Securities and Exchange Board of India

Group on Secondary Market Risk Management

Exchange Traded Interest Rate Derivatives in India

Consultative Document

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SEBI Group on Secondary Market Risk Management

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1 Background

The SEBI Group on Secondary Market Risk Management discussed the introduction of interest rate derivatives in India at its meeting on March 12, 2003. The Group's deliberations covered:

- The time table for introduction of exchange traded interest rate derivatives in India
- The specification of the initial set of interest rate derivative contracts to be introduced
- The road map for introduction of additional products
- The risk containment systems for the initial set of derivatives
- The road map for research in fixed income analytics and the resulting refinement of product design and fine tuning of the margining system.

In line with the Group's view that its conclusions on these issues be put up for public comments, the Group has prepared this consultative document.

2 Need for Exchange Traded Derivative Products

The Reserve Bank of India's Working Group on OTC Rupee Derivatives has stated the need for exchange traded interest rate derivatives admirably well:

> "While OTC derivatives market has traditionally played a dominant role in debt markets globally and would continue to do so in future, it is desirable to supplement the OTC market by an active exchange-traded derivative market. In fact, those who provide OTC derivative products can hedge their risks through the use of exchange-traded derivatives. In India, in the absence of exchange-traded derivatives, the risk of the OTC derivatives market cannot be hedged effectively. Exchange-traded derivative market has the following features: an electronic exchange mechanism and emphasises anonymous trading, full transparency, use of computers for order matching, centralisation of order flow, price-time priority for order matching, large investor base, wide geographical access, lower costs of intermediation, settlement guarantee, better risk management, enhanced regulatory discipline, etc. At present, in India, there exists a reasonable OTC market for interest rate products which raises the need for exchange-traded interest rate derivatives products." (Paragraph 3.1)

> "Also, some of the features of OTC derivatives markets embody risks to financial market stability, viz., (i) the dynamic nature of gross credit exposures, (ii) information asymmetries and lack of transparency, (iii) the high concentration of OTC derivative activities in major institutions, and (iv) the dominance of OTC derivatives markets in the global financial system. Instability arises when shocks, such as counterparty credit events and sharp movements in asset prices that underlie derivative contracts, occur which significantly alter the perceptions of current and potential future credit exposures. When underlying asset prices change rapidly, the size and configuration of counterparty exposures can become unsustainably large and provoke a rapid unwinding of positions." (Paragraph 3.2)

> "The Group felt that there is a need for exchange-traded interest rate derivatives (IRDs) as debt market volumes, particularly in IRS, have been growing rapidly and exchange-traded products would reduce the risk substantially through a clearing corporation, novation, multilateral netting, centralised settlement and risk management. The Group considered that India has already set up mature institutional infrastructure for trading, clearing and settlement in the equity markets which could be harnessed for the debt market. It, therefore, proposes to allow trading in IRDs through the anonymous order- driven screen-based trading system of the stock exchanges which will facilitate participation by all classes of investors and increase market access across the country." (Paragraph 3.3)

> "…interest rate futures, interest rate options, interest rate swaps – both plain vanilla swaps as well as swaps with embedded options like caps/floors/collars, as well as standardised repos may be allowed to be traded on the stock exchanges." (Paragraph 3.5)

It must also be added that interest rate risk is one of the most pervasive risks in the economy that affects not only the financial sector, but also the corporate and household sectors. The critical importance of interest rate risk management for banks and financial institutions is well understood, and its increasing importance for the corporate sector in a deregulated interest rate environment is also widely appreciated. However, interest rate risk is today very important for the household sector as well. The large stock of household financial savings on the assets side and the increasing amount of housing loans on the liabilities side makes interest rate risk increasingly important for the household sector. It is in fact likely that for many households interest rate risk is vastly more important than equity market risk. Moreover, because of the Fisher effect, interest rate products are the primary mechanism available to hedge inflation risk which is typically the single most important macroeconomic risk facing the household sector. In this context, therefore, it is important that the financial system provides the household sector greater access to interest rate risk management tools through exchange traded derivatives. Exchange traded derivatives are also potentially very attractive to the corporate sector and to the financial sector.

3 Time Table for Introduction

The Group is well aware that the *publicly* available fixed income analytics in India is not adequate for the development of a vibrant derivatives market. While recognizing that fixed income analytics is among the most intellectually challenging parts of modern finance, the Group is of the view that the development of this field has been held back in India less by a lack of supply and more by the paucity of demand. Therefore, rapid development of new markets and products is the best way to solve the "chicken and egg" problem of whether the market comes first or the analytics comes first.

The Group recommends therefore that the first set of exchange traded interest rate derivatives start trading almost immediately. In consultation with the exchanges, the Group has arrived at April 21 as the most feasible launch date.

As discussed later, the Group desires and expects that the Exchanges would spearhead a concerted research effort in fixed income analytics over the next three months. Allowing for a month for regulatory review and two months for software changes, the Group desires and expects that the improved product designs and more fine tuned margining systems arising out of this research would be implemented within a period of six months.

Early launch has three major implications:

1. The primary implication of early launch is a significant degree of over-margining in the initial six month period until more refined models are implemented. Since there can be no compromise on the issue of market safety, the Group is compensating for model risk by aggressive over-margining.

2. Another implication is that to the extent that the zero coupon yield curve that is publicly available currently is not fully accurate, there would be a basis risk in hedging interest rate risk using products based on this curve. Since all hedges involve some degree of basis risk, the Group does not regard this as a show stopper if there is complete transparency regarding the construction of the yield curve. The yield curve provider has been given clear directions to achieve this. The Group desires and expects that an improved yield curve be implemented within six months. The yield curve provider has been given quantitative benchmarks in this regard. These issues are discussed more fully in 4.3 below.

3. For software reasons, it would be possible to allow only two decimal places in the price quotes at the time of launch. Exchanges will however modify their software to allow four decimal places as soon as possible. The National Stock Exchange has indicated that this could be accomplished by mid-May, that is to say, within one month of launch. It must also be pointed out that one paisa is a small number compared with the one-day standard deviation of most bond prices, so the limitation of two decimal places does not significantly detract from the utility of the product for hedging purposes.

4 Product Specification: Long Bond Futures

4.1 Maturity and Coupon

The Group discussed three issues in connexion with product design for the futures on long maturity risk free bonds:

1. The maturity of the underlying long bond
2. Maturities of the futures contracts
3. The characteristics of the bond

Regarding maturity of the underlying, there was unanimity that the most liquid segment in the government securities market is the ten year maturity and that this should be the maturity of the underlying long bond for interest rate futures.

Regarding maturity of the futures contracts, it was decided that exchanges would be free to introduce contracts up to a maximum maturity of one year. Exchanges would be free to decide whether to have quarterly contracts beyond the first three months, and whether the quarters should be fixed months of the year or rolling quarterly horizons from the contract introduction date.

There was some discussion regarding the choice between whether the underlying should be a coupon bond or a zero coupon bond. The Group decided that the exchanges should have the freedom to offer either or both of these products and also to choose the coupon rate in case of the coupon bond. Exchanges indicated that the coupon rates could be in the range of 6-8%.

4.2 Physical Settlement versus Cash Settlement

The Group deliberated at length on the merits of physical and cash settlement. Several advantages were identified with physical settlement:

1. Some members felt that physical settlement would improve the linkages between the derivative market and the underlying market.
2. Some members also felt that the requirement of physical settlement would act as a restraining force on speculators and reduce volatility.
3. Some members also felt that physical settlement might reduce basis risk.

On the other hand, several disadvantages of physical settlement were also noted:

1. First and foremost was the problem of market manipulation. Relative to global standards, Indian banks hold a large fraction of their assets in government securities. Moreover, the issue size of any single government security is also relatively small. This means that the entire issued amount of even a very liquid

government security is sometimes less than 10% of the aggregate government securities holding of a single large player. This means that a large player could easily corner the entire floating stock of any specific issue. Gradual opening up of the Indian financial sector to global players adds to the vulnerability of most government securities to market manipulations. Most physically settled long bond futures deal with the problem of squeezes by allowing several different bonds to be delivered with different conversion factors. However, even in this system, there is a "cheapest to deliver" bond that could become the target of manipulation. The alleged squeeze[1] of German government bond futures in March 2001 by a large regulated entity in that country was also referred to as a pointer to what could happen in India. The "cheapest to deliver" bond that was allegedly squeezed in that case had an issue size of over €6b, much larger than the issue sizes in the Indian market, but this issue size was still regarded as too small.

2. Some participants (particularly households) may not have ready and easy access to the government securities market to achieve physical delivery at low cost. The current government securities market is not transparently and publicly accessible to many of these participants.

3. The absence of short selling makes physical settlement more problematic.

After carefully deliberating on both sides of the issue, the Group decided that the ten year long bond futures should initially be launched with cash settlement.

4.3 The Zero Coupon Yield Curve

The Group then discussed the issue of determining the settlement price. It was decided that the settlement price should be based on the value of the notional bond determined using the zero coupon yield curve computed by the yield curve provider designated by the exchange.

If the notional bond is zero coupon, the settlement price of the bond is simply the present value of the principal payment (at the end of 10 years) discounted for 10 years at the 10 year zero coupon yield. For example, suppose that on 18/1/2003, the ten year zero yield published by the yield curve provider was 5.9023% (annually compounded) implying a price for the ten year zero of 56.3568 ($100 \times 1.059023^{-10}$). On the next working day, 20/1/2003, suppose that the yield was 5.8492% (annually compounded) implying a price of 56.6401. A person who bought a ten year zero coupon future on 18/1/2003 would have a mark to market gain of 28.33 paise on 20/1/2003.

If the notional bond has a coupon, the present value of the bond is obtained as the sum of present value of the principal payment discounted at the 10 year zero coupon yield and the present values of the coupons obtained by discounting each coupon payment for the time period remaining till the coupon payment at the zero coupon yield for that maturity.

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1 "Traders Squeeze Bobl", *The Banker,* October 1, 2001

The Group decided that the following obligations should be imposed on the designated yield curve provider (which could be the exchange itself or a third party):

1. The yield curve should be computed by a completely objective process without any element of human judgement so that any market participant could arrive at the same yield curve by applying the published computation algorithm to publicly available data.

2. The computation algorithm must be fully disclosed to the public. The only effective way of disclosing a computation algorithm is to disclose the source code. The yield curve provider would therefore be required to make the entire source code for its algorithm available on the web site under a GNU General Public Licence. This requirement extends also to the source code of the algorithms used to convert a traded bond into a series of cash flows and any other similar pre-processing that may be carried out prior to the actual estimation itself. It also extends to the algorithms that convert yield curve parameters into actual zero coupon yields, the algorithms to value a notional bond given the zero coupon yields and any other similar post processing that may be carried out after the actual estimation itself.

3. The yield curve provider would be required to make available on the web site a set of at least 25 trading days (i.e. one month) of data suites for the input data. Each day's data suite would include the traded prices and other transaction data[2] that is input into the estimation algorithm. The data suite would also include the sample output from the algorithm on this data suite. Similar data suites and sample outputs must also be provided for the pre- processing and post-processing algorithms referred to above.

4. The yield curve provider would be required to make available on the web site the full time-series of yield curve parameters for as long a period as possible. This data set must extend back at least to April 1, 1999. The term yield curve parameters is used because many estimation methods represent the entire yield curve as a functional form that depends on a small number of parameters. For example, the Nelson-Siegel functional form has four parameters. A cubic spline could have as parameters the location of the knots and the coefficients of the cubic polynomial over each segment; alternatively the parameters may be the coefficients over a family of basis splines.

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[2] As a general matter of transparency, it is desirable that the entire historical transaction data is available to the public (market participants and the academic community). The NSE indicated that they have been making this data available to researchers on demand. The NSE further agreed to formalize this facility and publicize it on its web site. It was agreed that since the data is too large to be downloaded from a website it would be made available on CDs, which could be free or be priced on a cost recovery basis.

5. The Group desires that the yield curve provider use an estimation process that is conceptually correct and is based on sound econometric foundations. The Group also encourages the yield curve provider to continually refine and improve its estimation methods. The Group however recognizes that the characteristics outlined in this paragraph cannot be a formal regulatory requirement.

6. No major changes in the estimation process shall be implemented except after giving due notice to the market and providing appropriate backtests.

7. The Group encourages the yield curve provider to provide intra day estimates of the yield curve on as real time a basis as possible. A real time yield curve would greatly facilitate trading, but the Group recognizes that it could impose an intolerable computational burden if the yield curve estimation process is highly complex and computation intensive. The yield curve provider could therefore attempt to meet the needs of the market for real time yields by using an estimation process for the real time curve that is less computationally demanding than the end of day estimation process. If it does so, all the transparency requirements outlined above (for example source code and data suites) would apply to the intra-day algorithm as well.

The National Stock Exchange has been publishing a zero coupon yield curve for some years now – more as an educational exercise than as a commercial product. This curve already meets the objectivity requirement and part of the transparency requirement. The National Stock Exchange Market has agreed to meet all the transparency requirements before the launch of derivatives based on this curve. The Group therefore decided that subject to the fulfilment of the transparency requirements, the NSE zero coupon yield curve could be used for cash settlement of the ten year bond futures.

Market participants have noted that the NSE zero coupon yield curve produces significant pricing errors in case of certain liquid bonds. This does introduce a basis risk while hedging interest rate risk using products based on this curve. The Group noted that there is always a degree of basis risk in the use of exchange traded derivatives for hedging because the exposure and the hedge do usually differ on maturity, credit class, optionality and several other dimensions. As such, the derivative does not cease to be useful merely because of these pricing errors so long as the fitted prices are highly correlated with traded prices. In any case, using an imperfect but highly correlated hedge is far better than not being able to hedge at all. The Group therefore believes that in the interests of early launch, we must live with the deficiencies of the existing yield curve.

The Group noted during the course of the discussion that some of the deficiencies of the existing curve stem from the differing objectives and requirements of an educational exercise as opposed to a commercial product. When the zero coupon yield is used for trading purposes, the yield curve provider has an obligation to achieve higher levels of accuracy. The Group desires the NSE to modify its yield curve estimation process so as to significantly reduce the estimation errors for liquid bonds. Members of the Group who are familiar with the estimation process are of the view that by changing the estimation process to focus on minimizing the pricing error of liquid bonds, the observed mispricing could be brought down sharply. On the basis of these inputs as well as inputs from market participants, the Group desires that the NSE while refining its yield curve estimation should target a mean pricing error for liquid bonds of not more than 2 basis points of yield (approximately 20 paise for the 10 year bond) for all liquid bonds. The mean pricing error would be calculated as the simple arithmetic mean over a one month period of the daily mean pricing error which in turn would be calculated as the simple arithmetic mean of the pricing errors (in basis points of yield) of the bonds that were liquid on that day. Liquid bonds could for example be defined as those with at least 10 trades of at least one market lot (Rs 50 million) on the given day.

Yield curve estimation involves complex issues of modelling, econometrics and computational complexity. A reasonable estimate of the time involved in the development of a more acceptable zero coupon yield curve would therefore be about three months. We should also provide for another month for backtesting and regulatory reviews and another two months for software implementation. The Group therefore desires and expects that within six months, the NSE would develop and implement a new zero curve meeting the targeted accuracy requirements. Outstanding contracts would then be transitioned to the new curve and fresh contracts would be launched only on the new curve.

5 Product Specification: Notional T-Bill Futures

The Group agreed that there should be a future on a short term interest rate. The choice here is between a contract on an inter-bank rate and a contract on a risk free interest rate. It was generally agreed that the liquidity in the inter-bank market (MIBOR and MIFOR) is much higher than in the T-Bills and in dated securities with a residual maturity of less than one year. A contract on the inter-bank rate would therefore be highly desirable. The Group was however informed that some legal issues have been raised on whether contracts on indices like MIBOR would fall within the definition of derivatives under the SCRA. Since the Group does not profess any expertise in legal matters, it decided to sidestep the legal risk by focussing on contracts on the risk free interest rate. The product that is proposed is futures on notional T-Bills with a maturity of 91 days (three months).

Many of the issues here are similar to that for long bond futures and the Group's recommendations are also similar:

1. The contract would be cash settled.

2. The settlement price would be based on the risk free zero coupon yield curve. All the objectivity and transparency requirements discussed in 4.3 above would apply in this case also.

3. Exchanges would be free to introduce contracts up to a maximum maturity of one year. Exchanges would be free to decide whether to have quarterly contracts beyond the first three months, and whether the quarters should be fixed months of the year or rolling quarterly horizons from the contract introduction date.

As in the case of the long bond futures, it was decided to launch the contract on the basis of the existing NSE zero coupon yield curve though there are significant estimation errors. The Group desires and expects that the new yield curve to be implemented by the NSE within six months as discussed in 4.3 above would address this issue. The Group recognizes that estimation of the short end of the risk free yield curve is problematic because T-bills are quite illiquid in India. But there are ways to deal with this problem. The liquid long term bonds do have coupons that fall due within the next six months. As such the estimation of the short end of the zero coupon yield curve does have inputs from liquid bonds as well. Moreover, the inter-bank rate adjusted for credit risk could be an additional input into the estimation algorithm to improve the reliability and stability of the estimated 90 day risk free rate.

The restriction to two decimal places is more damaging for the short term futures than for the long bond. One possibility could be to quote on the basis of yield or in terms of 100 minus yield. In any case, this problem would disappear within a month of launch as the software changes are made to accommodate four decimal places.

6 Options on the Notional Long Bond and Notional T-Bills

The Group debated whether options should be introduced along with futures or whether the two products should be sequenced. In equities, we have tried both kinds of sequencing – index futures preceded index options, but single stock options preceded single stock futures. In the former case, the argument was the greater simplicity of the futures product. Since options have now been trading for two and a half years now, this argument is no longer relevant.

In the case of single stock derivatives, the sequencing was reversed. The principal argument was that options are safer than futures at least for the option buyer. The option buyer can at most lose the premium and nothing more. For the same reason, the option buyer does not need to be margined at all. This makes it very convenient for households and for smaller players. For households facing interest rate risk on their financial savings or on their housing mortgage liabilities, interest rate options could provide safe, effective and convenient tools for managing risks. There is therefore a strong case to be made for introducing interest rate options at the earliest.

The Group is of the view that there is no need to worry about whether options should come first or futures should come first. Both can and should be introduced at the same time. The Group therefore recommends that options on the notional long bond and on the notional T-Bill should start trading at the same time as the corresponding futures are launched in mid-April. Simultaneous launch of options and futures is the convention with derivatives product launches internationally.

One member of the Group however expressed the desire for more time to reflect on the matter before expressing an opinion on the issue.

The product specification for the options would be the same as that for the corresponding futures. As in the case of equities, exchanges would endeavour to offer at least three strikes – near money, in-the-money and out-of-the-money – for the call and put options on the ten year notional risk free bond and the three month notional T-Bill.

7 Roadmap for Additional Products

The Group believes that even as the initial derivative products are being launched, we should be preparing for the next slew of products to be launched. Among the products that need to be introduced quickly are:

1. Futures and options should be introduced on MIBOR and MIFOR to supplement the futures and options on the notional T-Bill. As already stated, the only thing holding the Group back on this issue at present is the legal issue of whether these products would have legal sanction under SCRA. As soon as there is legal clarity on this issue, contracts should start trading on them. The providers of these indices should be subject to the same objectivity and transparency requirements that we have imposed on the provider of the zero coupon yield curve.

2. Futures and options should be introduced on underlyings with maturities shorter than the 10 year bond but longer the three month T-Bill.

3. Exchange traded swaps should be introduced as soon as the risk containment issues involved with them have been sorted out. The Group intends to continue its deliberations on this issue.

4. Swaptions should be introduced when exchange traded swaps are introduced. The deliverable for the swaption could be an exchange traded swap. Alternatively, the swaption could be cash settled.

5. Caps and floors as well as swaps with embedded caps and floors should be considered.

8 Risk Containment

8.1 VaR Framework

The risk containment for interest rate derivatives would continue to be governed by the fundamental principle of 99% VaR based margins established by the L. C. Gupta Committee Report and employed in equity derivatives:

> "The level of initial margin required on a position should be related to the risk of loss on the position. The concept of "value at risk" should be used in calculating required levels of initial margin. The initial margin should be large enough to cover the one-day loss that can be encountered on the position on 99% of the days." (Paragraph 6.13(3)).

> "Since market volatility changes over time, the Committee feels that the Clearing Corporation should continuously analyse this problem and may modify the margin requirements to safeguard the market." (Paragraph 6.4)

Two members of the Group (Dr. Ajay Shah and Prof Jayanth R. Varma) shared with the Group some of the work[3] that they had done on the volatility of interest rates in India and the resulting margining requirements. Briefly, they stated:

1. Bond returns are further away from the normal distribution than stock returns. The kurtosis is several times larger than for stocks. This means that most of the time the changes in bond prices are very small with only occasional large changes.

2. Interest rates exhibit mean reversion and more complex volatility dynamics than stock prices.

3. In this context, the adaptation of the equity margining system to bonds (with only parameter changes to guarantee the 99% VaR requirement) would lead to significantly larger margins than a more refined model would mandate.

4. Development of a more elaborate model of interest rate dynamics and the underlying stochastic processes requires serious work which would take two to three months and would also partly depend on the availability of better yield curve data. Neither practitioners nor academics have any incentive to do this kind of work unless and until there is a derivative market that could actually use this kind of research.

They therefore proposed that the interest rate derivatives be launched with a risk containment system that produces significant over-margining (by making only parameter changes to the equity market margining system) but achieves the regulatory standards of market safety. This way, the regulatory goals are met from the very beginning and it is the exchanges and market participants who are hurt by the excessive margining. These are precisely the people who have the incentives to invest in research that could lead to a more refined margining system that would reduce the over-margining.

8.2 Risk Containment for Options

The Group discussed the issue of risk containment for options. It was well recognized that the *valuation* of interest rate options often requires more sophisticated models than Black-Scholes or its Black variant. Several models are available including Cox-Ingersoll-Ross, Black-Derman-Toy and Heath-Jarrow-Morton and the choice between them

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[3] Their respective papers are attached as Annexures 1 and 2. Both the authors would like to (1) assert authorship of their respective papers and (2) emphasize that their papers are initial drafts of what is very much a work in progress. They welcome comments.

depends on the prevailing term structure dynamics. Further research is needed to identify the term structure dynamics that prevails in the Indian market.

That said, it must be understood that there are important differences between *valuation* and *margining*. First, risk containment depends on the worst case scenario of option price changes and does not require the ability to produce precise valuations. Second, the one day horizon for risk containment in exchange traded derivatives simplifies the task. Third, the need for real time valuation of thousands of portfolios places immense demands on computing resources and tilts the balance in favour of closed form formulas rather than numerical valuation methods. For all of these reasons, exchanges typically use closed form valuation models for risk containment. For example, most exchanges worldwide use Black-Scholes for margining equity options though it is well known that this model does not apply to American puts. Similarly, it is not uncommon to find a Garch based volatility estimate being fed into a Black-Scholes formula though the changing volatility implied by the Garch model clearly calls for a stochastic volatility model.

Finally, the Black variant[4] of the Black-Scholes model is very versatile and produces reasonable approximation to option prices for a wide range of underlyings including stocks, commodities, exchange rates and interest rates. Moreover, the model can replicate option prices in a wide variety of situations if it is used in conjunction with a grid of implied volatilities. The volatility smile and term structure compensate for the theoretical inadequacies of the model.

The Group therefore believes that at launch, option risk containment should be based on the Black model. Exchanges would also be encouraged to use the implied volatility of options as the base from which volatility perturbations are applied to determine the worst case scenario. This should be done for equity derivatives as well. The margining system also includes an additional layer of margins (the short option minimum margin) to account for any residual model risk.

8.3 Recommended Margining System

Based on all this discussion, the Group recommends the adaptation of the equity market margining system to interest rate derivatives with the following parameter values. The corresponding parameters for the stock index are also shown for comparison:

[4] This variant is obtained from the Black-Scholes model by replacing the cash price of the underlying by its futures price, setting the risk free interest rate to zero, and finally discounting the resulting Black-Scholes option value at the risk free rate up to the expiry of the option.

Parameter	Stock index	Notional 10 year bond	Notional 91 day T-Bill
Volatility estimation	Exponentially weighted moving average method with smoothing parameter of 0.94 as in equity derivatives		
Futures Margin (Range of price changes for options margining)	3 standard deviations or 5% whichever is higher	3.5 standard deviations or 2% whichever is higher	3.5 standard deviations or 0.20% whichever is higher
Range of volatility changes for options margining	4%	4%	4%
Second line of defence (% of gross open positions including options notional value)	3%	1%	0.1%
Short option minimum margin (applies when portfolio margin is below this minimum)	3% of notional value of all short options		
Calendar spread margin (applied only on the far month contract). Benefit ceases three days before expiry on near month.	0.25% per month of spread subject to a minimum of 0.5% and a maximum of 1.5%	0.125% per month of spread subject to a minimum of 0.25% and a maximum of 0.75%	0.125% per month of spread subject to a minimum of 0.25% and a maximum of 0.75%

Since this consultative document is likely to be read by many who are not familiar with the margining system for equity derivatives, the salient features of the proposed margining system for interest rate derivatives are summarized below.

In the case of positions involving only futures contracts, the margining system is relatively simple:

- The exponentially weighted moving average method (also known as the IGARCH or Risk Metrics method) is used to estimate volatility daily

- The 99% VaR is operationalized by setting the margin equal to 3.5 standard deviations to account for the fat tails

- Since even a 99% VaR implies a margin shortfall once every hundred trading days (approximately once every six months), it is necessary to have a second line of defence to cover the likely margin shortfall in case of a VaR violation. This is set higher than the expected shortfall and is designed to cover all but the most extreme cases. For the notional 10 year bond, this is set at 1% and for the notional T-bill, it is set at 0.1%.

In the case of portfolios that include options, the margining is more complex. Essentially, the VaR is based on a portfolio approach similar to that of the SPAN system employed by leading derivative exchanges worldwide:

- The possible loss on the entire portfolio of any client is estimated under a variety of price and volatility scenarios.

- The range of prices considered for this purpose is set at ±3.5 standard deviations in conformity with the value used for futures.

- The range of volatility changes for option valuation is set at ±4%. The Black model could be used for option valuation.

- The margin is computed as the worst case loss under these various price and volatility scenarios

- The margin shall not however be less than 3% of the notional value of all short options. This minimum margin is intended to cover model risk and impacts option portfolios which are approximately delta, gamma and vega neutral and therefore attract very low margins under normal option valuation models.

- The second line of defence is set at the same percentage as for futures but applies on the basis of notional value.

Position limits are not really a part of the risk containment system as they are designed to reduce market manipulation, but they are discussed here for convenience. The Group recommends that position limit be applied only at the client level and only for the near month contract. The limit is set at Rs 1 billion or 15% of the open interest whichever is higher and is computed on the basis of notional value in case of options. A similar limit applies in the case of equity derivatives at the level of the trading member. However, given the structural characteristics of the interest rate market which are dominated by a few large institutions, it is proposed to apply the limit at the client level here. There will be no limit at the level of the trading member.

8.4 Extreme Stress Events

To a far greater extent than equities and other underlyings, the interest rate market is severely impacted by the impact of monetary policy responses to currency market pressures. The best example in the Indian context is the havoc created in the Indian bond markets on January 16, 1998 by the interest rate defence of the currency in response to the threat of contagion from the East Asian crisis. An example from a developed market would be the decision of Sweden to raise overnight interest rates to 500% on September 16, 1992 to combat the pressures emanating from the withdrawal of the British pound from the European exchange rate mechanism the previous day.

Normal margining schemes can not cope with such extreme stress events and are not designed to do so. These events are also very difficult to predict though the literature does identify several leading indicators and early warning signals. No formulas or mechanical rules can hope to provide a foolproof prediction of such extreme stress events because each currency crisis is somewhat different from the previous one.

Yet, the clearing corporation cannot ignore the possibility of an extreme stress event that could be disastrous to its financial health. The Group thinks that this is an area where the clearing corporation must rely on its own judgement and respond either by reducing positions or by raising margins to prohibitive levels. The clearing corporation cannot even hope to receive a suggestion or advice on this matter from the regulators because the signalling effect to the broader market of any such regulatory suggestion may be inconsistent with the goals of government policy at that point of time. The clearing corporation must be prepared to act on its own; indeed it must sometimes be prepared to act in the face of hints to the contrary from the government. Above all, the clearing corporation must be seen by the market as acting on its own and not at the regulator's behest.

9 Fixed Income Research

The Group believes that the development of a vibrant derivatives market in India requires significantly better fixed income analytics than is *publicly* available today. The Group desires that the exchanges take the initiative to spearhead a concerted research effort in this field over the next three months. As already indicated, one key component of this research effort would be the development of a significantly improved zero coupon yield curve. Another area where research is needed is in the field of term structure dynamics. This would help in developing appropriate models of derivative pricing and deciding whether the Black model needs to be supplemented or supplanted even for margining purposes. Better understanding of term structure dynamics would also be a key component in the building of better volatility dynamics and more fine tuned margining systems that would reduce the significant over-margining that would exist when the equity margining system is adopted with only parameter changes.

While the exchanges have an incentive to develop and support publicly available fixed income analytics, the Group hopes that the academic community would also step forward with more research efforts in this area. They would hopefully be spurred on by the knowledge that there is a growing interest rate derivative market where that research would find ready application.

10 Organizational and Structural Issues

The Group recommends that interest rate derivatives be regarded as additional contracts on the existing derivative segments of the exchanges. They would not constitute a separate segment for regulatory purposes and therefore existing members of the derivative segment would be able to participate in this segment without any additional documentation or regulatory clearances. Moreover, the existing settlement guarantee fund would be applicable to this segment. In short, the exchanges which are allowed to trade derivatives would be allowed to trade interest rate derivatives as a part of the existing derivative segment; the existing derivative brokers would be allowed to trade in the interest derivative market also; and the same clearing corporation and settlement guarantee fund would perform the novation and provide settlement guarantee. This means that to introduce the proposed interest rate derivative contracts, the exchanges would need to go through precisely the same regulatory procedures that it would need to introduce a new equity index contract – nothing more and nothing less.

The Group is also of the view that the exchange traded interest rate derivative market would benefit significantly from the participation of banks and other financial institutions. Banks and primary dealers should have access to trading screens which would allow them to do proprietary trading directly. Ideally, one should go a step further and allow these entities to become members of the exchange so that they could trade directly without going through a broker. The Group therefore recommends that banks and other financial institutions should be permitted to obtain membership of the stock exchanges in their own name and not through a separate broking subsidiary. If the RBI so considers necessary, the bank's trading rights as a member of the exchange in its own name could be restricted to carrying out only proprietary trades. The RBI could require the banks to conduct all third party trades through a separate broking subsidiary. Because of the existence of client codes, the exchanges would be able to verify this separation and confirm adherence to this to the RBI on a regular basis.

Annexure I

Risk containment for exchange-traded interest rate derivatives

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Risk containment
for exchange-traded interest rate derivatives

February 25, 2003

There appears to be natural market demand for derivatives on three interest rates:

- MIBOR
- The short rate off the zero coupon yield curve
- The long rate off the zero coupon yield curve.

Given daily marking to market, the goal of the derivatives clearing corporation is to ensure that on most days, the collateral in hand exceeds the one-day change in the price of the derivative.

Given the low duration of the short-dated products, there is no substantial challenge in risk containment. For example, consider the 30-day rate off the zero coupon yield curve. This may be used to have a futures contract on the notional 30-day bond. This is a product with duration $\frac{1}{12}$. Even if the short rate moves by 240 basis points, which it has never done, the change in the bond price would be roughly 20 basis points.

In contrast, the long rate presents more challenging questions of risk management. The volatility of the 10-year bond is of the same order of magnitude as that of Nifty on a one-day horizon (though not on longer horizons).

1 Understanding the 10-year rate

The database used in thinking about the time-series behaviour of interest rates in India is the NSE zero coupon yield curve database. From 1/1/1997 till 31/1/2003, this gives us 1759 zero coupon yield curves. We focus on the time-series of the one-day return on the notional 10-year zero coupon bond.

Figure 1 shows the time-series of squared daily returns on the notional 10-year bond. For example, a value of 100 here pertains to a one-day return on the notional 10-year bond of either -10% or 10%. This highlights 16 January 1998 as a singular event in the history of this series. In the following years, the long bond appears to have become much less volatile.

Figure 2 shows the time-series of annualised volatility (expressed in percent), of continuously compounded returns on the notional ten-year bond, using rolling windows of 288 days at a time. This roughly corresponds to a window width of one calendar year. Hence, at each

Figure 1 Time-series of squared daily returns on notional 10-year bond

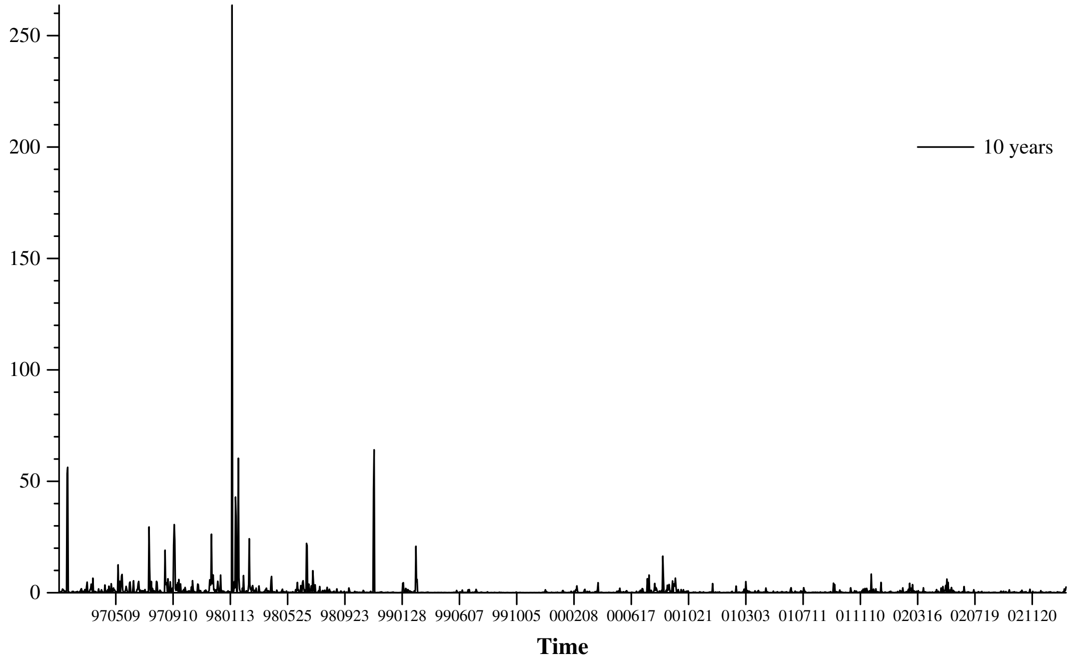
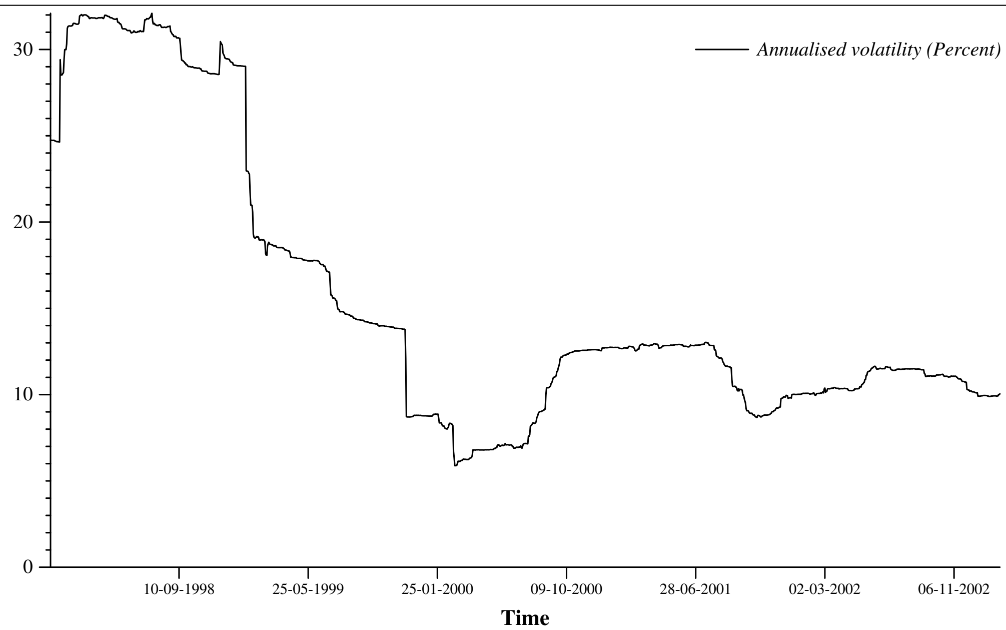


Figure 2 Time-series of rolling-window annualised volatility



date, this graph reports the annualised volatility of continuously compounded returns on the notional ten-year bond over the last one year.

This graph highlights the difference between the earlier period and the more recent period. If we focus on the period from late 1999 onwards, then the annualised volatility on the long bond has fluctuated between 5% and 15%. However, the older data shows values all the way up to 32%.

The summary statistics about the daily returns time-series are as follows:

- Mean 0.037 percent per day. This is linked to the drop in the long interest rate over the sample period.
- Standard deviation 1.02. This is around 30% lower than that of Nifty, but in the same order of magnitude.
- Skewness -2.42 and Kurtosis 51.6.
- The 95th percentiles are -1.17% and 1.30%.
- The 99th percentiles are -2.79% and 2.33%.
- The smallest value was -16.2% and the largest value was 7.77%. This extreme value of -16.2% occured on 16 January 1998. Apart from this extreme value, the next worst return was -8%.

A variety of tests all strongly reject normality. That is also seen with the extreme values for skewness and kurtosis seen here. This suggests that we cannot use simple rules, based on the normal distribution, such as an initial margin which is 3σ. This would generate margin requirements of the order of 3.03%. It turns out that in our dataset of 1759 observations, we had 14 days where $r < -3.03$ and 9 days where $r > 3.03$.

Further, if X is normally distributed, and if v is a VaR estimate, then the normal distribution guides us with rules governing $E(X|X < v)$. These rules break down given the pronounced non-normality of the 10-year bond.

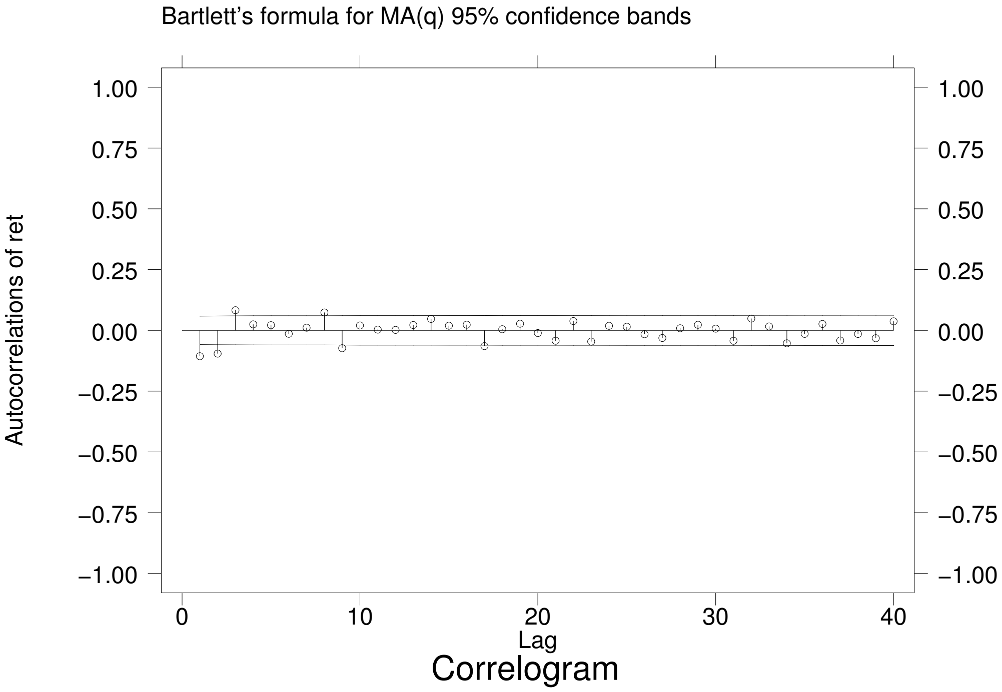
In summary, it appears that the one-day return on the 10-year bond is a difficult product in terms of modelling in a normal distribution framework. At a conceptual level, the key question concerns the treatment of the period before 6/1999. If the conduct of monetary policy before 6/1999 is considered representative of the data generating process *today*, then the low levels of volatility seen in the period after 6/1999 cannot be the basis of risk management, and conversely.

Using the entire dataset, of 1759 observations, suggests that if an initial margin of 4% were used, it was exceeded on 12 days on the left tail and on 8 days on the right tail.

2 A volatility model

Figure 2 highlights the regime change which took place in the returns time-series. It is well known that models of the ARCH family generate spurious persistence if there is a regime shift which is not adequately controlled for. Hence, we focus on the homogeneous period, which is dated as being from 15 March 1999 onwards. We call this 'Phase II' of the data.

Figure 3 Autocorrelation function of daily returns on notional 10-year bond



Focusing on Phase II only, the simple summary statistics work out to:

- Mean 0.0445 percent per day (as opposed to 0.037 percent/day for the full series).
- Standard deviation of 0.591 percent per day (as opposed to 1.02 percent/day for the full series, and 1.3 percent/day for Nifty).
- Skewness 0.11 (as opposed to -2.42) and Kurtosis 8.22 (as opposed to 51.6). This is clearly a much more tame series.
- The 95th percentiles are -0.92 and 0.91 (as compared with -1.17 and 1.30 for the full series).
- The 99th percentiles are -1.69 and 1.92 (as compared with -2.79 and 2.33).
- The smallest value was -2.89 and the largest value was 4.05 (as compared with -16.2 and 7.77).

Figure 3 shows the autocorrelation function for the daily returns series (focusing on Phase II only). This shows three significant lags, and some evidence of mean-reversion.

Figure 4 shows the autocorrelation function of squared daily returns on the notional 10-year bond. This shows strong short-dated volatility dynamics.

The Box-Ljung Q statistic works out to 79, which strongly rejects the null of normality. This is seen visually in Figure 5, where the deviation from the best-fit normal distribution is sharply visible.

A time-series model that could control for the short-dated mean-reversion and short-dated volatility clustering, as seen above, would yield improved forecasts of volatility. If the residual from this model was close to the normal distribution, it would give us confidence in using the normal distribution in thinking about risk management.

Figure 4 Autocorrelation function of squared daily returns on notional 10-year bond

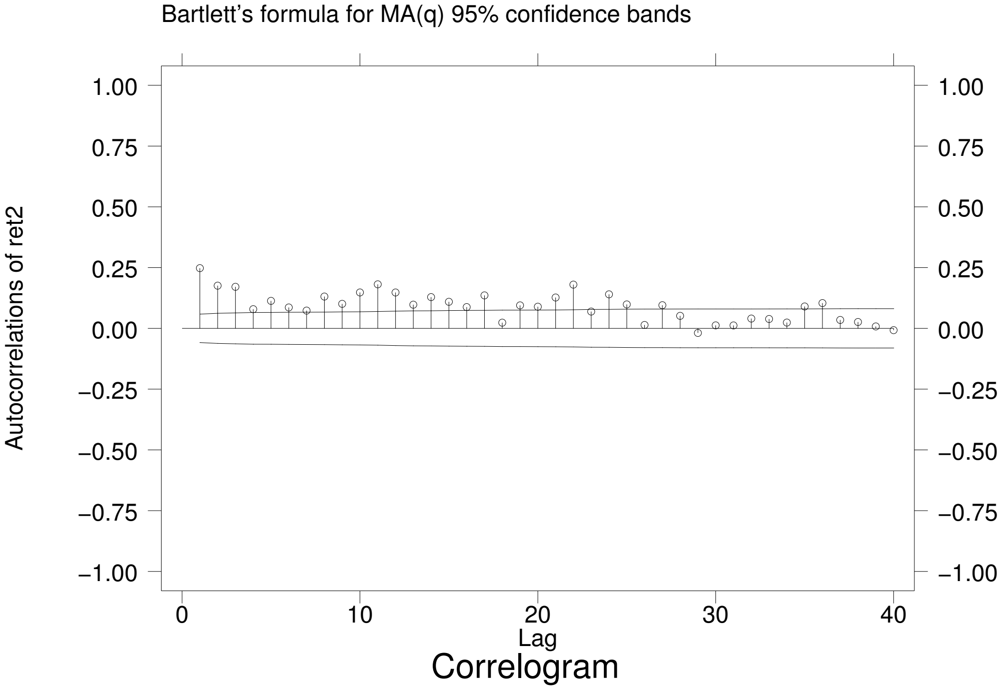


Figure 5 Kernel density plot of daily returns on notional 10-year bond

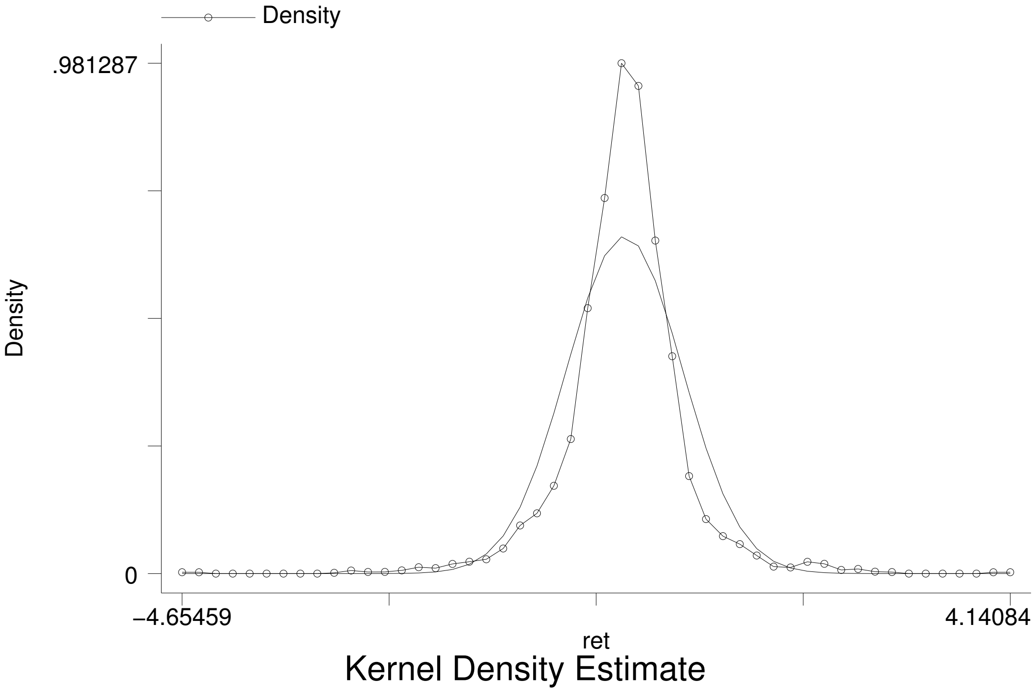


Table 1 AR(3)-ARCH(3) model estimates for daily returns on the notional 10-year bond

Parameter	Coefficient	t
Mean equation		
Intercept	0.06203	5.88
AR(1)	-0.10922	-3.56
AR(2)	-0.09782	-3.55
AR(3)	0.0975	4.25
Volatility equation		
Intercept	0.08936	10.78
AR(1)	0.32409	7.60
AR(2)	0.32657	12.28
AR(3)	0.30247	7.73

A null model (just an intercept) achieves a log likelihood of -1004. Table 1 shows estimates of an AR(3)-ARCH(3) model, which achieves a sharply better log likelihood of -846. The ARCH coefficients add up to near 1, showing very strong volatility persistence.

Figure 6 shows variance estimates from this model. We focus on the time-series of standardised residuals, $\epsilon_t = e_t/\sqrt{H_t}$.

Figure 7 shows the kernel density plot of the standardised residuals. This shows a much lower peak when compared with that in Figure 5. The Box-Ljung Q statistic works out to 37.5, where the null of i.i.d. normal cannot be rejected (the prob value is 0.58).

Figure 8 shows the ACF of the standardised residuals and Figure 9 shows the ACF of the squared standardised residuals. Both of them seem to suggest that time dependence in the returns equation and the volatility appear to have been contained.

These diagnostics suggests that we do have a plausible model of volatility dynamics of the returns on the notional 10-year bond in Phase II (i.e. from 15 March 1999 onwards). This is a satisfactory foundation for risk management if we believe that we are in the regime that has prevailed in the recent 1125 days.

Figure 6 Variance estimates from AR(3)-ARCH(3) model

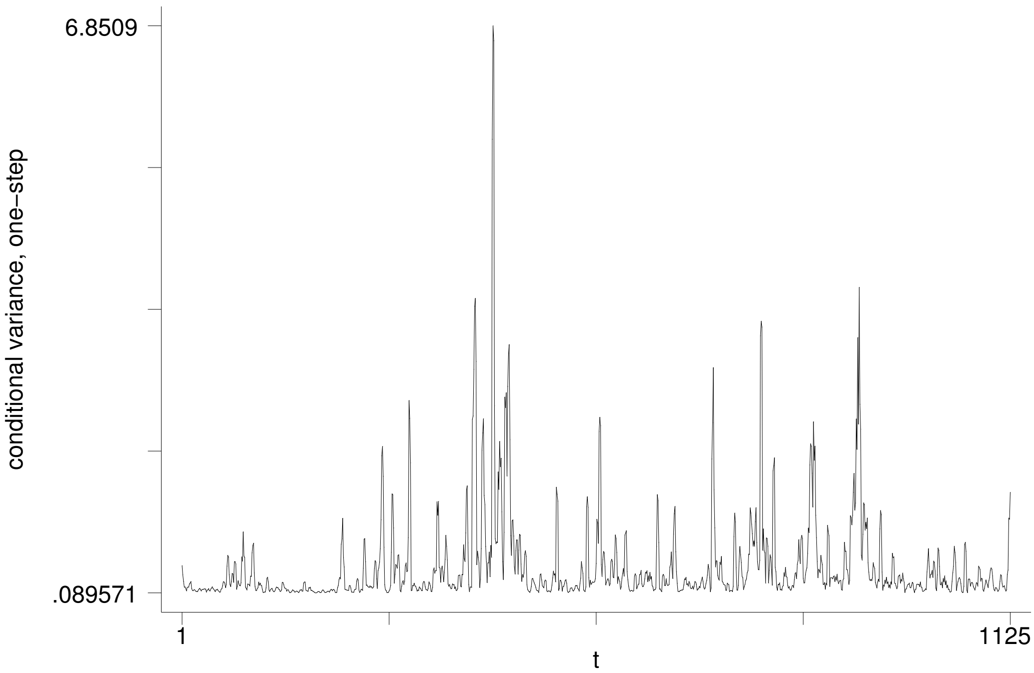


Figure 7 Kernel density estimates for standardised residuals

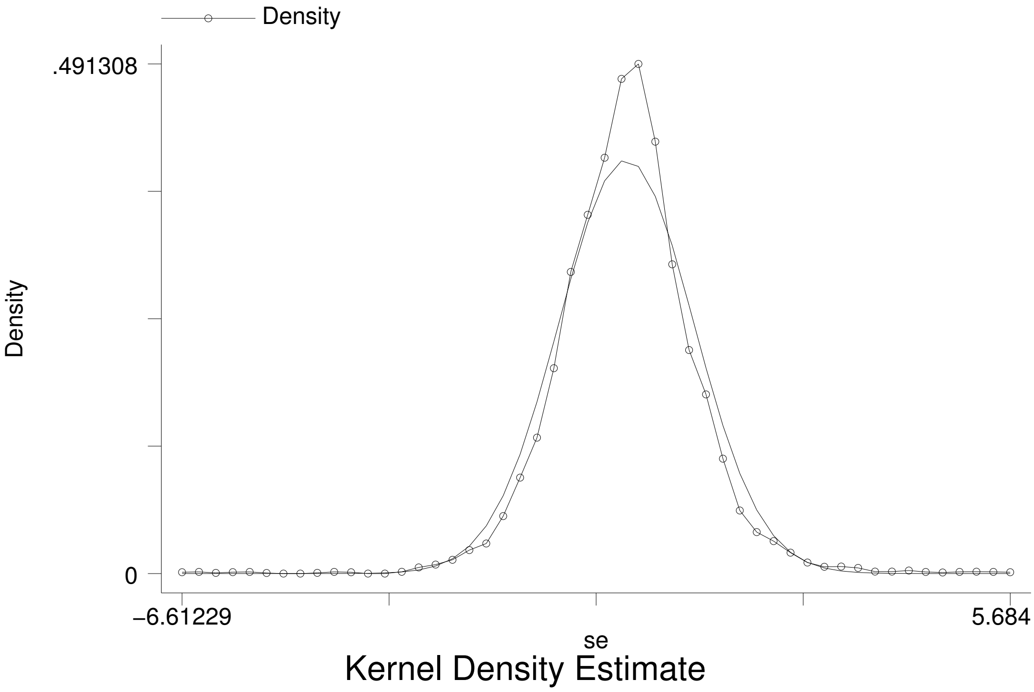


Figure 8 Autocorrelation function of standardised residuals

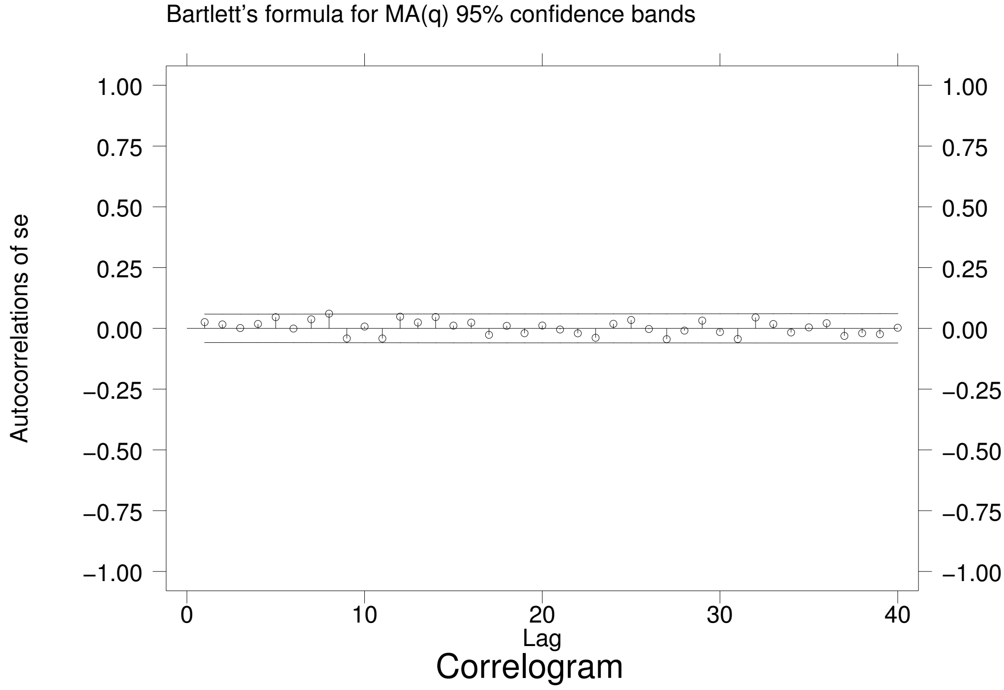
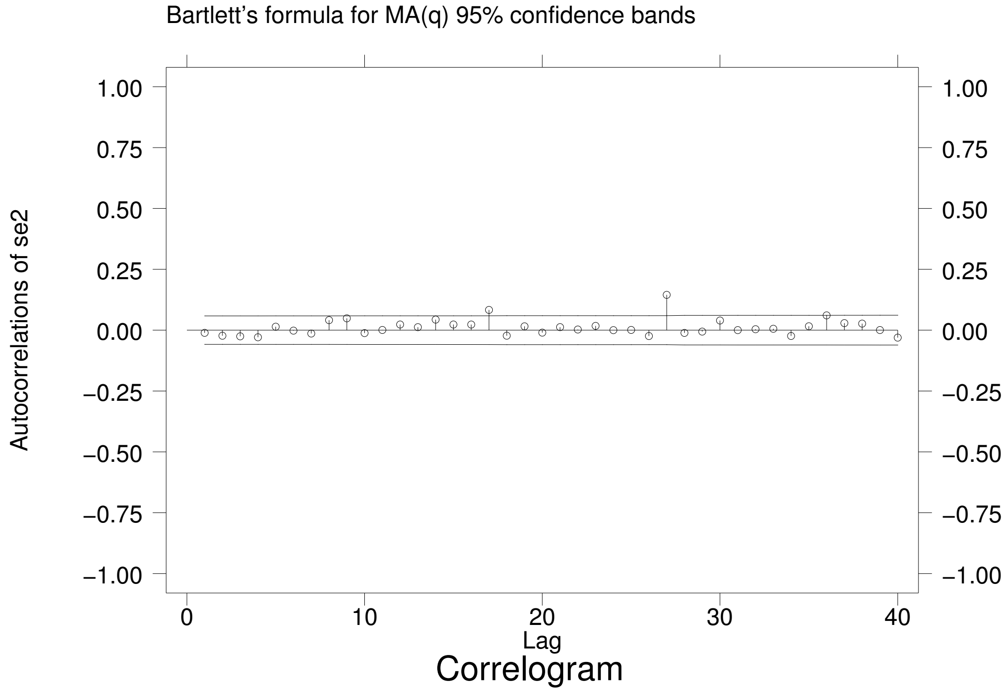


Figure 9 Autocorrelation function of squared standardised residuals



Annexure II

Robust Risk Containment Models for Interest Rate Derivatives in India

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March 2003

Robust Risk Containment Models for Interest Rate Derivatives in India

1 Introduction

Underlying this paper are three propositions:

1. The NSE zero coupon yield curve is not, as of now, sufficiently accurate for the estimation of sophisticated time series models for bond returns. This is primarily because the estimation error produces spurious components both in the autocorrelations and in the volatility clustering.

2. Frequent regime changes in the brief period since the inception of the yield curve series in 1997 also contributes to the difficulty of estimation of models with several estimable parameters.

3. It is dangerous to ignore periods of stress even if they belong to a period that is separated from the recent period by sharp regime shifts.

Flowing out of these three propositions is the belief that:

4. We should prefer simple and robust models with very few estimable parameters even if their performance is significantly worse than that of better models.

The paper therefore proposes a simple and robust margining system that provides adequate protection to the clearing corporation but produces a significant degree of over-margining.

2 Issues in Modelling the Times Series of Bond Returns in India

2.1 Estimation Errors and Autocorrelation

Estimation errors in the yield curve lead to spurious autocorrelations in the bond return series as shown below. I assume that the true yield x_t follows a random walk and that the observed yield y_t contains an estimation error e_t that is independently identically distributed (iid):

$y_t = x_t + e_t$	observation equation
$x_t = x_{t-1} + u_t$	random walk equation
$e_t \sim N(0,\sigma_e^2)$	noise is iid normal
$u_t \sim N(0,\sigma_u^2)$	yield changes are iid normal
$E(e_t\, u_t) = 0$	noise and yield changes are independent

We can then write:

$$y_{t-1} = x_{t-1}+e_{t-1}$$
$$y_t = x_{t-1}+u_t+e_t$$
$$y_{t+1} = x_{t-1}+u_t+u_{t+1}+e_{t+1}$$

This implies that the changes in yields δ_t are given by:

$$\delta_t = y_t - y_{t-1} = u_t + e_t - e_{t-1}$$
$$\delta_{t+1} = y_{t+1} - y_t = u_{t+1} + e_{t+1} - e_t$$

It follows therefore that

$$\mathrm{Var}(\delta) = \sigma_u^2 + 2\sigma_e^2$$

$$\mathrm{Cov}(\delta_t, \delta_{t+1}) = -\sigma_e^2$$

In other words, the estimation errors introduce a spurious autocorrelation in the observed yield changes though by assumption the true yields were following a random walk. The autocorrelation of δ is approximately $-\sigma_e^2/\sigma_u^2$ if we assume that σ_e^2 is much less than σ_u^2. Standard time series techniques would therefore indicate that the yield changes follow an AR(1) process (autoregressive process with one lag).

Similarly, there is a spurious ARCH (autoregressive conditional heteroscedasticity) component in the series of observed yield changes though the true yield changes (u_t) were assumed to be iid. The covariance between observed squared yield changes is as follows:

$$\mathrm{Cov}(\delta_t^2, \delta_{t+1}^2) = E(e_t^4) = 3\sigma_e^4$$

This implies that a high variance on one day is likely to be followed by a large variance on the next day as well. This volatility clustering would be reflected in an ARCH(1) model.

Thus a pure random walk would be transformed into a AR(1)-ARCH(1) process by the presence of estimation errors. Though the spurious autocorrelation and ARCH components have been demonstrated in terms of yield changes, the argument applies to bond returns as well. This is because zero coupon bond returns are roughly maturity times the negative of changes in yields.

The magnitude of the spurious autocorrelation and ARCH components obviously depends on the magnitude of the estimation errors (σ_e^2). At first, one might think that the maximum likelihood (and the associated non linear least squares) methodology that underlies the NSE's Nelson-Siegel yield curve ensures that there are no large estimation errors. Non linear least squares penalizes large errors disproportionately and the estimation would tolerate several modest errors rather than permit one large error. This appears to guarantee that σ_e^2 is unlikely to be large. This intuition is quite correct except for one possibility – the possibility that the long bond is not traded at all. In this situation there can be large errors in the long bond yield for the simple reason that if the long bond is not traded, there can be no pricing errors in the long bond. There is then nothing in the non linear least squares method to prevent very large errors in this yield. The question will doubtless be asked as to how the long bond yield is estimated if the long bond is not traded. The answer is that the Nelson-Siegel functional form will still estimate the slope of the yield curve from the short bond and intermediate term bonds and then extrapolate this slope (with some exponential damping) to the long bond. This extrapolation (like all extrapolations) can be completely off the mark and large errors in long bond yields are perfectly plausible. In India, until around 2001, the long bond was not quite liquid and there would have been many days in which too few long bonds traded to permit any sound estimation of the long bond yield.

Some evidence on this issue is presented below:

1. On 23/5/1997, the 10 year yield estimated by the NSE curve dropped 300 basis points, but this drop was completely reversed on the very next day. The newspapers of that period, report nothing unusual on those days and there is no mention of any upheaval in the market. It appears that long bonds were not traded at all on that day.
2. On 28/11/1998, there was a 75 basis point move in the 10 year NSE zero yield and this too was reversed the next day. Again there is nothing unusual reported in the newspapers.
3. A slightly different pattern is observed on 27/2/1999. Some volatility is to be expected on this budget date since the budget projected a fiscal consolidation and sent a strong signal to the RBI to ease rates. But the ten year yield *rose* sharply on this date. No major change took place on the next day which was a Saturday. On Monday, 1/3/1999, the RBI announced major interest rate cuts. The yield rise of 27/2/1999 was completely reversed. It is most likely that the movement of 27/2/1999 was an estimation error. It also demonstrates that intervening Saturdays (on which trading is very light) can delay the yield reversal by one day. This can induce spurious AR and ARCH components at two lags. A spurious AR(2)-ARCH(2) model is a serious possibility.
4. More troubling than any of the above is an error in the more recent period of the data after the regime shift of early 1999. On 25/8/2000, there was a 45 basis point move and this too was reversed on the next day. Discussions with market participants indicate that nothing unusual happened on that day, and this was almost certainly an estimation error.

As already argued, it is likely that most of these estimation errors arise from lack of trading in the long bond. It is likely that the period after 2001 where the long bond has become very liquid would have eliminated this problem. As such the spurious AR and ARCH components may well disappear if we estimate a time series model only from the last 2-3 years of data. However, this would create other problems as discussed later in this paper.

2.2 Mean Reversion and Autocorrelation

Theory tells us that interest rates exhibit mean reversion and this is bound to be reflected in AR terms in the model for bond returns. I now turn to an investigation of how large this component is and what is lost by ignoring the AR term.

Let

f(t) be the one day forward rate from day t to day t+1
s = f(0) be the one day rate spot rate at time 0
P(t_1,t_2) be the price on day t_1 of a bond maturing on day t_2
E denote expectation at time 0

All the interest rates are daily rates; that is to say they are not annualized. Time is measured in days so that the ten year bond is obtained by setting t=10*365. We have the following relationships for the prices today and tomorrow of the ten-year zero coupon bond and the ten-year-and-one-day zero coupon bond:

P(0,10*365+1) = P(0, 10*365)/(1+f(10*365)) by definition of forward rates
E [P(1, 10*365+1)] = (1+s) P(0,10*365+1) by the expectations hypothesis

The expected return on a constant maturity 10 year zero over the next one day is given by

$$E\,[P(1, 10*365+1) / P(0, 10*365)] - 1 = (1+s) / (1+f(10*365) - 1$$
$$\approx s - f(10*365)$$

The quantity [s – f(10*365)] is the difference between the current one-day spot rate and the forward rate for a one-day deposit beginning ten years from now. The difference between these reflects the mean reversion of the short rate to its long run expected value. The maximum value of [s – f(10*365)] over the period from 1/1/1997 to 5/3/2003 as estimated from the NSE yield curve is about 7.5% annualized on 23/5/1997 (it has not crossed 5% annualized after that date and is less than 1% annualized currently). If we take 7.5% annualized and convert to a daily rate we get 2 basis points. The median standard deviation of daily returns in the ten year bond over the last six years is 68 basis points. In other words mean reversion accounts for a tiny fraction of the return. The squared mean reversion is less than a thousandth of the median variance. Since it is the squared mean and the variance that are relevant while estimating a GARCH process, it follows that the mean (and any AR processes underlying it) can be safely ignored while estimating the GARCH model.

2.3 Regime Changes

It is difficult to deny that there have been many regime changes in the interest rate regime since the inception of the NSE yield curve in 1997. One very clear regime change is the end of the Asian crisis in late 1998 and early 1999. The RBI formally signalled the end of the crisis on March 1, 1999 with a deep cut in interest rates. Other regime changes could rise from the emergence of the interest rate swap market in 2001 and the (perhaps unrelated) rise in the liquidity of the long bond around the same period. There is some evidence of a change in volatility and persistence parameters in the post 2001 period[1].

These regime changes create a difficult dilemma while estimating an econometric model:

- We can estimate a single model across the whole period ignoring the regime shifts. However such an estimate across heterogeneous regimes leads to biased and inconsistent estimates.

- We can estimate a model only for the most recent time period hoping that this is a homogeneous regime. However, it is dangerous for risk management purposes to estimate a model using only a period of rising asset prices as in the post 2001 or even post 1999 periods. Ideally, the model should be estimated over at least one interest rate cycle and at least one complete business cycle.

2.4 Stress Events

In the Indian fixed income market, 1997 and 1998 stand out as periods of intense stress as the RBI used interest rates to defend the rupee from contagion from the Asian Crisis. In particular, September-October 1997, January 1998, May 1998 and August 1998 were periods of intense turbulence in the currency and debt markets.

It is possible to argue that 1998 belongs to a stage of evolution of the economy that is now well behind us. In particular, it has been argued[2] that in 1998 we were in the midst of a transition from a closed economy with financial repression to a more open economy with reduced repression and that as we move to more and more convertibility, the kind of monetary policy interventions that happened in 1998 would become both unnecessary and unlikely.

I do not deny that there is considerable merit in this argument. In particular, I would think that the increasing stock of floating rate housing loans would make it politically costly to implement a savage monetary tightening. If so, events like those of January 1998 would become less likely. But financial history teaches us that even mature economies have mustered the political will to inflict severe pain on the domestic economy in the pursuit of cherished exchange rate targets. Sweden's decision in 1992 to raise overnight rates to 500% rather than abandon its shadow membership of the European exchange rate mechanism is a notable example. In that case, the Prime Minister actually called an all party meeting to mobilize political support for his exchange rate policy.

Another problem with excluding 1998 from the sample is that by doing so we would be left without any significant period of falling bond prices. I have already argued that it is dangerous for risk management purposes to estimate a model using only a period of

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[1] Gangadhar Darbha, personal communication

[2] Ajay Shah, personal communication

rising asset prices. Ideally, the model should be estimated over at least one interest rate cycle and at least one complete business cycle.

3 Proposed Model

3.1 IGARCH Model for Volatility

All these considerations lead me to prefer a robust model with very few estimable parameters. There are many possible models that meet this requirement[3]. In this paper, however, I focus on the IGARCH model also known as the Risk Metrics or Exponentially Weighted Moving Average (EWMA) model. This model assumes that the mean return is zero and models the evolution of the volatility (σ_t^2) of the returns (r_t) as:

$$\sigma_t^2 = \lambda \sigma_{t-1}^2 + (1-\lambda) r_{t-1}^2$$

$r_t / \sigma_t \sim N(0,1)$ or more generally iid with zero mean & unit variance

In this model λ is a smoothing parameter to be estimated. However, I believe that all the arguments given above about the difficulties in parameter estimation because of estimation errors and regime shifts are equally applicable to the estimation of even this single parameter λ. I therefore avoid the estimation of this parameter by using the value of 0.94 which is used in the Risk Metrics model. Risk Metrics uses this value because (a) this value performed reasonably well for a wide range of asset classes in many countries, and (b) the use of a single λ for all assets allows the estimation of a multivariate IGARCH model in which the correlations are also estimated by an equation similar to that for volatility using the same value for λ.

3.2 Measuring Exchange Rate Stress

As I have argued earlier, I do not agree with the idea of ignoring the stress events of 1998 on the ground of a subsequent regime shift. On the contrary, I propose to measure exchange rate stress and account for it in the margining process.

Basically this measurement relies on three sets of variables[4]:

- ***Monthly data on the real effective exchange rate (REER).*** Figure 1 shows the 5 country REER (1993-94=100). Inspection of the plot suggests that this could be converted into an index which is

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[3] For example, Gangadhar Darbha (personal communication) recommends the use of EVT models with Hill type estimators.

[4] The underlying data for all these variables were extracted from the CMIE's Business Beacon

0 if the REER is below 103,
1 if the REER is between 103 and 106 and
2 if the REER is above 106.

High values of the index signal possible downward pressure on the currency according to Purchasing Power Parity (PPP). Unlike the next two measures, this index does not measure actual ongoing stress, but is an indicator of vulnerability to future stress. The primary justification for including the REER in the stress index is that PPP is the single most important fundamental driving the exchange rate market. There are two different ways in which PPP deviations could lead to currency market stress. First, the central bank may resist the PPP correction when it comes. Second, if the central bank lets the market find its own level, the currency could well overshoot and fall beyond the required PPP correction. This in turn might bring the central bank into the fray to correct the overshooting. Either way, PPP corrections could induce interest rate volatility.

- ***Weekly data on loss of reserves.*** Figure 2 plots cumulative changes in foreign exchange assets excluding gold and SDR over the last 13 weeks (one quarter) as a percentage of M3. Inspection of the plot suggests that this could be converted into an index which is

  0 if the 13 week reserve loss is less than 0.5% of M3,
  1 if the loss is between 0.5% and 1% and
  2 if the loss is over 1%.

  High values of the index signal that downward pressure on the currency has been resisted by expending reserves. At some stage the central bank could decide that it has lost enough reserves and that it is time for other steps (including interest rates) to defend the currency.

- ***Daily data on INR-USD rate.*** Figure 3 shows the standard deviation of daily logarithmic returns over the last 13 weeks of the INR-USD rate. This is a simple sample standard deviation and not a GARCH estimate. Inspection of the plot suggests that this could be converted into an index which is

  0 if the daily standard deviation during the last 13 weeks is less than 0.4%, and
  1 if the standard deviation exceeds 0.4%.

  High values of the index signal that the central bank has let the currency be buffeted a lot by market forces. At some stage, the central bank could decide that the volatility needs to be controlled and that it is time to intervene. Interest rates could be part of the arsenal when intervention begins.

Figure 1: Real Effective Exchange Rate. Visual inspection of this plot of the 5 Country REER (1993-94 = 100) suggests that the REER component of the index of exchange market stress be computed as follows: 0 if the REER is below 103, 1 if the REER is between 103 and 106 and 2 if the REER is above 106. Source for underlying data is CMIE.

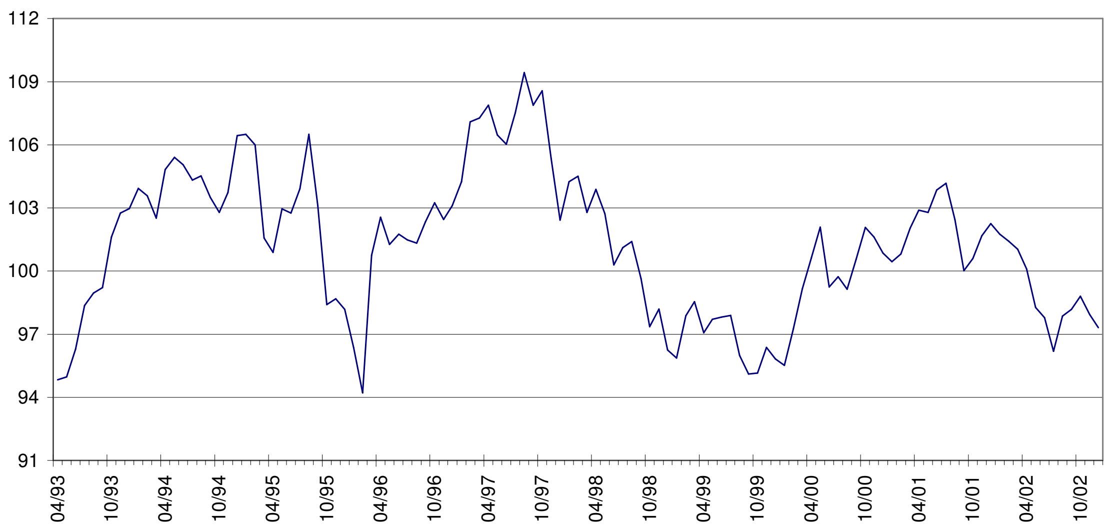

Figure 2: Last Quarter Change in Foreign Exchange Reserves. This is a plot of the cumulative change in reserves (foreign exchange assets excluding gold and SDR) in the last 13 Weeks (one quarter) as a percentage of M3. Visual inspection of this plot suggests that the reserve loss component of the index of exchange market stress be computed as follows: 0 if the quarterly reserve loss is less than 0.5% of M3, 1 if the reserve loss is between 0.5% and 1% of M3 and 2 if the reserve loss is over 1% of M3. Source for underlying data is CMIE.

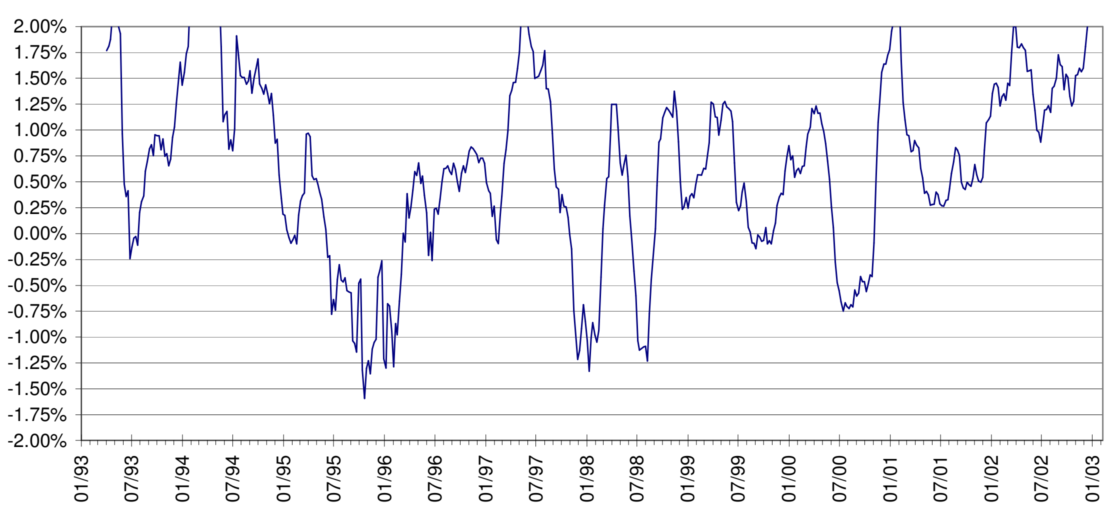

Figure 3: Exchange Rate Volatility. This is a plot of the sample standard deviation of of daily log returns of the rupee-dolar exchange rate during the last 13 weeks. This is a simple sample standard deviation and not a GARCH estimate. Inspection of the plot suggests that the exchange rate volatility component of the index of exchange market stress be computed as follows: 0 if the daily standard deviation during the last 13 weeks is less than 0.4%, and 1 if the standard deviation exceeds 0.4%.. Source for underlying data is CMIE.

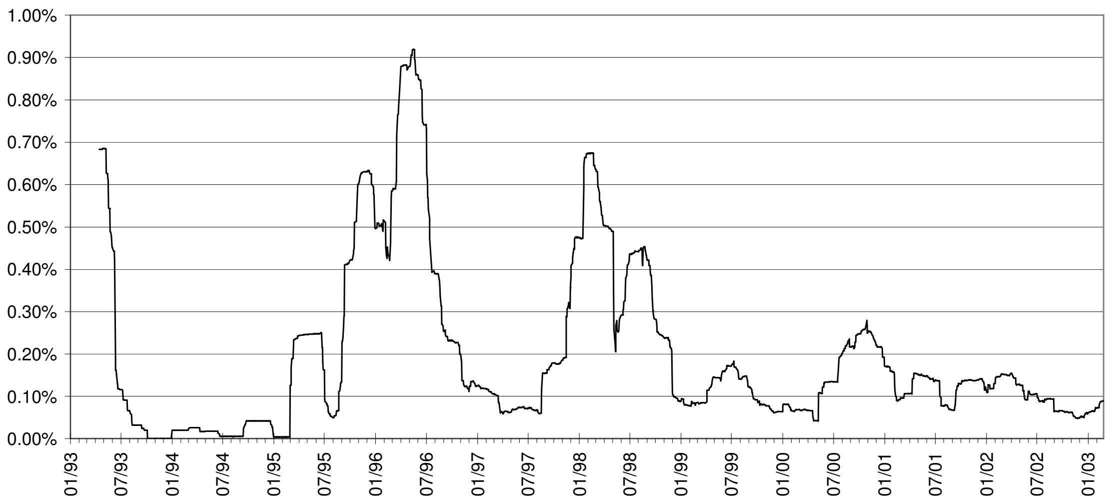

Figure 4: Index of exchange market stress. This index is the sum of three sub indices. The first component which measures deviations of the real effective exchange rate (REER) from its 1993-94 value is equal to 1 if the REER is between 103 and 106 and is equal to 2 if the REER is above 106. The second component which measures loss of foreign exchange reserves is equal to 1 if the reserve loss is between 0.5% and 1% of M3 during the last quarter and is equal to 2 if the reserve loss exceeds 1% of M3. The third component which measures exchange rate volatility is equal to 1 if the standard deviation of daily log returns of the rupee-dollar exchange rate over the last quarter exceeds 0.4%. Exchange market stress is signified when the composite index (sum of the three sub indices) exceeds 2.

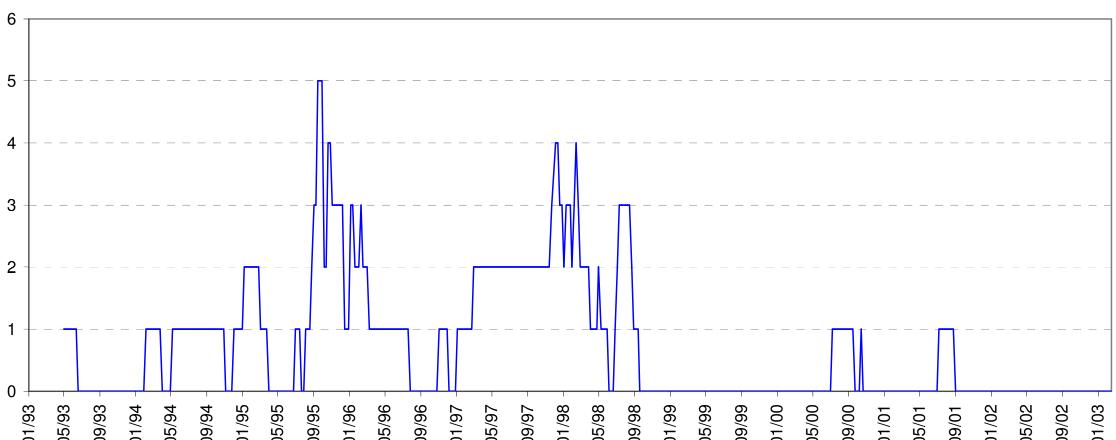

Figure 4 shows a plot of the composite index of exchange market stress computed by simply adding the above three sub indices. Acute stress appears to be reflected in an index value exceeding 2 (that is to say 3 or above). The periods of stress identified by this criterion are September/October 1995, parts of January/February 1996, December 1997-

February 1998 and July/August 1998. All of these have been periods of intense interest rate turbulence.[5]

4 The Proposed Risk Containment System

4.1 VaR Margins for the 10 year bond

This paper proposes a simple model for VaR margins:

1. Volatility is computed using the IGARCH (Risk Metrics or EWMA method) with a smoothing constant of 0.94.

2. The daily margin is computed as 3.5 times the standard deviation to provide a 99% value at risk estimate. For moderately non normal distributions, 3 times the standard deviation is regarded as a rule of thumb for 99% value at risk. As such, the multiplier of 3.5 reflects higher than moderate degree of non normality of the returns even after using an IGARCH model to account for conditional heteroscedasticity.

3. Additional margins need to be imposed to account for exchange market stress. For the sake of concreteness, this paper uses an *additional* margin of 10% applied on the 10 year bond on days when the index of currency market stress exceeds 2. In practice, the exchanges would need to evolve their own practices in regard to the treatment of exchange rate stress.

The result of this exercise is shown in Figure 5. The blue lines represent the margins (on long and short positions), the black crosses represent the actual returns, and the red squares represent returns that exceed the margins available. There are 20 occasions (out of 1792 trading days) when the return exceeds margins based on 99% value at risk. This is slightly above the expected number of 18 violations for a 1% violation rate, but a two-tailed test at the 5% significance level cannot reject the hypothesis that the true rate of violations is 1%. This is a perfectly acceptable performance. However, the large amounts of white space between the blue lines are indicative of over margining – most of the time, the margins are well in excess of the actual returns. This is part of the price that we pay for a relatively crude margining model.

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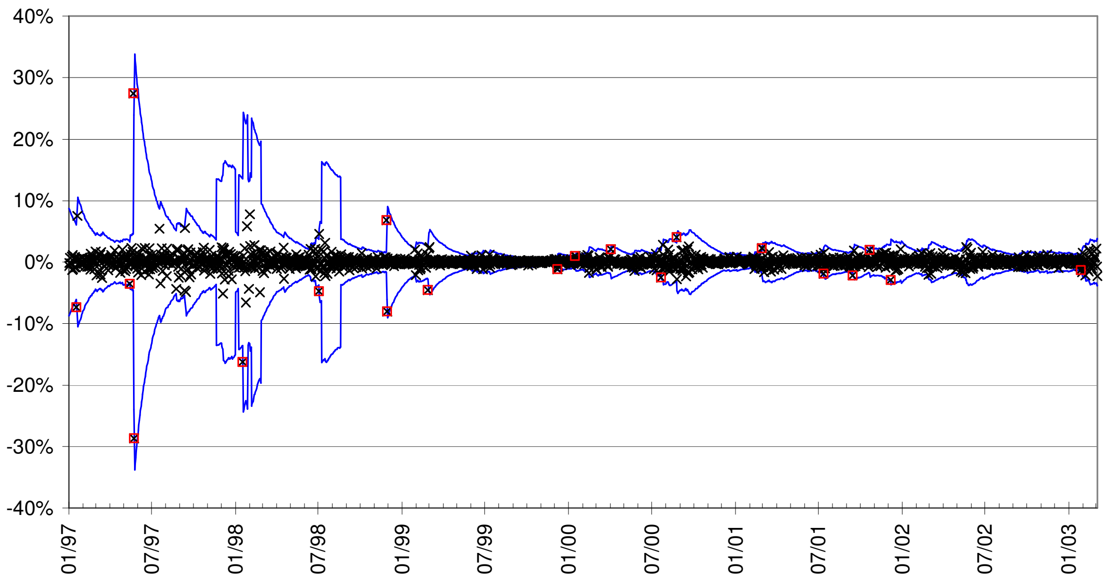
[5] . Of course, the NSE ZC YC does not extend back to the first two periods in 1995-96, but the interest rates havoc was quite visible in that period. Inter bank call rates went to 40-50% during this period and high grade commercial paper went at 20-30%. The interest rate volatility is not visible in the cut-off yields in T-Bill auctions, but this is because the RBI preferred to accept only non competitive bids and let most of this paper devolve on itself, rather than raise the cut-off yields.

Figure 5: Margins, Returns and Shortfalls: The blue lines represent the margins (on long and short positions), the black crosses represent the actual returns, and the red squares represent returns that exceed the margins available. The large amounts of white space between the blue lines are indicative of over margining - most of the time, the margins are well in excess of the actual returns. This chart ***includes*** reversal errors like that on 23-24 May 1997 which causes the big surge in margins in that month.



Closer inspection shows that some of the large margin violations are possibly spurious – they arise from the yield curve estimation errors discussed earlier in this paper. For example, the "reversal error" of 23-24 May 1997 causes large margin violations and through the IGARCH model, also causes a big spike in margins for the next several days. To get a more reasonable measure of the performance of the margining model, it is necessary to eliminate such obvious estimation errors. A simple way of dealing with this problem is to eliminate all days on which the 10 year yield moves by 50 basis points or more and reverses on the next day. This is not designed to trap all errors – it does not capture the error on 25/8/2000 discussed above since the move on that day was only 45 basis points.

With this correction, there are only 14 days on which the return exceeds the margin. This is somewhat below the expected number of 18 violations for a 1% violation rate, but a two-tailed test at the 5% significance level cannot reject the hypothesis that the true rate of violations is 1%.

4.2 Second line of defence for the 10 year bond

I now turn to the second line of defence that is required to cover the expected shortfall in a margining system when the return distribution has fat tails. With normally distributed returns, the second line is not required since the expected shortfall is for all practical purposes equal to the 99% VaR[6].

After excluding reversal errors, the shortfalls are as follows:

- the average shortfall is 0.57%
- the maximum shortfall is 2.67%
- the next highest shortfall (maximum but one) is 1.81%
- the next highest shortfall (maximum but two) is 0.60%

If it is desired that the second line cover only the average shortfall, the second line should be around 0.60%. This would also cover all but the two most extreme cases of margin shortfall. To be conservative, however, the second line of defence could be set at 1%.

4.3 Minimum margin for the 10 year bond

The IGARCH model has one serious problem in that it could drive margins down to near zero if the returns are close to zero for a long period. By contrast, a proper GARCH model continually pulls the estimated variance towards the long run variance and therefore prevents it from approaching very low levels. Since the IGARCH model does not have this inbuilt protection, it is necessary to impose this from outside in the form of a minimum margin. Setting this minimum slightly below the median margin would imply a minimum margin of about 2%. This would be about half the average margin.

Needless to say, the minimum margin also contributes to the over-margining in the total system.

4.4 Margining for other maturities

The margining system described above can be extended to other maturities as well. The performance of the model for various maturities is shown in Figure 6.

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[6] From Extreme Value Theory, we know that for large X, the conditional expectation $E[Z \mid Z \geq X]$ is close to X if Z follows the normal distribution or any other distribution with thin tails. Thus a 99% VaR covers the expected shortfall in 99% of the cases. For fat tailed Z, however, the conditional expectation (the expected shortfall) can be significantly higher than X.

Figure 6: Performance of IGARCH (Risk Metrics) Based Margining Models for 99% VaR

Margining Parameters

Volatility is estimated using an exponentially weighted moving average with a smoothing constant of 0.94. The VaR Margin is set at 3.5 standard deviations. The data period is from 1/1/1997 to 5/3/2003.

Adjustment for FX-Pressure

When the Index of FX pressure exceeds 2, an extra margin of 10% is imposed on the 10 year bond. For other maturities the 10% margin is scaled up in proportion to the volatility of that maturity.

Exclusion of reversal errors

Violations and margin shortfalls are ignored if they are associated with days on which the 10 year zero yield moves by 50 basis points or more with a reversal of 50 basis points or more on the next day. For other maturities the 50 basis points cut-off is scaled up in proportion to the volatility of that maturity.

Maturity (years)	**0.25**	**1**	**3**	**5**	**7**	**10**	**15**	**20**
Number of observations	1789	1789	1789	1789	1789	1789	1789	1789
Violation Count								
Positive	4	5	4	6	3	5	6	6
Negative	6	8	10	10	8	9	10	8
All	10	13	14	16	11	14	16	14
Average Shortfall								
Positive	0.01%	0.03%	0.21%	0.37%	0.60%	0.33%	0.64%	1.37%
Negative	0.04%	0.13%	0.33%	0.39%	0.91%	0.70%	0.78%	1.43%
All	0.03%	0.09%	0.30%	0.38%	0.83%	0.57%	0.73%	1.40%
Maximum Shortfall								
Positive	0.04%	0.05%	0.37%	1.15%	1.23%	0.88%	1.43%	3.11%
Negative	0.17%	0.52%	0.81%	0.97%	2.13%	2.67%	2.38%	4.83%
All	0.17%	0.52%	0.81%	1.15%	2.13%	2.67%	2.38%	4.83%
Max_but_one Shortfall								
Positive	0.01%	0.04%	0.21%	0.72%	0.35%	0.47%	1.20%	1.54%
Negative	0.02%	0.23%	0.79%	0.70%	1.53%	1.81%	1.65%	2.14%
All	0.04%	0.23%	0.79%	0.97%	1.53%	1.81%	1.65%	3.11%
Max_but_two Shortfall								
Positive	0.00%	0.02%	0.16%	0.24%	0.22%	0.18%	0.51%	1.08%
Negative	0.02%	0.20%	0.63%	0.59%	1.21%	0.60%	1.36%	1.53%
All	0.02%	0.20%	0.63%	0.70%	1.21%	0.60%	1.36%	1.54%
Average Volatility	0.08%	0.19%	0.30%	0.43%	0.62%	0.98%	1.83%	2.94%
Shortfalls as % of Median Margin								
Average	14%	16%	34%	32%	51%	24%	16%	17%
Ave sans 2 max	6%	7%	24%	24%	37%	12%	12%	12%
Maximum	78%	95%	92%	97%	130%	113%	51%	58%
Max but one	17%	42%	90%	82%	93%	76%	36%	38%
Max but two	11%	36%	72%	59%	74%	25%	29%	19%
Margins								
Minimum	0.05%	0.16%	0.25%	0.28%	0.33%	0.54%	1.12%	1.85%
Maximum	1.53%	4.23%	7.24%	13.92%	21.64%	33.79%	54.52%	75.38%
Average	0.32%	0.80%	1.23%	1.77%	2.55%	4.02%	7.50%	12.03%
Median	0.22%	0.55%	0.88%	1.18%	1.64%	2.37%	4.66%	8.30%
FX Pressure Margining								
Margin rate	0.79%	1.98%	3.06%	4.41%	6.34%	10.00%	18.64%	29.89%
No of days	103	103	103	103	103	103	103	103

The proposed margining system is as follows:

1. Volatility is computed using the IGARCH (Risk Metrics or EWMA method) with a smoothing constant of 0.94.

2. The daily margin is computed as 3.5 times the standard deviation.

3. Additional margins need to be imposed to account for exchange market stress. For the sake of concreteness, this paper uses an *additional* margin of 10% applied on the 10 year bond on days when the index of currency market stress exceeds 2. The margins for other maturities are obtained by with the 10% margin being scaled up in proportion to the volatility of that maturity relative to the volatility of the 10 year bond. In practice, the exchanges would need to evolve their own practices in regard to the treatment of exchange rate stress.

4. The second line of defence can be set at approximately half the median margin.

5. The performance of the margining system shown in Figure 6 is without the imposition of any minimum margin. As argued in 4.3 above, it is desirable to impose a minimum margin which could be set slightly below the median margin. This would add to the over-margining that already exists.

The resulting margining system would provide adequate protection to the clearing corporation, but would include a significant element of over-margining.