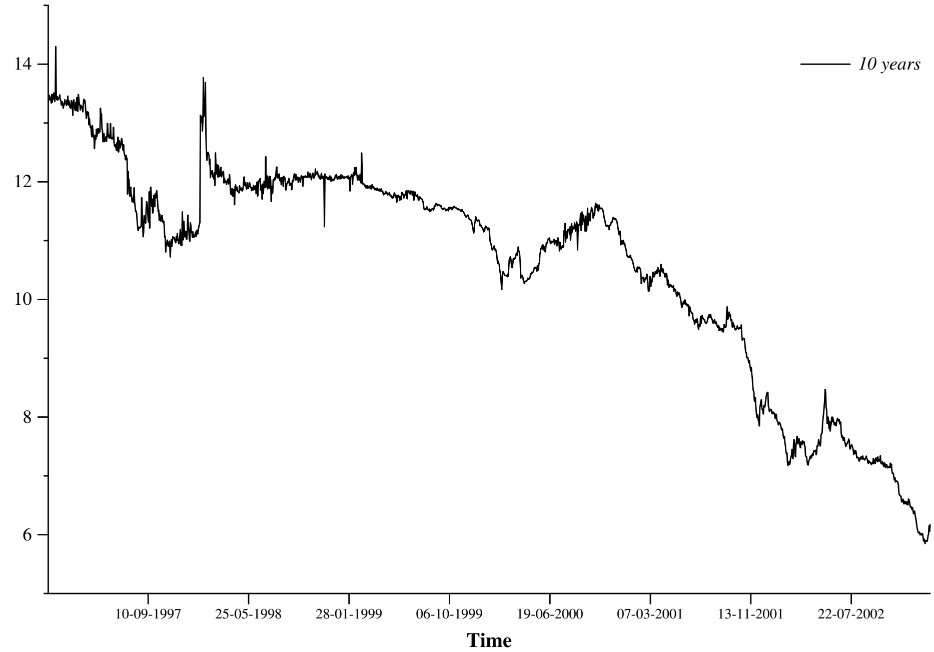
In India, interest rates were decontrolled as recently as 1993. Bank employees, boards of directors, and supervisors hence have relatively little experience with measuring and monitoring interest rate risk. Our results suggest that in addition to credit risk, interest rate risk is also economically significant.

These results emphasise that a casual perusal of 'gap' statements is an unsatisfactory approach to measuring interest rate risk. There is a need for banks and their supervisors to reduce the gap statement into a single scalar: the rupee impact of a given shock to the yield curve.

RBI has asked banks to create an 'investment fluctuation reserve' (IFR), expressed as a fraction of the investment portfolio held by each bank. This approach is unsatisfactory in only focusing on a subset of the assets of banks. Requirements for equity capital should reflect the vulnerability that banks face, taking into account the interest rate exposure of all assets and liabilities. Our results also suggest that banks have a strong heterogeneity in their interest rate risk, so that rules which require equity capital covering a fixed proportion of the investment portfolio would penalise banks that are hedged, and fail to cover the full risk of some banks which are not.

The remainder of this paper is organised as follows. Section 1 describes the backdrop of interest rate risk in Indian banking. Section 2 describes the two methodologies that are used in this paper, and the data resources employed. Section 3 shows results from both the methodologies. Section 4 highlights some major policy implications of this work. Finally, Section 5 concludes.

Figure 1 The 10-year spot rate



1 Introduction

The major focus of prudential regulation, and of concerns about systemic fragility in banking, has traditionally been upon credit risk. Most countries of the world have experienced significant bank failures owing to non-performing loans of banks.

Looking beyond credit risk, interest-rate risk is also an important source of vulnerability for banks. The assets and liabilities of a bank are affected by changes in interest rates. In general, the impact of a given interest rate change on the assets and liabilities need not be equal. This would generate an impact upon equity capital, which has to absorb profits or losses (if any).

In India, from 1993 onwards, administrative restrictions upon interest rates have been steadily eased. This has given a unprecedented regime of enhanced interest rate volatility, depicted in Figure 1. Hence, banks and supervisors in India now have a new need for measuring and controlling interest rate risk in banks. In particular, interest rates have fallen sharply in the last four years. If interest rates go up in the future, it would hurt banks who have funded long-maturity assets using short-maturity liabilities.

By international standards, banks in India have a relatively large fraction of assets held in government bonds. Government bond holdings of banks in India stood at 27.2 per cent of assets as of 31 March 2001. In contrast, government bonds comprised only 4.6 per cent of bank assets in the US and a mere 0.3 per cent of bank assets in UK. In the Euro area the ratio was a little higher at 6.9 percent.

The phenomenon of large government bond holdings by banks is partly driven by the large reserve requirements which prevail in India today. However, many banks, who have been facing difficulties in creating sound processes for handling credit portfolios, have been voluntarily holding government securities in excess of reserve requirements. This has consequences for the interest risk of banks, since the bulk of corporate credit tends to be in the form of floating-rate loans (which are hence effectively of a low duration), while the bulk of government bonds are fixed-rate products (which can have a higher duration than the typical credit portfolio).

For the commercial banking system as a whole in India, short-term time deposits and demand deposits constitute about 50 per cent of total deposits. Consider a typical bank, which has government bonds making up 30 percent of assets. In this case, an increase in interest rates would often erode its net worth. If interest rates went up, the value of the deposits would not change, but the investment portfolio would depreciate.

The interest-rate risk associated with large government bond holdings was exacerbated by a conscious decision on the part of RBI in 1998, to stretch out the yield curve and increase the duration of the stock of government debt. This is consistent with the goals of public debt management, where the issuance of long-dated debt reduces rollover risk for the government. The weighted average maturity of primary issuance of bonds went up from 5.5 years in 1996-97 to 14.3 years in 2001-02.[3]

In countries with small reserve requirements, policies concerning public debt management can be crafted without concerns about the banking system. In India, large reserve requirements imply that a policy of stretching out the yield curve may innately involve forcing banks to increase the maturity of their assets.

Internationally, banks have smaller government bond holdings, and they also routinely use interest rate derivatives to hedge away interest rate risk. In India, while RBI guidelines advise banks to use Forward Rate Agreements and Interest Rate Swaps to hedge interest rate risks, these markets are quite small. Exchange-traded futures and options on interest rates have yet to come about. Hence, this avenue for risk containment is essentially unavailable to banks.

These arguments suggest that interest rate risk is an important issue for banks and their supervisors in India. There is a need for sound measurement of exposure, and for an evaluation of associated policy issues.

RBI has initiated two approaches towards better measurement and management of interest rate risk. There is now a mandatory requirement that assets and liabilities should be classified by time-to-repricing, to create the 'interest rate risk statement'. This statement is required to be reported to the board of directors of the bank, and to RBI (but not to the public). In addition, RBI has created a requirement that banks have to build up an 'investment fluctuation reserve' (IFR), using profits from the sale of government securities,

[3] *Source:* Box XI.I page 177, Annual Report 2001-02, Reserve Bank of India.

in order to better cope with potential losses in the future.

Going beyond these initiatives, in measuring the vulnerability of banks, it is important to quantify potential losses in rupee terms. Since equity capital has to absorb losses owing to interest rate risk (if any), the most important focus of measurement should be the fraction of equity capital that is consumed in coping with shocks in interest rates.

In this paper, we seek to measure the interest rate risk exposure of banks, using publicly disclosed information. If future cashflows can be accurately estimated, then the impact upon the NPV of assets and liabilities of certain interest rate shocks can be measured.

In addition, we can also harness the information processing by speculators on the stock market, who seek to arrive at estimates of the value of equity capital of banks. When interest rates fluctuate, banks who have significant interest rate risk exposure should experience sympathetic fluctuations in their stock price. If information disclosure is adequate, and if banks stocks have adequate liquidity, then the speculative process should impound information about interest rate risk into the observed stock prices. This could give us an alternative mechanism for measuring the interest rate risk exposure of a bank.

The questions explored in this paper are pertinent to banks and their supervisors. From the viewpoint of a bank, measurement of interest rate risk exposure is an important component of the risk management process. From the viewpoint of bank supervision, there are numerous questions about the interest rate exposure of banks that require elucidation. Are banks homogeneous in their interest rate risk, or are some entities more exposed than others? Can the most vulnerable banks be identified through quantitative models? Can better mechanisms for the measurement of interest rate risk impact upon the mechanisms of governance and regulation of banks?

1.1 Goals of this paper

The questions that this paper seeks to address are :

- What are the interest-rate scenarios which should be the focus of banks and their supervisors, in assessing interest-rate risk?
- What is the impact upon equity capital of parallel shifts to the yield curve of this magnitude, for important banks?
- Are banks in India homogeneous in their interest-rate risk exposure, or is there strong cross-sectional heterogeneity?
- Do speculators on the stock market impound information about the interest-rate exposure of a bank in forming stock prices?
- Can we corroborate measures of interest-rate risk inferred from the stock market, with measures obtained from accounting data?

- What are useful diagnostic procedures through which banks and their supervisors can measure interest-rate exposure?

2 Methodology

In this section, we describe the two methodologies for risk measurement employed in this paper.

2.1 Measurement of interest-rate risk via accounting disclosure

One traditional approach to measurement of the interest-rate risk of a bank is to focus on the *flow* of earnings. This would involve measuring the impact upon the net interest income of a unit change in interest rates. This is sometimes called "the earnings perspective".

However, changes in these flows tell an incomplete story, insofar as changes in interest rates could have a sharp impact upon the stock of assets and liabilities of the bank, on a mark-to-market basis. This motivates "the NPV perspective", which seeks to measure the impact of interest-rate fluctuations upon the net present value of assets, and liabilities, and ultimately equity capital.

A thorough implementation of this approach would require a comprehensive enumeration of all assets, liabilities and off-balance-sheet obligations. Each of these would need to be expressed as a stream of future cashflows. Once this is done, an NPV can be computed under the existing yield curve. In addition, scenarios of interest-rate shocks can be applied to the yield curve, and their impact upon equity capital measured.

In the measurement of interest-rate risk via accounting data, our first step is to utilise public-domain disclosures in arriving at estimates of future *cashflows* of the bank on both assets and liabilities. The full methodology through which this imputation is done is shown in Appendix A.

Through this, we emerge with estimates of cashflows $((a_1, t_1), (a_2, t_2), \ldots, (a_N, t_N))$ for the assets, where cashflow a_i is received on date t_i. Similarly, future cashflows on the liabilities side are estimated as $((l_1, t_1), (l_2, t_2), \ldots, (l_N, t_N))$. This paper is based on data for 2001-02. Hence, we have projections of future cashflows as of 31 March 2002.

We use estimates of the zero coupon yield curve as of 31 March 2002.[4] Let $z(t)$ be the interest rate as of 31/3/2002, for a cashflow t years in the future. This leads us to NPVs of assets and liabilities :

[4] Some efforts in interest-rate risk measurement use the concept of YTM and apply shocks to YTM. This has many logical inconsistencies, such as the application of a constant interest rate for discounting all cashflows. We seek to estimate the NPV of cashflows that have a maturity structure, with interest rates that have a genuine variation by maturity. This requires usage of the 'zero coupon yield curve'.

$$
\begin{aligned}
A(0) &= \sum_{i=1}^{N} \frac{a_i}{(1+z(t_i))^{t_i}} \\
L(0) &= \sum_{i=1}^{N} \frac{l_i}{(1+z(t_i))^{t_i}}
\end{aligned}
$$

We then compute these NPVs under certain interest-rate scenarios.[5] Appendix B applies the methodology recommended by the BIS, through which we find that a shock of 320 basis points merits examination. Hence, in this paper, we work with two cases, a 200 bps shock and a 320 bps shock. For a parallel shift of Δ, we arrive at modified NPVs:

$$
\begin{aligned}
A(\Delta) &= \sum_{i=1}^{N} \frac{a_i}{(1+\Delta+z(t_i))^{t_i}} \\
L(\Delta) &= \sum_{i=1}^{N} \frac{l_i}{(1+\Delta+z(t_i))^{t_i}}
\end{aligned}
$$

Here the expression $A(\Delta)$ denotes the NPV of assets under a parallel shift Δ. The expression $A(0)$ denotes the unshocked NPV of assets. The impact of the interest rate shock Δ upon the asset side is $A(\Delta) - A(0)$. However, some of this risk is passed on by the bank to depositors. The residual impact on equity capital of the shock Δ is hence $(A(\Delta) - A(0)) - (L(\Delta) - L(0))$

In this paper, we only deal with the simplest interest rate shock, that of a parallel shift of the yield curve. In practice, the exposure of banks can be larger or smaller under other modes of fluctuation of the yield curve. For example, if the yield curve twists anticlockwise, with a higher rise in the long rate and a smaller rise (or even a drop) in the short rate, then the exposure of banks which have long assets and short liabilities would be even greater than those estimated under a parallel shift. Conversely, clockwise twisting of the yield curve would involve smaller losses to a bank with long assets and short liabilities.

One major difficulty faced in this process is that of accurately estimating future cashflows using public-domain information. As Appendix A suggest, there are many elements in this imputation which are unambiguous. There are primarily two areas where there are subtle issues in imputation – the treatment of savings and current accounts, and the extent to which assets have floating rates.

[5] The GOI yield curve is used in discounting all cashflows of assets and liabilities. This is, strictly speaking, incorrect, since the interest rates used in the real world for many elements are not equal to those faced by the GOI. However, our focus is upon the *change* in NPV when there is a *shocks* to the yield curve. We do not seek to accurately measure A and L and the *level* of NPV of the bank. The impact of this imprecision is hence of second-order importance.

2.1.1 Extent to which savings and current deposits are long-dated

The most important issue affecting the imputation of future cashflows lies in assumptions about the extent to which savings and current accounts can be viewed as long-term liabilities.

Technically, savings and current deposits are callable, and can flee at short notice. This suggests that they should be treated as short-dated liabilities. In practice, banks all over the world have observed that these deposits tend to have longer effective maturities or repricing periods (Houpt & Embersit 1991). To the extent that these liabilities prove to be long-dated, banks would be able to buy long-dated assets, and earn the long-short spread, without incurring interest rate exposure.

The baseline assumptions we use in this paper, which are loosely grounded in empirical experience in India, are as follows. We assume that 15% of savings accounts are volatile, and the remainder have a maturity of 1-3 years. We assume that 25% of current accounts are volatile, and the remainder have a maturity of 1-3 years. These baseline assumptions are more optimistic tha RBI's guidelines for the interest rate risk statement. These assert that 75% of savings deposits are "stable", and that these have an effective maturity of 3-6 months. This appears to be an unusually short time horizon, given (a) the strong stability of savings accounts and (b) the long time till modification of the savings bank interest rate in India. RBI's requirements suggest that 100% of current accounts should be considered volatile. This appears to be an unusually strong requirement, when compared with the empirical experience of banks in India.

The extent to which savings and current deposits would move when interest rates changed is a behavioural assumption, and alternative assumptions could have a significant impact upon our estimates of interest-rate risk.[6] Hence, in Appendix D, we engage in sensitivity analysis where these behavioural assumptions are altered, using the largest bank (SBI) as an illustration.

2.1.2 Extent to which assets are floating-rate

In the case of investments, which are made up of government bonds and corporate bonds, we make the assumption that all assets are fixed-rate. Floating rate assets appear to predominate with demand loans, term loans and bills.

We make the following assumptions:

- All demand loans and term loans are PLR-linked,

[6] One facet of this problem is linked to money market mutual funds (MMMFs), a product which competes with demand deposits. In countries where MMMFs are well established, a significant fraction of demand deposits move to them. India has yet to create a significant MMMF industry. Hence, looking forward, the shock to demand deposits owing to the growth of MMMFs lies in store.

- 90% of bills are PLR-linked.

These assumptions are highlighted here since they are important in understanding and interpreting the results. However, there appears to be a consensus that these are sound assumptions. Hence, we do not undertake sensitivity analysis which involves varying these assumptions.

2.1.3 The usefulness of simple models

The approach taken here is sometimes criticised on the grounds that it constitutes a highly oversimplified model of the true interest rate risk of a bank. At a conceptual level, there are four major issues which could impact upon this measurement:

- Imputation of future cashflows,
- Optionality embedded in assets and liabilities,
- Basis risk,
- Interest-rate derivatives.

Our approach is focused on the first; we impute future cashflows using public domain data, with some treatment of the optionality embedded in savings and current deposits. In this paper, we do not deal with other difficulties associated with optionality, or with basis risk and interest-rate derivatives.

There are four arguments in favour of our simple approach:

Interest rate derivatives India is a relatively unique country, by world standards, in the negligible extent to which interest-rate derivatives are used by banks to transform the balance sheet. Hence, measurement of interest-rate risk of banks while paying no attention to the off-balance sheet positions of banks on interest-rate derivatives markets is uniquely pertinent in India.

Optionality Banks in India do carry significant risk, in addition to that modelled by us, owing to prepayment options which are believed to exist for a significant fraction of the assets.

In particular, this is a particularly important issue in the treatment of home loans. However, as of 31 March 2002, home loans were a relatively small fraction of bank assets.[7]

Basis risk In this paper, we assume that all the interest rates, on both assets and liabilities, move synchronously with parallel shifts in the GOI yield curve. In practice, most rates do exhibit idiosyncratic variation. This implies that banks carry basis risk, over and above that measured in this paper.

[7] However, home loans are experiencing extremely high growth rates in India. In the future, a more thorough treatment of optionality will become more important in the measurement of interest rate risk of banks in India.

In particular, banks carry significant basis risk in terms of the lack of adjustment of the savings bank rate to fluctuations in the yield curve, which is inconsistent with the baseline assumptions, that 85% of savings deposits have a maturity of 1-3 years.

Using detailed information from banks Such an effort could, in principle, be done using much more detailed information about bank assets and liabilities. Banks do have access to much more information when compared with the highly limited information set which is placed in the public domain.

Wright & Houpt (1996) describe a comparison of a simple model, similar to that presented here, against a much more extensive modelling effort at the United States *Office of Thrift Supervision*, where 500 distinct numbers from within each bank were utilised to create a more complex model. This comparison reveals that the simple model yields values which are fairly close to those obtained using the more complex effort. This helps encourage us on the usefulness of simple models.

Our work here is also important insofar as it reflects the information processing that can be done by shareholders and depositors of a bank, using public domain information. If non-public information were utilised here, the results would not reflect the expectations of rational external economic agents who make decisions involving a bank.

Our conservative treatment of optionality and basis risk suggests that the estimates of interest-rate risk shown here contain a downward bias. In reality, banks in India are likely to have a true vulnerability to interest-rate fluctuations which is *larger* than these estimates.

2.1.4 Relationship with 'value at risk'

Value at Risk (VaR) is an attractive framework for risk measurement (Jorion 2000). If the VaR with respect to interest rate risk of a bank were desired, at a 99% level of significance on a one year horizon, we would need to go through the following steps:

1. Model the data generating process for the zero coupon yield curve,
2. Simulate N draws from the yield curve on a date one year away,
3. Reprice assets and liabilities at each of these draws,
4. Compute the 1^{th} percentile of the distribution of profit/loss seen in these N realisations.

This procedure is difficult to implement, primarily because the existing state of knowledge, on the data generating process for the yield curve, is weak. This motivates three simplifications:

- We focus on parallel shifts of the yield curve as the prime source of risk. This is the assumption made in existing BIS proposals.

  This ignores risks that arise from other modes of fluctuation of the yield curve.

- The BIS proposal for interest rate risk measurement suggests that the distribution of one-year changes in the long rate should be utilised to read off the 1^{th} percentile point.

  This is a highly unsatisfactory approach, given the fact that a daily time-series of overlapping one-year changes in the long rate exhibits strong violations of independence.

- We compute the profit/loss consequences of this one interest rate shock.

  However, the profit/loss associated with a 1^{th} percentile event on the interest rate process is not the 1^{th} percentile of the distribution of profit/loss, given the nonlinearities of transformation in computing NPV.

For these reasons, the procedure adopted here, while widely used in industry and consistent with existing BIS proposals, may at best be interpreted as a poor approximation of VaR at a 99% level of significance on a one-year horizon. If VaR is the goal of interest rate risk measurement, the framework used in this paper clearly entails substantial model risk.

The BIS proposals advocate the use of an ad-hoc 200 bps shock, in the absence of the data-driven procedure which yields the magnitude of the shock of interest to the risk manager. While results for 200 bps are shown in this paper for sake of completeness, this is a purely ad-hoc number, with little value in interpretation. We focus on the results using the data-driven procedure when it comes to interpretation.

2.2 Measurement of interest-rate risk via stock market information

If fluctuations in interest rates have a material impact upon the assets and liabilities of a bank, then this should be reflected in stock prices. A bank which has a lot to lose when interest rates go up should be one where the stock price reacts sharply when interest rates go up (Robinson 1995, Drakos 2001).

The 'market model' is a standard framework for measuring the sensitivity of an individual stock to fluctuations in the market index. It consists of the time-series regression:

$$(r_j - r_f) = \alpha + \beta_1(r_M - r_f) + \epsilon$$

where r_j is the return on a stock, r_f is the returns on a short-dated government bond, and r_M is the return on the equity market index. This yields estimates for β_1, the elasticity of returns on the stock against returns on the index. It is conventional in the finance literature to express returns on both sides of the market model as returns on zero-investment portfolios (Fama 1976).[8] For example, $r_M - r_f$ is the return on a zero-investment portfolio which holds the market index, and is financed by borrowing at the short rate.

[8] When the market model has returns on zero-investment portfolios on both sides of the equation, as is the case here, the null hypothesis $H_0 : \alpha = 0$ is a useful specification test. This is one reason to favour

In this paper, we estimate an 'augmented market model', of the form:

$$(r_j - r_f) = \alpha + \beta_1(r_M - r_f) + \beta_2(r_L - r_f) + \epsilon$$

where r_L is the return on a long government bond. This differs from the conventional market model in having one additional explanatory variable, $(r_L - r_f)$. This regressor can be interpreted as the return on a portfolio where the long bond is purchased, using funds borrowed at the short rate. This is particularly appropriate for our goal of measuring the extent to which banks are engaged in this very investment strategy.

When this model is estimated using data over a given period, it gives us an estimate $\hat{\beta}_2$ of the *average* interest rate sensitivity over this period. In reality, the interest rate exposure of a bank can fluctuate from day to day. This regression approach does not capture these fluctuations. This is in contrast with our work with accounting data, which captures the interest rate risk *as of* one day, 31 March 2002.

The augmented market model can be estimated using daily or weekly data. In an ideal efficient market, information that impacts upon interest rates should get absorbed into the equity price on the very same day. In practice, the non-transparency of India's government bond market, and the illiquidity of many bank stocks, could generate slower responses. Hence, there is merit in estimating this model using both daily and weekly data.

Another aspect which needs to be addressed is the time-series structure of the explanatory variables. In an ideal efficient market, the r_M, r_L and r_f time-series should be free of serial correlations. In the real world, many market imperfections may exist, particularly in the case of the government bond market, which suffers from non-transparency, barriers to access, regulatory constraints on short selling, etc. In addition, the time-series of the market index can exhibit spurious autocorrelations owing to non-synchronous trading of index components (Lo & MacKinlay 1990). Hence, we may find significant serial correlations in all the three time-series, i.e. r_M, r_L and r_f.

Stock market returns at time t are likely to respond to the *innovations* in explanatory variables. This problem can be addressed by estimating ARMA models for the r_f and r_L series, extracting residuals, and using these residuals as explanatory variables in the augmented market model. Appendix C shows the models through which this is done.

2.3 Data description

As background, Table 1 shows summary statistics about the dataset. The banking system is highly concentrated in these banks, with Rs.10 trillion of deposits placed here, of a total

using $(r_M - r_f)$ as an explanatory variable on the augmented market model, instead of directly using interest rates.

Table 1 Major banks in India

(Rs. crore)

Rank	Bank	Deposits	Total Assets	Gross value added	Market Capitalisation
1	State Bank Of India	270560.14	348541.15	30148.63	15220.56
2	I C I C I Bank Ltd.	32085.10	104963.08	2125.24	9045.28
3	Punjab National Bank	64123.48	72980.14	6469.19	2091.91
4	Canara Bank	64030.01	72211.39	6778.85	2662.95
5	Bank Of Baroda	61804.47	70910.07	5924.49	2215.56
6	Bank Of India	59710.60	70059.08	5707.76	2003.18
7	Union Bank Of India	39793.86	44374.96	3911.88	1161.80
8	Indian Overseas Bank	31808.49	35441.13	3214.14	789.52
9	Oriental Bank Of Commerce	28488.40	32262.92	3043.84	1148.50
10	Syndicate Bank	28548.33	31756.18	2758.02	818.87
11	Uco Bank	26848.78	31381.39	2595.20	
12	Allahabad Bank	22665.94	24764.47	2222.94	533.92
13	H D F C Bank Ltd.	17653.81	23787.38	1736.12	6708.35
14	Corporation Bank	18924.27	23604.20	2035.15	2089.20
15	State Bank Of Hyderabad	17402.75	22120.80	1955.92	
16	Bank Of Maharashtra	19130.64	21470.45	2025.04	
17	Andhra Bank	18490.76	20937.24	2067.49	1176.75
18	Dena Bank	15354.68	18434.80	1541.24	292.65
19	State Bank Of Patiala	13947.10	17336.94	1490.11	
20	State Bank Of Travancore	13459.68	16493.37	1434.23	232.00
21	Vijaya Bank	14680.51	16144.48	1576.74	585.56
22	State Bank Of Bikaner & Jaipur	11661.00	15552.21	1447.49	265.50
23	Jammu & Kashmir Bank Ltd.	12911.11	14698.66	1456.33	608.43
24	U T I Bank Ltd.	12287.21	14403.76	1314.79	851.65
25	Punjab & Sind Bank	12482.62	13753.57	1229.37	
26	I N G Vysya Bank Ltd	8068.28	10777.29	1024.49	596.17
27	State Bank Of Mysore	8524.85	10353.67	1011.62	164.56
28	Indusind Bank Ltd.	8400.12	10242.84	685.62	264.80
29	Federal Bank Ltd.	8865.30	10163.80	1053.48	206.85
30	Karnataka Bank Ltd.	7001.48	7784.48	885.81	191.45
31	Global Trust Bank Ltd.	6443.08	7416.15	690.57	211.77
32	I D B I Bank Ltd.	5234.49	6663.62	525.34	389.35
33	South Indian Bank Ltd.	5919.70	6555.01	672.89	135.50
34	Karur Vysya Bank Ltd.	4180.05	5112.47	531.35	219.30
35	Bank Of Rajasthan Ltd.	3959.98	4820.00	494.79	170.03
36	Centurion Bank Ltd.	3534.99	4059.16	386.16	143.32
37	Bank Of Punjab Ltd.	3353.57	3882.87	376.39	159.07
38	Lakshmi Vilas Bank Ltd.	2476.92	2870.01	303.90	
39	City Union Bank Ltd.	1973.71	2230.19	221.40	84.60
40	Bharat Overseas Bank Ltd.	1823.26	2106.94	186.18	
41	Dhanalakshmi Bank Ltd.	1657.24	1888.60	196.66	60.59
42	Lord Krishna Bank Ltd.	1502.38	1724.88	179.39	
Sum of above banks		1011773	1277035	105636	53499
Sum over 153 banks		1222285	1555600	131534	54462
Fraction in our dataset (percent)		82.77	82.09	80.31	98.23

of Rs.12.2 trillion with the universe of 153 banks observed in the CMIE Prowess database. Our dataset of 42 banks covers around 80% of bank deposits, assets or value added.

2.3.1 Accounting information about banks

For the purpose of monitoring liquidity risk, RBI requires banks to disclose a statement on the maturity pattern of their assets and liabilities classified in different time buckets. This table is shown in the annual report of each bank. This disclosure commenced from the accounting year 1999-2000 onwards.

This "liquidity table" reports assets and liabilities of the bank classified according to when they are expected to mature. Liabilities consist of deposits and bank borrowing classified into different time buckets. While bank borrowings and time deposits are bucketed according to their time remaining to maturity, current and saving deposits that do not have specific maturity dates are classified according to RBI ALM guidelines. Assets consist of loans and advances and investments. Investments in corporate and government debt are combined into one category and bucketed according to their time to maturity. Similarly, loans are bucketed according to their maturity patterns.[9]

RBI requires banks to additionally submit an 'interest rate risk statement', where assets are classified by their time to *repricing*. However, this statement is not released to the public.

Apart from the liquidity statement, we utilise some other information from the balance sheet. Table 10 shows an example of the full set of information from public domain accounting disclosure about one bank (SBI) that is utilised by us.

In this paper, 'equity capital' is measured as the sum of paid up capital and reserves. Existing RBI rules do not require banks to do a full marking-to-market of all securities. As a consequence, many banks had unrealised gains on their GOI bond portfolios as of 31 March 2002. To the extent that this is the case, our estimate of their equity capital would be understated. Our estimates of the rupee impact of a given interest rate move would be

[9] There appear to be some discrepencies in the audited annual reports released by some banks. There were 4 banks in our sample where adding up deposits, across time buckets in the maturity statement, does not tally with deposits measured on the balance sheet.

(Rs. crore)

	Deposits	
Bank	From balance sheet	Summing in maturity stmt.
State Bank of Patiala	13947.10	13684.87
State Bank of Mysore	8524.85	8481.34
Uco Bank	26848.77	25224.00
Central Bank of India	47137.38	46380.82

accurate, but when expressed as a fraction of equity capital, we have an upward bias in estimates of the interest rate exposure.

2.3.2 The yield curve

We follow the specification search of Thomas & Pawaskar (2000) which suggests that the Nelson-Siegel model offers a good approximation of the spot yield curve in India (Thomas & Shah 2002). In the Nelson-Siegel model (Nelson & Siegel 1987), the yield curve is approximated by a functional form that involves four free parameters a_0, a_1, a_2, a_3:

$$z(t) = a_0 + a_1 \frac{(1 - \exp(-t/a_3))}{t/a_3} + a_2 \exp(-t/a_3)$$

We use the database of daily yield curves from 1/1/1997 till 31/7/2002 produced at NSE using this methodology (Darbha et al. 2002), which gives us parameters (a_0, a_1, a_2, a_3) for each day.

2.3.3 Data for the augmented market model

We use stock market returns data from the CMIE Prowess database. We use the Nifty Total Return index as the market index (Shah & Thomas 1998).

In the case of time-series on the short and long government bond, we derive these from the time-series of the zero coupon yield curve. We define the short rate as being for 30 days, and the long rate as being for 10 years. The bond returns series is computed as follows. Suppose the interest rate, for a zero coupon bond of maturity T, goes up from r_1 on day 1 to r_2 on day 2. Then the log returns on the bond, where the bond price goes from p_1 to p_2, can be computed as:

$$\log(p_2/p_1) = -T\left(\log(1 + r_2) - \log(1 + r_1)\right)$$

The numerical values obtained with $100 \log(p_2/p_1)$ are closer to percentage changes and are hence easier to interpet. Hence, we work with the time-series of $-100T$ times the first difference of $\log(1 + r)$.

Through this mechanism, we create time-series of notional bond returns on the 30-day and the 10-year zero coupon bond, priced off the NSE ZCYC. This gives us time-series for r_L and r_f.

Figure 2 Data span and annual report release

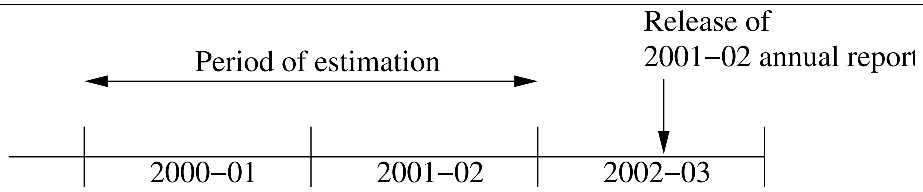
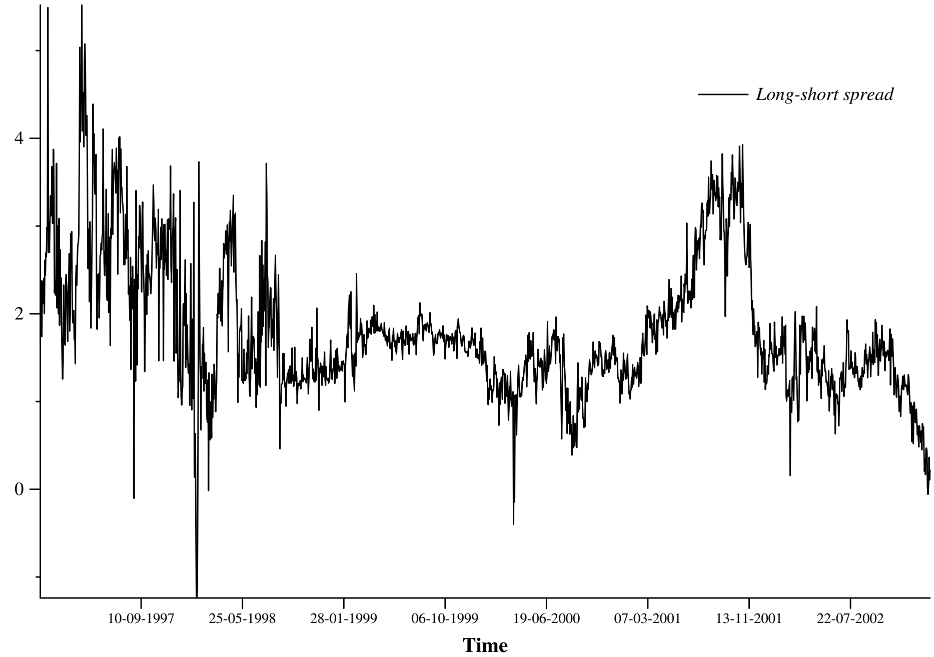


Figure 3 The spread between the long and short interest-rates



2.3.4 Period examined

Our work with accounting data pertains to the fiscal year 2001-02. This is a relatively short period for estimation of the augmented market model. Hence, for the market model estimation, we use a two–year period, from 1 April 2000 to 31 March 2002.[10]

There is an innate problem in the span of data used in the augmented market model (see Figure 2). We use stock market data from 1 April 2000 to 31 March 2002. However, the accounting information for 2001-02 (which is used in our accounting-based measurement of exposure) is only released much after 2001-02 has ended. Hence, this accounting information is not in the public domain in the time-period over which stock returns are observed.

In our exploration of the sensitivity of stock market returns to fluctuations in $(r_L - r_f)$, the statistical precision with which we measure the coefficient β_2 is related to the volatility

[10] If, in principle, our sole goal was to measure β_2, it would be desirable to have a longer span of data. However, that would conflict with our goal of linking up estimates of exposure from the two methodologies.

Table 2 Banks with 'reverse' exposures

This table shows the seven banks in our sample who prove to have a significant 'reverse' exposure, in the sense that they stand to earn profits in the event that interest rates go up. The exposures here range from Global Trust Bank, which would gain 58.9% of equity capital in the event of a +320 bps shock, to Uco Bank, which would gain 21.1%.

(Percent)

		$\Delta E/E$		$\Delta E/A$	
Sr.No.	Bank	200 bps	320 bps	200 bps	320 bps
1.	Global Trust Bank	39.0	58.9	1.3	1.9
2.	State Bank of Patiala	35.0	53.0	2.3	3.5
3.	Bank Of Maharashtra	33.3	52.1	1.1	1.7
4.	Canara Bank	22.2	34.4	1.1	1.7
5.	State Bank of Mysore	17.3	27.4	0.6	0.9
6.	Centurion Bank	17.2	27.0	0.7	1.1
7.	Uco Bank	13.8	21.1	1.2	1.9

in $(r_L - r_f)$ which was experienced over this period. Figure 3 shows a time-series of the spread between the short interest-rate (30 days) and the long interest-rate (10 years). We see that from the viewpoint of statistical efficiency, the period of interest was fortunately one where this spread was highly variable.

3 Results

As an example, Appendix E shows detailed results of applying the two methods to the largest bank of the system, SBI. In this appendix, we also show sensitivity analysis, across four sets of assumptions for the extent to which savings and current accounts are long dated.

3.1 Results with accounting data

We show results of simulating shocks to the yield curve for our sample of 42 banks, as of 31 March 2002. For each bank, we show $\Delta E/E$, the impact expressed as percent of equity capital, and $\Delta E/A$, the impact expressed as percent of assets.

We focus on the percentage impact upon equity capital for a 320 bps shock, as the metric of interest rate risk. This proves to range from +58.9% for Global Trust Bank to -104.7% for Indian Overseas Bank.

Table 2 shows the seven banks who seem to have significant 'reverse' exposures; i.e. they would stand to earn significant profits if interest rates went up (and conversely). While

Table 3 Banks which appear to be hedged

This table shows the nine banks in our sample who seem to be fairly hedged w.r.t. interest rate risk. The exposures here range from PNB, which would gain 6.3% of equity capital in the event of a +320 bps shock, to ICICI Bank, which would lose 15.4%.

(Percent)

		$\Delta E/E$		$\Delta E/A$	
Sr.No.	Bank	200 bps	320 bps	200 bps	320 bps
8.	Punjab National Bank	3.5	6.3	0.1	0.3
9.	Karur Vysya Bank	2.1	3.3	0.2	0.3
10.	HDFC Bank	0.1	0.5	0.0	0.0
11.	Allahabad Bank	-0.7	0.0	-0.0	0.0
12.	UTI Bank	-0.5	-0.5	-0.0	-0.0
13.	Syndicate Bank	-0.8	-1.1	-0.3	-0.5
14.	Bank Of Rajasthan	-7.1	-10.2	-0.3	-0.5
15.	State Bank of India	-8.5	-11.2	-0.4	-0.5
16.	ICICI Bank	-10.3	-15.4	-0.7	-1.0

this appears profitable in the event of a rise in interest rates, it would generate losses in the event of a rise in interest rates, as has been the case between 31/3/2002 and 31/12/2002.

Table 3 shows the nine banks who appear to be hedged, in the sense of having an exposure in the event of a +320 bps shock which is smaller than 25% of equity capital.

Table 4 shows the 26 banks in the sample who seem to have significant interest rate exposure. These banks could lose 25% or more of their equity capital in the event of a +320 bps shock. Of these, there are 15 banks which stand to lose more than 50% of equity capital.

In summary, of the 42 banks in this sample, nine lack significant interest rate exposure, while 34 have significant exposure. Figure 4 gives a graphical presentation of the size of banks and their total exposure.

3.2 Results based on stock market data

We obtain estimates using both daily and weekly data for the augmented market model. In both cases, we work via the raw returns, and additionally using ARMA residuals. This gives us four sets of estimates for each bank.[11]

Table 5 shows the coefficient β_2 and the t statistic for this coefficient for the four cases. The table is sorted by the coefficient value with weekly data using the raw $(r_L - r_f)$ as an explanatory variable.

[11] In all cases, we find that the specification test, using the null hypothesis $H_0 : \alpha = 0$ is not rejected.

Table 4 Banks with significant exposure

This table shows the 26 banks in our sample who seem to have significant interest rate exposure. The exposures here range from Laxshmi Vilas Bank, which would lose 24.6% of equity capital in the event of a +320 bps shock, to Indian Overseas Bank, which would lose 104.7%.

(Percent)

		$\Delta E/E$		$\Delta E/A$	
Sr.No.	Bank	200 bps	320 bps	200 bps	320 bps
17.	Laxshmi Vilas Bank	-16.8	-24.6	-1.0	-1.4
18.	Union Bank of India	-18.1	-26.1	-0.9	-1.2
19.	Bharat Overseas Bank	-19.9	-29.4	-1.2	-1.7
20.	Corporation Bank	-20.2	-30.1	-1.8	-2.6
21.	Punjab and Sind Bank	-22.9	-33.6	-0.7	-1.1
22.	Lord Krishna Ltd.	-23.6	-34.8	-1.5	-2.2
23.	Vyasa Bank	-23.9	-35.4	-1.5	-2.2
24.	Jammu and Kashmir Bank Ltd.	-25.4	-37.7	-1.6	-2.4
25.	Bank of India	-26.8	-39.8	-1.1	-1.6
26.	Bank of Baroda	-27.8	-41.5	-1.5	-2.2
27.	Indusind Bank	-28.2	-42.8	-1.6	-2.4
28.	South Indian Bank Ltd.	-34.0	-49.8	-1.4	-2.1
29.	S. B. of Bikaner and Jaipur	-35.3	-52.6	-1.7	-2.5
30.	Andhra Bank	-35.6	-52.7	-1.5	-2.2
31.	IDBI Bank	-35.3	-53.8	-1.6	-2.4
32.	Dhanalakshmi Bank	-37.9	-56.0	-1.7	-2.5
33.	City Union Bank	-37.5	-56.3	-2.4	-3.6
34.	Oriental Bank of Commerce	-38.6	-57.1	-1.9	-2.9
35.	Federal Bank	-41.6	-61.9	-1.8	-2.7
36.	Bank of Punjab	-44.5	-66.6	-2.2	-3.3
37.	State Bank of Travancore	-50.3	-74.7	-1.9	-2.8
38.	State Bank of Hyderabad	-49.9	-74.9	-2.2	-3.4
39.	Karnataka Bank	-51.7	-77.1	-2.9	-4.4
40.	Vijaya Bank	-53.5	-80.1	-2.2	-3.3
41.	Dena Bank	-64.6	-95.9	-2.0	-3.0
42.	Indian Overseas Bank	-70.3	-104.7	-2.2	-3.4

Figure 4 Results based on accounting data

The figure summarises the exposure of all banks in the sample. The width of each bar is proportional to the assets of the bank. Large banks are labeled.

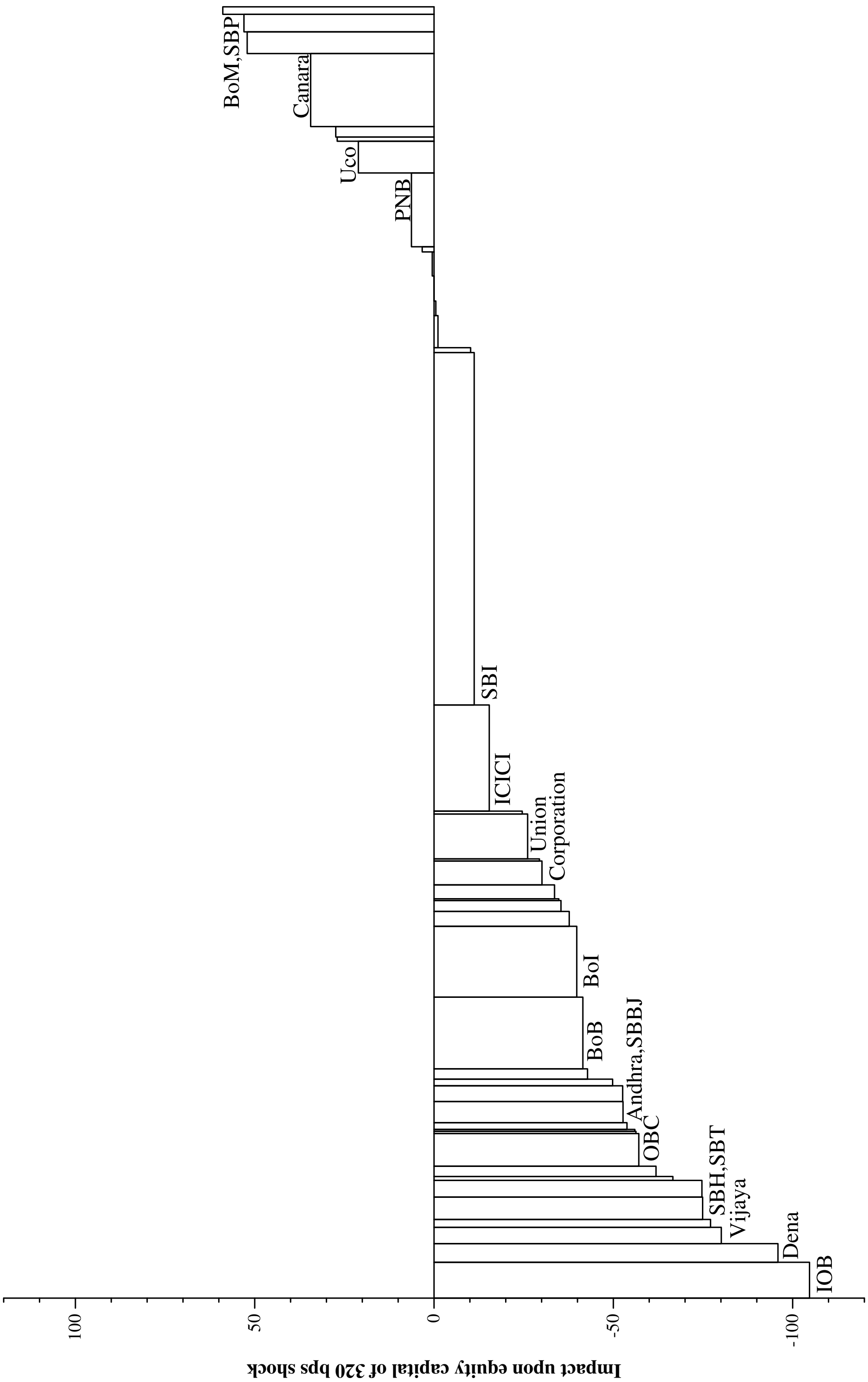


Table 5 Sensitivity of stock returns to interest-rate movements

This table reports the coefficient on the interest-rate factor in the augmented market model. Estimates based on both daily and weekly returns are displayed. In each case, we show the coefficient (and the t statistic) of $x_L = r_L - r_f$, and of the excess returns computed using innovations, $\mathrm{ix}_L = \mathrm{ir}_L - \mathrm{ir}_f$. Coefficients which are significant at a 95% level of significance are shown in boldface.
For example, in the case of Vijaya Bank, the coefficients with daily data prove to be -0.053 and 0.107 respectively, with t statistics of -0.17 and 0.36. With weekly data, we get much larger coefficients of 1.355 and 1.330, with t statistics of 2.78 and 2.75. This is consistent with the idea that Vijaya Bank is a relatively illiquid stock where interest-rate fluctuations may not appear in stock returns on the same day.
The table is sorted by the numerical value of the coefficient seen with x_L with weekly data. This first seven banks in the list are thus the most vulnerable, with interest-rate sensitivities which are in the top quartile amongst listed banks.

Bank	Daily				Weekly			
	x_L	t	ix_L	t	x_L	t	ix_L	t
VIJAYA BANK	-0.053	-0.17	0.107	0.36	**1.355**	2.78	**1.330**	2.75
U T I BANK LTD.	0.058	0.30	0.035	0.18	**1.026**	2.21	**0.853**	1.96
BANK OF BARODA	0.169	0.92	0.360	1.92	**1.015**	2.37	0.757	1.85
I D B I BANK LTD.	-0.028	-0.14	0.012	0.06	0.980	1.89	0.733	1.49
BANK OF INDIA	0.245	1.39	**0.356**	1.98	**0.939**	2.32	**0.825**	2.15
STATE BANK OF INDIA	**0.281**	2.02	**0.333**	2.34	**0.836**	2.32	0.587	1.66
DENA BANK	0.184	0.69	0.233	0.86	0.831	1.72	0.831	1.81
STATE BANK OF MYSORE	0.428	0.73	0.499	0.81	**0.805**	2.10	0.696	1.92
INDIAN OVERSEAS BANK	-0.350	-1.11	-0.318	-1.02	0.741	1.85	**0.780**	1.97
SOUTH INDIAN BANK LTD.	-0.199	-0.62	0.015	0.04	0.632	1.07	0.443	0.79
ORIENTAL BANK OF COMMERCE	0.124	0.99	0.165	1.29	**0.616**	3.12	**0.519**	2.69
GLOBAL TRUST BANK LTD.	0.246	0.82	0.254	0.83	0.595	0.85	0.090	0.13
CITY UNION BANK LTD.	0.385	1.16	0.655	1.94	0.503	1.30	0.471	1.29
I C I C I BANK LTD.	-0.123	-0.50	0.003	0.01	0.448	0.69	0.273	0.44
SYNDICATE BANK	0.111	0.84	0.105	0.78	0.385	1.26	0.352	1.21
CORPORATION BANK	0.126	0.63	0.238	1.16	0.278	0.61	0.161	0.37
CENTURION BANK LTD.	-0.060	-0.25	-0.144	-0.58	0.269	0.53	0.236	0.50
BANK OF RAJASTHAN LTD.	-0.063	-0.33	-0.046	-0.23	0.259	0.68	0.196	0.54
FEDERAL BANK LTD.	**0.688**	2.97	**0.644**	2.71	0.237	0.46	0.002	0.00
JAMMU and KASHMIR BANK LTD.	0.117	0.67	0.169	0.94	0.208	0.55	0.153	0.42
STATE BANK OF BIKANER and JAIPUR	**0.382**	2.24	**0.416**	2.38	0.184	0.69	0.252	0.99
DHANALAKSHMI BANK LTD.	0.476	1.89	0.502	1.95	0.153	0.30	-0.184	-0.38
ANDHRA BANK	0.082	0.40	0.139	0.69	0.113	0.34	0.021	0.06
INDUSIND BANK LTD.	-0.043	-0.21	0.013	0.06	0.060	0.14	0.042	0.11
UNITED WESTERN BANK LTD.	0.110	0.51	0.038	0.17	0.012	0.02	-0.074	-0.14
STATE BANK OF TRAVANCORE	0.339	0.93	0.310	0.83	-0.107	-0.27	-0.029	-0.07
BANK OF PUNJAB LTD.	-0.106	-0.67	-0.117	-0.72	-0.199	-0.65	-0.039	-0.13
H D F C BANK LTD.	-0.049	-0.33	-0.033	-0.22	-0.351	-1.00	-0.418	-1.27
VYSYA BANK LTD.	0.082	0.32	0.013	0.05	-0.402	-0.74	-0.513	-0.99

In the case of SBI, which is the most liquid bank stock in the country, we see strong t statistics of 2.02 and 2.34 with daily data. Apart from this, most of the banks show stronger coefficients with weekly data. This suggests that the stock market is not able to rapidly absorb information about interest rates in forming bank stock prices.

Roughly speaking, a 320 bps shock would give returns on the long bond of -32%. If we have a β_2 of 0.8, then this implies an impact on equity of -25.6%.

For roughly one third of the banks in our sample, the null $H_0 : \beta_2 = 0$ can be rejected at a 95% level of significance, for one or more variants of the augmented market model. The coefficients seen here are economically significant, suggesting significant interest-rate exposure on the part of these banks.

3.3 Comparing results obtained from the two approaches

There are some banks where both approaches show similar results. For example, Vijaya Bank, Dena Bank, OBC and IDBI Bank stand out as banks which have a large exposure by both approaches. However, there are numerous banks where the two approaches disagree significantly. Global Trust Bank and State Bank of Mysore seem to have significant 'reverse' exposures, however their β_2 coefficients are positive. UTI Bank is a case where the accounting data suggests that there is no exposure, however the stock market clearly disagrees.

There are 29 listed banks for which we have results from both approaches. We cannot reject the null hypothesis of a zero rank correlation between β_2 (from the stock market approach) and the percentage impact upon equity of a 320 bps shock (from the accounting data approach).

To some extent, this may be explained by innate difficulties in comparing these results. The accounting data tells us something about exposure as of 31 March 2002. The stock market data tells us about the *average* exposure over a two year period. Further, the accounting data for 2001-02 is typically released by September 2002. This suggests that the information that we attribute to 2001-02 only became available to speculators on the stock market much later. Finally, this lack of connection between results from the two approaches may suggest a need for improved rules about disclosure under listing agreements with stock exchanges.

One additional feature which has an important impact here is stock market liquidity. If we focus on the three banks with the most liquid equity, we see that:

SBI By the accounting approach, SBI stands to lose 8.5% of equity capital in the event of a 200 bps rise in the long rate. The market model at weekly frequency has a coefficient of 0.836, which would imply an drop in the share price of roughly 16.6% in the event of a 200 bps rise.

ICICI Bank By the accounting approach, ICICI Bank stands to lose 10.3% of equity capital in the event of a 200 bps rise. The market model implies that there is no significant exposure.

HDFC Bank Both approaches agree that there is no significant exposure.

This suggests for these liquid stocks, there is some agreement between the results from the two approaches. This may suggest that the market efficiency of the stock price process for many other banks is inhibited by inadequate stock market liquidity.

4 Policy implications

Our results suggest that in addition to credit risk, interest rate risk is also important in India's banking system. The potential impact of interest rate shocks, upon equity capital of many important banks in the system, seems to be economically significant. These problems are compounded by public ownership; banks such as Dena Bank and Vijaya Bank have substantial exposures and are likely to make claims upon the exchequer in the event of adverse interest rate movements.

Our results emphasise that the casual perusal of 'gap' statements is an unsatisfactory approach to measuring interest rate risk. There is a need for banks and their supervisors to reduce the gap statement into a single scalar: the rupee impact of a given shock to the yield curve.

This paper was based on complex imputation procedures which proceed from public domain disclosure of the 'liquidity statement' in the annual reports of banks, to an estimate of future cashflows of the bank. There is a case for improving rules governing disclosure, so that the 'interest rate risk statement' and estimates of future cashflows are also revealed by banks.

One striking feature of these results is the heterogeneity seen across banks. Banks holding similar portfolios of government securities seem to often have rather different exposures. This suggests that RBI's 'investment fluctuation reserve', which is computed as a fraction of holdings of the investment portfolio, without regard for the extent to which risk is hedged away, is an unsatisfactory approach to addressing interest rate risk.

Our results highlight the consequences of stretching out the yield curve for banking system fragility. While stretching out the yield curve is a sound strategy for public debt management, it can generate vulnerabilities in the banking system. If there is a perception that the banking system is vulnerable in the event of an increase in interest rates, it could have deleterious consequences by constraining the conduct of monetary policy at RBI.

Finally, the techniques used in this paper can be effective in throwing up names of banks in the top quartile by the vulnerability to interest-rate fluctuations. Our results suggest that banks such as Vijaya Bank appear to be much more vulnerable to interest rate risk than banks such as HDFC Bank. These techniques could be used by banking supervisors in identifying the most vulnerable banks and putting a special focus on their risks.

5 Conclusion

In this paper, we hope to have obtained persuasive answers to some important questions on the interest rate risk exposure of banks in India.

- *What are the interest-rate scenarios which should be the focus of banks and their supervisors, in assessing interest-rate risk?*

  We find that the BIS notion of a 99% percentile movement on a one–year holding period implies envisioning and analysing the consequences of a shock of 320 bps.

- *What is the impact upon equity capital of parallel shifts to the yield curve of this magnitude, for important banks in the Indian banking system?*

  We find that for 33 of the 42 banks in our sample, over 25% of equity capital would be gained or lost in the event of a 320 bps move in the yield curve.

- *Are banks in India homogeneous in their interest-rate risk exposure, or is there strong cross-sectional heterogeneity?*

  Both the accounting data and the stock market sensitivities suggest that there is strong heterogeneity across banks in India in their interest rate exposure.

- *Do speculators on the stock market impound information about the interest-rate exposure of a bank in forming stock prices? Can we corroborate measures of interest rate risk from the stock returns process with those obtained from accounting data*

  We find that for many banks, the stock market returns process does exhibit strong interest rate sensitivity; i.e. we can reject the null hypothesis that the stock market is unaware of interest rate risk when valuing bank stocks. At the same time, we find that there are only weak links between estimates of interest rate exposure obtained through the two methodologies.

- *What are useful diagnostic procedures through which banks and their supervisors can measure interest-rate exposure?*

  Our work suggests that banks and their supervisors may benefit from computing interest rate exposure through these two approaches. The board of directors of a bank could use such estimates as an outside check upon risk management procedures. Supervisors could use such tools to isolate the most vulnerable banks in the system, and better allocate scarce supervisory capacity.

A Estimating the maturity pattern of future cash-flows

Banks are required to disclose a statement on the maturity pattern of their assets and liabilities classified in different time buckets. We use this data, along with data on the composition of their assets and liabilities, to arrive at an assessment of future cash flows in different time buckets.

As a general principle, the accounting procedures of banks associate the face value on a stated asset or liability on the terminal (maturity) date T. We need to go beyond this, to enumerate the complete list of cashflows. Hence, for each class of assets reported by banks, we impute a certain 'coupon rate', using which cashflows are imputed for the time intervals between date 0 and date T.

The time bands used in the 'statement of structural liquidity' are 1-14 days, 15 to 28 days, 29 days to 3 months, 6 months to 1 year, 1 to 3 years, 3 to 5 years and greater than 5 years. We impute a statement of cash flows that corresponds to the time bands in the 'statement of interest rate sensitivity' as specified by RBI. This imputation proceeds in the following steps:

A.1 Assets

On the asset side, *Loans and Advances* can be broken up into two parts: (a) bills and (b) demand loans and term loans. We observe the maturity structure of loans and advances, however we do not separately observe the maturity structure of bills, demand loans and term loans. We assume that the maturity structure of each of these is identical to the maturity structure of Loans and Advances.

In the case of demand loans and term loans, we assume these are entirely floating rate loans, linked to the Prime Lending Rate. We assume that PLR revisions can take place in 3 months. Hence, demand loans and term loans upto 3 months are classified according to their maturity. The remainder are placed into the 3–6 month bucket. The cash flows generated from the interest earned at the PLR rate is distributed in the 0 to 1 month bucket and the 1 to 3 month bucket, while the 3 to 6 month bucket has both the interest earned and the principal.

In the case of bills, short-dated bills are directly classified. Beyond the 3–6 month bucket, we assume that 90% of the bills are floating rate products (which are classified into 3–6 months) while the remainder are placed in the relevant bucket.

For *Investments*, both government and corporate bonds are assumed to be fixed rate and are classified as per the liquidity statement.

For *Cash and balances with the* RBI, we consider cash to be non-sensitive. Balances with the RBI upto 3 percentage points of CRR is also assumed to be zero maturity as no interest is paid on them. The CRR balance in excess of 3 percentage points, which earns interest, is classified into the 3–6 month bucket.

A.2 Liabilities

The liquidity statement shows a single maturity pattern of deposits. We need to unbundle time deposits as opposed to savings deposits and current deposits from this statement.

RBI's Asset-Liability Management (ALM) Guidelines suggest that in the liquidity statement, current and savings deposits are divided into their core and volatile portions through the following mechanism. A "volatile portion" (15% of current accounts and 10% of savings accounts) may be classified in the liquidity table in the 1-14 days bucket. The remainder is be classified in the 1-3 year bucket of the liquidity statement.

RBI regulations suggest that banks are free to use alternative modeling frameworks in arriving at estimates of core versus volatile demand deposits. We estimate the maturity pattern of time deposits while assuming that all banks are using RBI guidelines. In this fashion, we subtract current and savings deposits from the maturity pattern of total deposits as shown in the liquidity statement.[12]

In the case of both current accounts and savings accounts, we have an imputation scheme where some fraction is placed into a near bucket and the remainder is placed into a far bucket. The fractions are varied in producing multiple sets of assumptions (see Table 8).

The maturity pattern of time deposits directly goes into imputed future cashflows on the liabilities side.

Equity capital and reserves are placed in the zero-maturity time bucket.

A.3 Assumptions used in this imputation

The assumptions which are made in this process, for the accounting year 2001-02, are summarised as follows:

- The interest-rate on savings bank deposits: 3.54%.
- The interest rate on time deposits: 7%.
- The interest rate on the liabilities side for borrowings by the bank: 6.58%.

[12]Let C represent current accounts and S represent savings accounts. RBI's ALM guidelines suggest that $0.15C + 0.1S$ is added to time deposits (if any) in the 1-14 days bucket, and $0.85C + 0.9S$ is added to time deposits (if any) in the 1-3 year bucket.

In our dataset, we find 6 banks where this imputation procedure yields a *negative* value for time deposits in the 1-3 year bucket. These are : Karur Vysya Bank, State Bank of Patiala, State Bank of Mysore, Allahabad Bank, Uco Bank and Bank of Rajasthan. In addition, for Central Bank of India we obtain a negative value for the time deposits in the 1-14 days bucket. This would suggest that these seven entities use other models for estimation of core versus volatile demand deposits.

Once the entire imputation process is complete (and all assets and liabilities have been mapped into cashflows), we find only one case (Central Bank of India) where a value in the cashflow vector is negative. Hence, Central Bank of India was dropped from our dataset.

- The interest rate earned on bills purchased by the bank: 10%.
- The PLR of the year: 11%.
- The level of CRR: 5.5%.
- The interest rate that RBI paid beyond three percent points on CRR: 6.5%.
- The average interest rate for imputing intermediate cashflows on all investments: 5.58%.
- The time bucket to place PLR-linked investments: 6 months to 1 year.
- The fraction of bills (in higher buckets) which are actually PLR linked: 90%.
- Duration of assets and liabilities classified as "greater than five years" : 10 years. The rationale for this is as follows. The bulk of bank assets with maturity over 5 years are government bonds. GOI bonds beyond 5 years stretch out to 20 years. Hence 10 years appears to be a plausible average point.

As a general principle, our focus is on the measurement of interest rate sensitivity. Hence, certain elements (on either assets or liabilities) which are insensitive to fluctuations in interest rates, do not feature in our vector of cashflows. This implies that the NPV of cashflows, which we call A or L, would not be correct. However, data elements which feature in the impact upon NPV of *changes* in interest rates are captured by us.

Table 6 The change in the 10-year rate over 288 days : summary statistics

Mean	-0.8828
Std. devn.	1.0411
1%	-3.2024
Median	-0.7164
99%	1.1233
Observations	1321

B What is the size of the interest-rate shock envisioned?

The Basel Committee on Banking Supervision (2001) suggests that the *central* issue in interest-rate risk is parallel shifts of the yield curve; it suggests that the economic significance of parallel shifts substantially exceeds the significance of localised movements in certain parts of the yield curve.

BIS suggests that a parallel shift of 200 basis points should be simulated in the absence of data analysis. Alternatively, it suggests that five years of daily data should be utilised in measuring the change in the long rate over 240-day holding periods, and the 1th percentile and the 99th percentile should be read off for the purpose of simulations.

B.1 Data in India for the long rate

We use the NSE yield curve dataset, and evaluate the interest rate at $t = 10$ every day, thus giving us a daily time-series of the ten-year rate.

The BIS suggests that the one-year move in the long rate should be approximated by changes in the long rate over 240 days. We find that there are (on average) 288 trading days per year in India. Hence, we focus on the change in the long rate over 288 trading days.

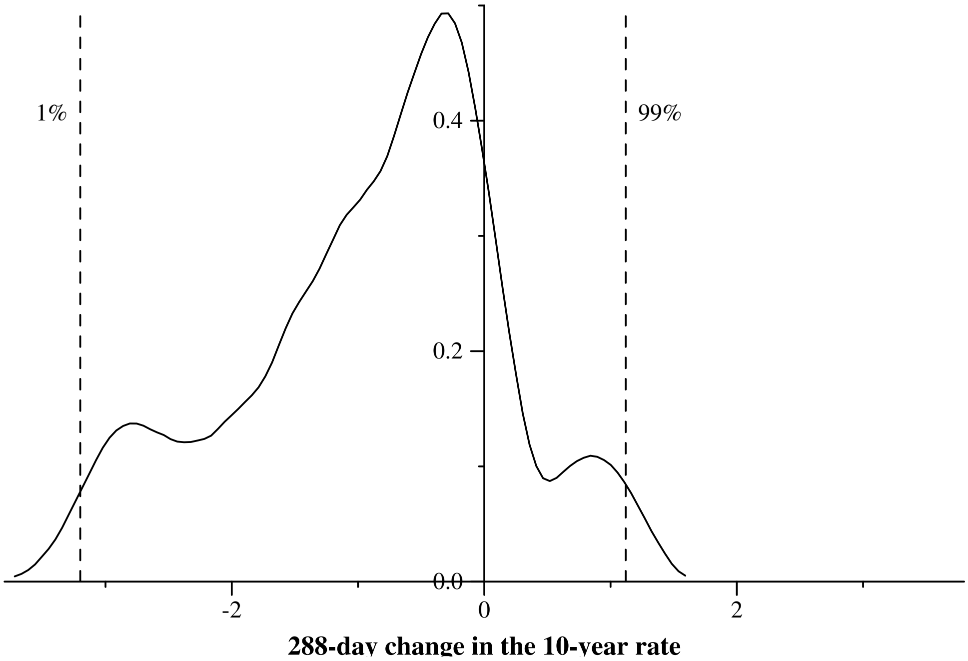
B.2 Empirical results

Table 6 shows summary statistics of the 288-day change in the 10-year rate. We see that over this period, i.e. from 1/1/1997 to 31/7/2002, the typical year has experienced a drop in the 10-year rate. Figure 5 shows a kernel density estimator of the 288-day change in the 10-year rate.

The BIS procedure recommends simulating parallel shifts of the yield curve using the 1% and the 99% points off the distribution of the 288-day rate. We see that these values are -320 basis points and +112 basis points respectively.

Looking forward, there is no reason to expect asymmetry in movements of the yield curve. Hence, in this paper, we will undertake two simulations of parallel shifts of the yield curve: of 200 basis points and 320 basis points.

Figure 5 Kernel density estimator of the 288-day change in the 10-year rate



C Calculating ARMA residuals for r_M, r_L and r_d

As discussed in Section 2.2, we need to extract *innovations* in the returns time-series for the explanatory variables of the augmented market model. Table 7 shows AR(10) estimates for the three daily series, at both daily and weekly frequencies. Our specification search suggested that an AR model with ten lags was a parsimonious specification which captured a significant part of the correlation, and served to sharply reduce (though not entirely eliminate) the extent to serial correlation in the series.

These tables show remarkably sharp rejections of the null of non-predictability of returns on the bond market. There is a striking contrast between Nifty and the two bond returns time-series, where Nifty is much closer to the efficient–markets ideal of zero serial correlations. This is particularly the case with returns on the short bond, which exhibits extremely strong serial correlations, by the standards of financial market returns.

Table 7 AR(10) estimates for the three series

This table shows AR(10) estimates for r_M, r_L and r_f series, at both daily and weekly frequencies. Coefficients which are significant at a 95% level of significance are shown in boldface.
The estimates at a daily frequency show strong correlation structure, i.e. violations of market efficiency, for the bond returns. For example, the first lag has a value of just 0.038 for Nifty, but has large values of -0.3378 for the long bond and -0.4464 for the short bond. The Q statistic for daily returns on the short and long bond proves to be 250 and 294, both of which are extremely large values.
At a weekly frequency, returns on the short bond has strong serial correlations, but returns on the long bond does not.
At the bottom of the table, the Box-Ljung Q statistic is shown for the raw returns, and for the residuals obtained from the AR(10) model. In all cases, we see that the $H_0 : Q = 0$ is not rejected for the residuals at a 95% level of significance. These residuals are utilised in estimation of the augmented market model.

	Daily			Weekly		
	r_M	r_L	r_f	r_M	r_L	r_f
Intercept	0.0239	0.0340	0.0003	0.0171	0.1894	0.0012
	(0.046)	(1.548)	(0.784)	(0.075)	(1.68)	(1.079)
Lag 1	**0.0381**	**-0.3378**	**-0.4464**	**0.0990**	-0.0215	**-0.4864**
	(2.086)	(-36.2)	(-31.3)	(2.056)	(-0.71)	(-13.4)
Lag 2	-0.0226	**-0.1600**	**-0.1852**	-0.0611	-0.0619	**-0.3516**
	(-1.19)	(-9.83)	(-10.3)	(-0.98)	(-0.71)	(-6.63)
Lag 3	0.0134	-0.0133	**-0.0980**	-0.0023	**-0.1726**	**-0.1884**
	(0.560)	(-0.57)	(-5.63)	(-0.04)	(-3.98)	(-2.68)
Lag 4	0.0122	0.0179	**-0.1391**	-0.0719	-0.0210	**-0.2101**
	(0.496)	(0.881)	(-9.22)	(-1.31)	(-0.25)	(-2.82)
Lag 5	**0.0554**	0.0247	**-0.0726**	-0.0191	-0.0284	**-0.1682**
	(2.916)	(1.146)	(-4.85)	(-0.32)	(-0.24)	(-2.71)
Lag 6	**-0.0649**	**0.0773**	0.0046	-0.0258	-0.0444	**-0.1359**
	(-2.93)	(7.310)	(0.239)	(-0.38)	(-0.49)	(-1.95)
Lag 7	-0.0143	-0.0006	**-0.0596**	-0.0095	-0.0129	-0.0988
	(-0.90)	(-0.04)	(-3.20)	(-0.15)	(-0.12)	(-1.68)
Lag 8	-0.0084	-0.0090	**-0.1314**	0.0662	0.0642	**-0.2691**
	(-0.37)	(-0.34)	(-7.77)	(1.038)	(-0.78)	(-4.46)
Lag 9	**0.0548**	0.0208	**-0.0600**	0.0681	-0.0175	**-0.1515**
	(2.332)	(0.897)	(-3.55)	(1.067)	(-0.23)	(-2.31)
Lag 10	0.0430	**0.0857**	-0.0286	0.03662	0.0250	**-0.1103**
	(1.840)	(4.809)	(-1.71)	(0.696)	(0.291)	(-2.04)
T	1626	1608	1608	351	290	290
$\log L$	-3229.12	-2279.22	3550.56	-959.14	-615.47	479.62
Q statistic						
Returns	**58.3414**	**250.3557**	**293.7092**	41.26	31.953	**86.66**
Prob value	0.0305	0.0000	0.0000	0.415	0.814	0.000
Residuals	34.5350	51.3533	55.6464	25.46	19.782	43.33
Prob value	0.7142	0.1077	0.0510	0.964	0.997	0.331

Table 8 Four sets of assumptions for behaviour of current and savings deposits

Behavioural assumptions about savings accounts and current accounts have a significant impact upon the results. Hence, in addition to the rules specified by RBI for the interest rate risk statement, we can have three assumptions, labelled Pessimistic, Baseline and Optimistic. This gives us a total of four assumptions.

Parameter	Optimistic	Baseline	Pessimistic	RBI
Savings accounts				
Short fraction	0%	15%	30%	25%
Short maturity	0	0	0	0
Long fraction	100%	85%	70%	75%
Long maturity	1-3 years	1-3 years	1-3 years	3-6 months
Current accounts				
Short fraction	10%	25%	50%	100%
Short maturity	0	0	0	0
Long fraction	90%	75%	50%	0%
Long maturity	1-3 years	1-3 years	1-3 years	

D Alternative assumptions about treatment of demand deposits

As emphasised in Section 2.1.1, a major factor which affects estimates of interest rate risk of banks is the extent to which demand deposits can be viewed as being 'stable'. While our main focus has been on one 'baseline' set of assumptions, we also explore the sensitivity to four alternative sets of assumptions.

First, we have a set of assumptions titled RBI, which uses RBI's requirements for the interest rate risk statement. It involves assuming that 75% of savings deposits are "stable", and that these have an effective maturity of 3-6 months. This appears to be an unusually short time horizon, given (a) the strong stability of savings accounts and (b) the long time till modification of the savings bank interest rate in India. RBI's requirements suggest that 100% of current accounts should be considered volatile. This appears to be an unusually strong requirement, when compared with the empirical experience of banks in India.

We report calculations for SBI using the RBI assumptions, since it is the regulatory requirement. In addition, we have Baseline assumptions, where 15% of savings accounts are assumed to be volatile, and the remainder have a maturity of 1-3 years. We assume that 25% of current accounts are volatile, and the remainder have a maturity of 1-3 years. We perturb these assumptions to produce two additional sets of assumptions: Optimistic (from the viewpoint of a bank seeking to hold long dated assets) and Pessimistic. This gives us four sets of assumptions in all, which are summarised in Table 8.

Table 9 shows banks with the highest and lowest five values, seen in our dataset, for the fraction of demand deposits in total deposits. This is relevant when interpreting our four sets of assumptions for the treatment of demand deposits. For banks such as IDBI Bank, where as much as 46% of deposits were demand deposits, alternative assumptions about stability of demand deposits would

Table 9 Variation in fraction of demand deposits

The fraction of demand deposits in total deposits is important insofar as it expresses the extent to which alternative behavioural assumptions about core versus volatile demand deposits could affect the results. This table shows the value for SBI, and the highest and lowest 5 values found in our dataset.

(Percent)

Bank	Demand deposits in Deposits
I D B I Bank Ltd.	46.22
Punjab National Bank	44.32
State Bank Of Bikaner and Jaipur	43.43
Bank Of Rajasthan Ltd.	42.91
Allahabad Bank	42.23
State Bank Of India	36.48
U T I Bank Ltd.	16.50
I C I C I Bank Ltd.	16.31
Indusind Bank Ltd.	12.96
Lord Krishna Bank Ltd.	12.14

matter more.

Table 10 Accounting information : Example (SBI)

The maturity pattern of assets and liabilities is derived from the 'liquidity statement' which is disclosed in the annual report of banks. In addition, we also require many auxiliary elements of information derived from the annual report, which are used in the algorithm for estimating the maturity pattern of cashflows. We see that the equity capital of SBI, which is the sum of paid up capital and reserves, was Rs.15,224 crore.

Liquidity statement (Rs. crore)

	1-14d	15-28d	29d-3m	3m-6m	6m-12m	1-3y	3-5y	>5y	Sum
Advances	21425.0	9935.0	10967.0	1293.0	2274.0	27898.0	9766.0	15407.0	98965.0
Investments	7635.0	879.0	4494.0	7151.0	5361.0	30085.0	22269.0	62599.0	140473.0
Deposits	17414.0	1593.0	3105.0	4532.0	9407.0	159207.0	46804.0	7253.0	249315.0
Borrowings	0.1	0.9	26.1	33.2	338.9	732.8	907.2	114.7	2153.9

Other information from annual report (Rs. crore)

Parameter	Value
Schedule 9 Bills	11555.36
Schedule 9 Demand loans	64178.41
Schedule 9 Term loans	45072.70
Cash in hand	1052.58
Balance with RBI	20819.95
Savings deposits	56396.36
Demand Deposits	42312.79
Paid up Capital	526.30
Reserves	14698.08

E An example: SBI

In this section, we show detailed results of applying the two methods to the largest bank of the system, SBI.

1. Table 10 shows the maturity statement, and auxiliary annual report information, about SBI.

2. Table 11 applies the methods of Appendix A to this information. It gives us vectors of cashflows for assets and liabilities.

3. Table 12 shows the NPV impact of simulated interest rate shocks under baseline assumptions. This calculation suggests that on 31 March 2002, SBI would lose 11.2% of equity capital in the event of a 320 bps parallel shift of the yield curve.

   To the extent that SBI has unrealised gains on GOI bonds, and the balance sheet does not reflect full marking to market, our estimate of the *equity capital* of SBI is an underestimate. Our estimate, that SBI could lose roughly Rs.1,704 crore in the event of a 320 bps parallel shift of the yield curve, is unaffected. However, when we express this as a fraction of equity capital, we are overstating SBI's exposure.

Table 11 Imputed maturity pattern of cashflows : Example (SBI)

(Rs. crore)

		Liabilities			
Bucket	Assets	Optimistic	Baseline	Pessimistic	RBI
Zero	12409	19456	34262	53300	71636
0-1mth	41659	8078	8053	8028	8037
1-3mth	18382	5163	5113	5063	5079
3-6mth	21927	7558	7483	7408	49730
6-12mth	87411	15571	15421	15272	14573
1-3yrs	43282	189635	174229	154593	91164
3-5yrs	31882	55414	55414	55414	55414
> 5yrs	80285	9944	9944	9944	9944

Table 12 Measurement of impact of interest-rate shocks: Example (SBI)

This table shows an example, for State Bank of India in 2001-02, of simulating hypothetical parallel shifts to the yield curve as of 31 March 2002.
The first line shows the impact of a 200 basis point shift in the yield curve. This would have an impact of Rs.11,126 crore on assets, Rs.9,833 crore on liabilities, and hence Rs.1,294 crore on equity capital. The drop of Rs.1,294 crore proves to be 8.50% of equity capital, and 0.37% of total assets. Similar calculations are shown for a shock of 320 basis points also.

Shock	ΔA	ΔL	ΔE	$\frac{\Delta E}{E}$	$\frac{\Delta E}{A}$
	(Rs. crore)				
200	-11,126	-9,833	-1,294	-8.50	-0.37
320	-17,079	-15,375	-1,704	-11.19	-0.49

Table 13 Impact upon equity capital under four sets of assumptions: Example (SBI)

This table is an example, of measuring the impact of interest rate shocks upon equity capital and upon assets, of the four sets of assumptions about demand deposits, for one bank (SBI). Our definitions of Pessimistic, Baseline and Optimistic correspond to an impact upon equity capital of 17.83%, 11.19% and 5.98% respectively, for a 320 bps shock. The RBI assumptions implies an impact of 36.28% of equity capital.

	Optimistic		Baseline		Pessimistic		RBI	
Δ	$\Delta E/E$	$\Delta E/A$	$\Delta E/E$	$\Delta E/A$	$\Delta E/E$	$\Delta E/A$	$\Delta E/E$	$\Delta E/A$
0.0200	-5.19	-0.23	-8.50	-0.37	-12.71	-0.56	-24.45	-1.07
0.0320	-5.98	-0.26	-11.19	-0.49	-17.83	-0.78	-36.28	-1.58

Table 14 Augmented market model estimation : Example (SBI)

As explained in Section 2.2, we estimate the augmented model:

$$(r_j - r_f) = \alpha + \beta_1(r_M - r_f) + \beta_2(r_L - r_f) + \epsilon$$

One example of these estimates, for SBI, is shown here. We report four variants: using daily versus weekly data, and using raw returns versus ARMA residuals. In all cases, we find that $H_0 : \alpha = 0$ is not rejected. As with stock betas, β_2 is interpreted as an elasticity. For example, in the results for raw weekly returns, it appears that in a week where the long bond $(r_L - r_f)$ lost 1%, SBI shares dropped by 0.8359% on average.

	Daily		Weekly	
	Raw	Residuals	Raw	Residuals
α	0.0665	0.0701	0.108	0.2662
	(0.70)	(0.74)	(0.218)	(0.527)
β_1	**0.8928**	**0.8929**	**0.8369**	**0.8204**
	(16.32)	(16.16)	(6.402)	(6.038)
β_2	**0.2807**	**0.3330**	**0.8359**	0.5872
	(2.019)	(2.344)	(2.316)	(1.656)
R^2	0.3744	0.3698	0.3732	0.3270
T	473	473	104	104

4. Table 13 shows the results for sensitivity analysis through four sets of assumptions. Our definitions of Pessimistic, Baseline and Optimistic correspond to an impact upon equity capital of 17.83%, 11.19% and 5.98% respectively, for a 320 bps shock. The RBI assumptions imply an impact of 36.28% of equity capital.

5. Table 14 shows estimation results for the augmented market model. As a first approximation, the coefficient of 0.8359 may be interpreted as follows. A 100 bps parallel shift in the yield curve would give a roughly 10% impact on r_L. This would hit the equity of SBI by roughly 8.3%.

References

Basel Committee on Banking Supervision (2001), *Principles for the management and supervision of interest rate risk*, Bank for International Settlements.

Darbha, G., Roy, S. D. & Pawaskar, V. (2002), Estimating the term structure of interest rates for India, Technical report, National Stock Exchange.

Drakos, K. (2001), Interest rate risk and bank common stock returns: Evidence from the Greek banking sector, Technical report, London Guildhall University.

Fama, E. F. (1976), *Foundations of Finance : Portfolio Decisions and Securities Prices*, Basic Books.

Houpt, J. V. & Embersit, J. A. (1991), 'A method for evaluating interest rate risk in U.S. commercial banks', *Federal Reserve Bulletin* pp. 625–637.

Jorion, P. (2000), *Value at Risk : The Benchmark for Controlling Market Risk*, 2nd edn, McGraw Hill.

Lo, A. W. & MacKinlay, A. C. (1990), 'An econometric analysis of nonsynchronous trading', *Journal of Econometrics* **45**, 181–211.

Nelson, C. R. & Siegel, A. F. (1987), 'Parsimonious modeling of yield curves', *Journal of Business* **60**.

Robinson, K. J. (1995), 'Interesting times for banks since Basle', *Federal Reserve Bank of Dallas Financial Industry Studies* pp. 9–15.

Shah, A. & Thomas, S. (1998), Market microstructure considerations in index construction, *in* 'CBOT Research Symposium Proceedings', Chicago Board of Trade, pp. 173–193.

Thomas, S. & Pawaskar, V. (2000), Estimating a yield curve in an illiquid debt market, Technical report, IGIDR, Bombay, India.

Thomas, S. & Shah, A. (2002), Interest rates and their markets, *in* K. Parikh & R. Radhakrishna, eds, 'India Development Report 2002', Oxford University Press, chapter 12, pp. 177–194.

Wright, D. M. & Houpt, J. V. (1996), 'An analysis of commercial bank exposure to interest rate risk', *Federal Reserve Bulletin* pp. 115–128.