Methodologies for Determining Minimum Capital Standards for Internationally Active Securities Firms Which Permit the Use of Models Under Prescribed Conditions

A Report by the Technical Committee of the International Organization of Securities Commissions

May 1998

Executive Summary

- In July 1995, the Technical Committee of IOSCO (the Technical Committee) issued a report on "the implications for securities supervisors of the increased use of value at risk models by securities firms". In view of the significance of market risk capital requirements for securities firms, the Technical Committee took the view that the state of knowledge and experience on the use of value at risk (VaR) at that time was insufficient to allow VaR to be used for regulatory capital purposes. In particular, the Technical Committee called for more work to be done on model testing and the development of "standards of best practice" to be adopted by firms which wish to use VaR models for regulatory purposes.

- To ensure that the 1995 recommendation was kept under review, the Technical Committee set up a prudential taskforce to examine the key issues. It has become clear that much of the work that the Technical Committee called for in 1995 has been undertaken or is in progress.

- Overall, greater familiarity with the theory of modelling and the growing body of experience in its application, means that the Technical Committee is prepared to accept that VaR models can have a role to play in the setting of regulatory capital for market risk. However, supervisors need to be mindful of the limitations of VaR methodologies. The market risk capital charge should be increased over and above the VaR output to address these limitations.

- Supervisors need to ensure that they have the resources and the expertise to make appropriate supervisory judgements about the quantitative and qualitative aspects of a VaR approach. The adoption of VaR models involves a shift to greater reliance on a firm's controls and therefore requires an enhancement in the supervisor's ability to assess their effectiveness.

- While VaR models can have a role to play in setting regulatory capital for market risks, the Technical Committee believes that for credit risk VaR methodologies are currently being developed and may have a role in the future for regulatory capital purposes.

- If VaR is going to provide the starting point for calculating market risk regulatory capital, supervisors should not lose sight of all the other risks that cannot be easily quantified such as legal risk and operational risk. To cover these other risks it is envisaged that additional capital or "buffers" should be introduced over and above the market risk capital charge. To this end, the report sets out a number of possible avenues that supervisors and securities firms might wish to explore to ensure that appropriate buffers and other complementary approaches are put in place.

- A combination of the new market risk capital charge, the existing charge for credit risk and additional buffers can provide sufficient capital. However, there is no implication in this report that the adoption of VaR models will lead to a fall in the current level of regulatory capital, but will instead enable firms to manage their risks more efficiently.

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Introduction

This report reviews the role of capital and controls in a supervisory context with reference to the key risks faced by securities firms. An assessment is made of value-at-risk (VaR)[1] models in respect of those risks and regulatory capital requirements. The paper then identifies the need for additional capital charges ("buffers") to deal with the risks not captured through models and discusses options for providing those buffers. Finally, it looks at complementary regulatory approaches to dealing with some of these risks.

Role of Capital and Controls

The acceptance of risk and its management is an integral part of a securities firm's business. Firms develop systems of control designed to keep losses at a manageable level, (i.e. absorbable by current earnings, ideally without jeopardising overall goals for return on assets or capital). On top of this, firms will keep some capital to act as "internal insurance" in the event that losses are higher than expected. If a firm gets this capital / risk ratio wrong, it runs the risk of insolvency.

The supervisor's involvement is motivated by two key considerations. First, the need to protect investors and preserve the integrity of the market. Second, the reduction of systemic risk. The purpose of regulatory capital is therefore to reduce the probability of insolvency to an acceptable level and provide for an orderly wind-down of a firm.

Capital is not the only tool available to a supervisor. It is however an attractive tool because it is relatively non-intrusive. The supervisor can set capital requirements without getting involved in assessing a firm's day-to-day business decisions. Nevertheless, the level of capital should be proportional to the risks being run by the firm. If not, the supervisor will be giving firms the wrong incentives as the charges shape the way firms undertake their business. Gaps or anomalies in capital requirements may lead to damaging insolvencies as firms look to reducing the capital charge at the expense of managing the risks.

Of equal importance to capital are effective controls. The Technical Committee has published 12 benchmarks by which supervisors and securities firms can measure the adequacy of control systems.[2] Adequate systems and controls reduce the risks being run by a firm and hence implicitly increase the capital / risk ratio and reduce the probability of insolvency. Whether supervisors prefer to increase the capital / risk ratio by focusing on capital rather than controls will to some extent depend on the type of risk being examined. The following section examines particular risks in turn with a view to identifying the role of capital and controls in relation to each risk.

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[1] Generally, VaR is an estimate of the maximum potential loss expected over a fixed time period at a certain probability or confidence level. In practice, VaR models aggregate several components of price risk into a single quantitative measure of the potential for loss.

[2] Risk management and control guidance for securities firms and their supervisors. A report by the Technical Committee of IOSCO - May 1998

Risks Faced by Securities Firms and the Role of Capital and Controls

It is not the intention of this paper to define all the risks faced by firms. However, it is necessary to provide some working definitions of the key risks to inform this paper and ensure common understanding amongst the readership. The definitions are given in italics followed by a commentary on the role of capital and controls.

Market Risk: *The risk that a position will not be as profitable as an investor expected because of fluctuations in market prices or rates (e.g. equity prices, interest rates, currency rates or commodity prices).* Internal management defences against this risk include continuous marking to market, monitoring against limits and active hedging. There will still be exposures and hence the possibility of the firm's net worth being eroded through unfavourable market moves impacting on the mark-to-market value of positions. Regulatory capital aims to provide an acceptable margin for this erosion to occur prior to the firm becoming insolvent.

Liquidity Risk: *The risk that a position cannot be funded (**funding risk**) or unwound/hedged except at a loss compared to the mark-to-market valuation (**market liquidity risk**). In the latter case, the risk is related to a miscalculation in the assumption of market liquidity in a particular instrument or market segment.* As far as **funding risk** is concerned, key internal management protections will include limiting maturity mismatches between cash inflows and outflows, securing funding lines, and maintaining a stock of highly liquid assets. This is primarily a matter for controls rather than a capital issue. **Market liquidity risk**, however, is an extreme form of market risk. Capital and controls will play similar roles as for 'normal' market risk.

Credit Risk: *The risk that one of the parties to a contract will not perform on its obligations.* Internal management defences include counterparty assessment and monitoring; limits on exposure concentrations; active risk transfer or hedging (e.g. through credit derivatives); and risk reduction through collateralisation or netting. Regulatory capital requirements are imposed to protect against the credit risk that remains (again, by establishing an acceptable margin for the erosion of net assets).

Operational Risk: *The risk that loss will occur from a breakdown in systems and controls. It may also include losses from external events such as natural disasters.* The Technical Committee recognises that the industry is devoting considerable resources to identifying and dealing with specific elements of operational risk. For the purposes of this paper, however, the term 'operational risk' is used in its broadest sense. Ensuring adequate systems and controls are in place and operating effectively is of major importance in relation to operational risk. Regulatory action in cases of perceived high risk firms is likely to take the form of requiring changes in staff / management / procedures or restricting the business of the firm. Capital is relevant, however, since requiring higher capital from higher risk firms is a way of adjusting incentives and helping ensure action in areas of weakness. And the more capital a firm has, the bigger the loss from operational failure that would be required to send it under.

Legal Risk: *The risk that loss will arise from deficiencies in contracts and legal opinions, from extended legal proceedings or from conduct of business infractions.* This risk can best be

guarded against by internal systems of control including adequate legal and compliance resources. However, as with operational risk, a capital buffer will help a firm survive unexpected losses in this area.

Systemic Risk: *The risk that failure in one firm / segment of the market will trigger failure in another firm / segment or throughout the entire financial market (the domino effect).* Adequate risk management and controls across the system will reduce the risk in this area. Furthermore, the chance of a domino effect will be reduced by ensuring that securities firms individually are well capitalised in relation to the risks set out above.

Risks and VaR Models

As seen in the previous section, the emphasis between capital and controls varies according to the nature of the risk. However, securities firms have put forward a number of arguments against the way existing capital requirements are structured. These can be summarised as follows:

(i) they are uneconomic, and drive business into unregulated or less regulated entities;

(ii) they have little relevance to how firms internally manage their business and hence create unnecessary costs;

(iii) they do not reflect the real risk at an individual firm, specifically because they offer only limited recognition to hedges, correlations and offsets.

The Technical Committee agrees that capital requirements should be based on risk (insofar as this can be measured), not least in order to give firms the right incentives to reduce risk. The increased use and experience of VaR models by securities firms for internal risk management purposes has caused the Technical Committee to look again at the case for basing some part of regulatory capital requirements on the output of VaR models. In the last four to five years, securities firms and supervisors have gained practical experience in modelling, particularly of market risk. This has been assisted by a number of studies (see the appendix for references).

The above work has established that VaR models are more readily applicable to environments with the following characteristics:

- Where there is a long run of data for the risk factors being modelled, with a very high frequency of observations. The more information there is to calibrate the model, and then test it, the more confidence firms (and supervisors) can have in the appropriateness of the output.

- Where the distributional assumptions made by the model reflect the essential features of the market, e.g. if the model assumes a normal distribution, the actual returns exhibit a low degree of skew or fat tailedness.[3]

- Where underlying exposures lend themselves to aggregation without undue loss of risk sensitivity.

From this combination of practical experience and research, supervisors have been in a position to develop a framework to approach the use of models for regulatory capital purposes. It is recognised that there can be no certainty that the future will resemble the past. In addition, assumptions that seemed reasonable at the time of developing the model could well, at some point in the future, lose their validity. Considering these points, the recognition of models requires supervisory involvement in the following areas:

(i) verifying that VaR models are fully integrated into the day to day risk management processes of the firm with an appropriate level of independent verification;

(ii) approving the parameters of the models such as minimum holding period, confidence level and historical observation period;

(iii) assessing the reliability of the models including the use of correlations (e.g. through establishing a framework for backtesting);

(iv) ensuring that firms regularly review the performance of their models and take action on the outcomes of their internal backtesting;

(v) ensuring that firms supplement their modelling approach by a programme of stress testing that is appropriate to their particular risk profile and concentration of exposures;

(vi) obtaining appropriate and timely information on the outcomes of backtesting and stress testing;

satisfying themselves that firms have adequate financial and human resources to adopt and operate a VaR model;

(viii) determining an additional amount of capital to be added to the value at risk number as a safeguard against unavoidable shortcomings of the VAR approach;

There are some qualifications in a move to VaR modelling that securities supervisors should be mindful of. In particular the following should be noted:

[3] A 'fat tail' means that a greater number of extreme events (such as significant price changes) occur than would be implied by a normal distribution.

- the adoption of VaR models involves a shift to greater reliance on a firm's controls and therefore requires an enhancement in the supervisor's ability to assess their effectiveness.

- model recognition will be an onerous process that will be demanding on supervisory resources and raise difficult issues regarding timing and prioritisation of VaR applications.

- there is systemic risk inherent in a generalised move towards VaR in any standardised way. Were this to happen, there would be two risks: first, that an unknowingly flawed model would become the standard; second, that the primary purpose of meeting internal risk management requirements would be jeopardised as firms seek to obtain supervisory recognition and / or lower capital charges. Supervisors must therefore be open to innovation in the way that, for example, stress testing scenarios are developed and relevant correlations recognised.

VaR - For Today

Market Risk

Market risk has been the proving ground for the VaR methodology. In all the major markets for equities, debt and foreign exchange, as well as for many commodities markets, there is a huge amount of publicly available daily price data. Pre-processing techniques have been developed which allow transactions to be aggregated into fewer positions to facilitate a modelling approach.

VaR models have been increasingly used and accepted as a risk management tool in the area of market risk. Many of the largest investment banks have now accumulated significant experience in the design, operation, and management of models for the purpose of controlling risk and pricing products. A number of supervisors have for some years been developing expertise in reviewing the integrity of individual models (e.g. option pre-processing models and foreign exchange VaR models) and the effectiveness of the associated control systems. Other supervisors have worked closely with major firms in improving their understanding of the strengths and weaknesses of market risk modelling.

The VaR approach to modelling market risk has a number of attractions as a basis for regulatory capital charges. The supervisory framework based on VaR should not require frequent updating to take account of market evolutions. It bases risk measures on an extensive, and continuously updated, dataset of empirical observations. The dataset allows for backtesting of models and hence assessment of their accuracy.

It is recognised that the output of VaR models does vary (as shown by the studies cited in the appendix); it will be a task for supervisors to design a framework to ensure that models are used appropriately and that the level and bias of variations is not of economic significance.[4] The aim

[4] Some firms currently use models that assume a normal distribution, whereas market returns are not normally distributed. However, the experience of the Basle Models Taskforce, for instance, was that there was no systematic difference between the results of banks using the historical simulation approach and variance / co-variance.

of using VaR models (subject to supervisory oversight) would be to achieve a better relationship between regulatory capital and the relative risks of portfolios.

To the extent that models rely on historical data (and in practice most do), they will be faced with the problem that the future will not always resemble the past. However, this is a problem for all methods of quantifying risk, and therefore for any supervisory approach that attempts to measure risk. Again, it is a matter for supervisory judgement how, and to what extent, capital charges have to be increased to compensate for this.

Market Liquidity Risk

In the normal course of events, market risks can be captured by VaR models. The danger lies in extreme market movements when correlations and other assumptions break down. For example, in a serious crisis buyers may desert the market and stay away for an extended period. This market liquidity risk is difficult to capture with current VaR methodologies (and to that extent it shares similarities with credit risk). The prior provision of secure funding arrangements is critical, but attempts to quantify the risk and provide capital against it can also be made. Stress testing of portfolios would be one approach to assessing the possible impact of extreme events and calculating an additional capital requirement.

Possible Future Applications of Modelling Techniques

Credit Risk

VaR currently is not recognised by supervisors as a measure of credit risk for the following reasons:

- Data on both defaults and recovery rates are much less complete. Internal data are often not collected in a useful format, while external data - whether ratings or equity price based - tend to be dominated by US experience which may not be replicated elsewhere. There is poor information on the influence of factors such as the economic cycle, geographic location, industry sector or loan maturity upon default and recovery rates. The paucity of data also affects the estimate of credit correlations, which may have to be based on proxies (e.g. equity return correlation, bond spread correlation, industry sector correlation); these introduce further approximations.

- The appropriate holding periods will be widely different ranging from a comparatively short period for marketable securities to a much longer one for non-marketable loans held to maturity. This will complicate the task of parameter setting.

- Credit returns are highly skewed and fat-tailed. Simulation methods may therefore be more appropriate for credit risk, but are computationally burdensome, particularly for large portfolios.

Two further points are particularly relevant when supervisors are considering the application of VaR to credit risk. First, the profile of an individual firm's counterparties will be important in determining the appropriateness of models; estimations of correlations could be more problematic where, for example, companies cannot satisfactorily be classified by industry type. Second, where firms have a relatively limited range of counterparties, the problem of credit risk concentrations arises. Although VaR models would favour firms with a diversity of credit exposures and hence less correlated default probabilities, and penalise firms with highly correlated credit exposures, supervisors may well feel that additional safeguards - e.g. in the form of large exposure rules or additional capital requirements - are needed to prevent overexposure to single counterparties.

Nevertheless, firms have made significant progress in improving credit risk modelling techniques. It is conceivable that with further development of models and initiatives such as data pooling, credit risk VaR models will have a role in the future in the setting of regulatory capital requirements.

Legal and Operational Risk

Statistical techniques for modelling legal and operational risk, at least if this is taken in a broad sense, are less well developed. Low probability events are liable to have very extreme consequences, in that gaps and failures in systems and controls have in the past been a prime cause of insolvency. Moreover, the past severity of losses from a particular cause offers little guide to the future; even if a particular gap or failure has in the past only resulted in minor losses, it still has the potential to push the firm into insolvency if circumstances change, even slightly. Since in this sense the maximum potential loss from any one incident can be effectively unquantifiable, an approach of basing regulatory capital on historic loss percentiles would be questionable. This is not to say that a more analytical approach to these risks is not possible and a number of firms are working in this area.

VaR Models - The Technical Committee's Position

Overall, greater familiarity with the theory of modelling and the growing body of experience in its application has allowed supervisors to develop appropriate supervisory responses that are both quantitative and qualitative in approach (see (i) - (viii) above). For supervisors who are satisfied that they have the resources and expertise to make the judgements set out there, the Technical Committee accepts that the output of VaR models can provide the starting point for calculating market risk regulatory capital charges.

Additional Capital Requirements in a Models Environment

Regulatory capital has to date taken as its starting point the more easily quantifiable risks and exposures, notably credit and market risk. Capital charges currently applied by securities supervisors and banking supervisors (the latter under the Basle 'standard' approach) in some

respects overcompensate for these particular categories of risk. For instance, on the market risk side, both securities and bank supervisors allow limited or no recognition of correlations across currencies or across markets. Similarly, there is only limited recognition of offsets in the area of credit risk; even within the trading book, exposures may only be fully offsettable for opposite positions in exactly the same issue.

Implicitly, this conservatism creates a "buffer" (i.e. additional capital) that serves a dual purpose.[5] First, it gives protection against the eventuality that in some extreme circumstances - such as very sharp market moves or credit quality deterioration in a whole geographical region - capital weightings or haircuts calculated on the basis of more normal market conditions will be inadequate. Secondly, it gives some protection against those risks which are not included in the calculation at all, notably operational risk. Overall, therefore, current capital charges are not excessive for the totality of risks.

Capital requirements based solely on the outputs of VaR models are not in themselves sufficient. In moving towards a capital regime that gives wider recognition of hedges and correlations - such as VaR modelling - part of the implicit buffer will be lost. Supervisors will, however, need to ensure that overall capital remains adequate, implying that two types of explicit buffers should be introduced into the capital calculation: first, a cushion against model risks (including inadequate capture of extreme market moves), and second, a cushion for operational and other non-modelled risks (other than credit risk which for the time being would be covered by existing approaches).

The following sections discuss various approaches. In considering these, supervisors should bear in mind the balance of cost and benefit which arises from the greater degree of supervisory involvement and complexity of judgement entailed by many of these approaches.

Buffers for Modelled Risk

(i) A Multiple of the VaR

By multiplying the VaR output, the aim is to provide a cushion against potential weaknesses in the model itself as well as some cover over and above the confidence level (e.g. 99%) used. Furthermore, the VaR output is the estimated maximum loss at a certain confidence level and in a given holding period. In reality, this level of loss might occur more than once in a short period of time.

Pros

- The multiplier covers potential weaknesses of the modelling approach such as fat tail issues.

[5] This implicit buffer is supplemented in many regimes by explicit buffers. For example, most regulators require a minimum level of capital to be in business, and securities firms operating in the European Union under the Capital Adequacy Directive (CAD) must maintain capital equal to one quarter of their previous year's fixed overheads (to help ensure an orderly wind-down of the firm). Of course, these only act as additional buffers to the extent that they add to capital required against market and credit risk (for most firms they would not bite). In addition, some regulators (eg the UK banking supervisors) require higher capital ratios for higher risk firms.

- Multipliers are used by some firms to manage their market risk internally.
- Simple.
- Emphasises the relative riskiness of products (i.e. it loads significantly more capital onto riskier products).

Cons

- A multiplier might encourage firms that would otherwise take a conservative approach to calculating VaR to be less conservative in order to reduce the impact of the multiplier. The multiplier might therefore be a perverse incentive to design a model to minimise regulatory effects rather than optimise its use as a risk management tool.
- A low initial number from a flawed model will not be corrected by a multiplier.
- The particular multiplier chosen is open to the charge that it is arbitrary.

(ii) Add-on Based on Stress testing

Another approach would be to use VaR plus an add-on that reflects, in some fashion, the simulation of extreme market movements, including the breakdown of correlations and other assumptions.

Pros

- Risk based.
- Can capture liquidity and fat tail risks.
- Can provide a flexible tool to re-inforce supervisors' qualitative approach.

Cons

- It gives firms an incentive to tailor their stress testing to meet supervisory requirements.
- It is difficult to establish a consistent approach to the calculation of the add-on.

Buffers for Non-Modelled Risks

(i) Add-on Based on Key Operational Ratios

A firm's operational risk will not necessarily bear any relationship to its market or credit risk. It would therefore make sense to move away from the market or credit risk calculations and calculate an operational risk capital charge related to data that somehow reflected the scale of this risk. Examples might be variability in earnings, turnover, staff costs (e.g. broken down between front and back office), staff turnover, error rates and technology costs.

Pros

- These numbers would have some relationship to operational risk e.g. a turnover to staff costs ratio that is "high" might indicate greater operational risk.
- It would use readily available management information.
- The operational risk buffer could be scaled according to the ratios.
- It could provide rewards for risk reducing behaviour.

Cons

- The methodology would require detailed research to establish benchmark ratios and how to convert any overshoot into a capital charge.

- All ratios have limitations due to a lack of consistency in their calculation and to difficulties in interpreting the outcome e.g. a high turnover to staff costs might indicate under-investment in staff or good management control.

(ii) Base Requirement

One approach would be to apply a base requirement reflecting the scale of a firm's activities to capture non-measurable risks (e.g. x% of fixed costs).

Pros

- Straightforward.
- Relates capital to size (which has some logic to it).

Cons

- There is not a straightline relationship between operational risk and size.
- Could be seen as a penalty on success.
- Can encourage firms to modify group structures to meet regulatory needs rather than their own risk management needs.

Non-Capital Based Approaches

The approaches outlined in this section can only be considered as complementary, and not alternatives, to capital. Clearly more work is required in these areas and the initial thoughts given below in no way pre-judge the outcome of any further work that the Technical Committee might undertake.

(i) Internal Controls

The Technical Committee, in its report on risk management and control guidance for securities firms,[6] aimed to provide a contribution to establishing a more rigorous approach to capturing non-measurable risks that relies on qualitative assessments. The report sets out 12 "elements of a risk management and control system" which are intended to be benchmarks which can be used by supervisors to measure the adequacy of firms' control systems.

Increased emphasis on internal controls aims to limit the losses from operational failure. It recognises that capital and effective risk management are equally important and focuses management's attention on controls.

To make this supervisory approach more effective it may be necessary to respond to weak controls with some form of sanction - e.g. extra capital requirement, restrictions on business, or fines.

[6] See footnote 2.

(ii) Disclosure of Operational Losses

Operational risk might be dealt with via a more explicit disclosure regime covering all losses arising from operational problems. While these disclosures would, realistically, be made privately to the supervisor, such a regime might be coupled with public disclosure of more appropriate information on a firm's risk profile.

Quantification of operational risks will provide useful data to the supervisor and possibly, via the supervisor, to the market. Reputational risk applies a market discipline to management. Furthermore reporting trends could act as an early warning signal of growing operational risks at a firm. There are however issues regarding the materiality of the losses to be disclosed, the timing of disclosure and the appropriate sanctions.

(iii) Insurance

A limited market exists to insure against some elements of operational risk. This approach is market-based and therefore will benefit well-controlled firms. It would also shift risk to a group of firms capable of assessing occasional, random major problems (earthquakes, hurricanes etc.). But it could lead to a false sense of security and the incentive for improved risk control may be limited by the markets' ability to price these risks. There are major issues regarding the reliability of coverage and the timing of payouts. Furthermore the risk is merely shifted to another group of regulated firms on whose solvency the value of many individuals' assets depend.

Conclusion

The Technical Committee believes that the current levels of regulatory capital are necessary. At the same time, the Technical Committee believes that capital requirements should be based on risk. For the calculation of market risk regulatory capital, in the light of the development of VaR methodologies since 1995, the use of VaR models is acceptable in appropriate circumstances and subject to suitable safeguards. This will enable securities firms to manage their risks more efficiently.

The supervisory framework would include not only qualitative assessment of the model and the firm's expertise in using it, but also standard parameters for the calculation of VaR outputs. The capital charge, while taking the VaR output as its starting point, would have to be adjusted upwards in some way in order to provide some coverage of extreme market events and other shortcomings of the VaR approach. Supervisors will need to ensure that they have sufficient resources and expertise for the task of VaR model recognition.

VaR methodologies for credit risk are currently being developed and may have a role in the future for regulatory capital purposes.

There are operational and other non-modelled risks which supervisors should not lose sight of. It is essential that additional buffers continue to be put in place against these risks until more risk based approaches are developed.

Appendix

Selected VaR Papers

This appendix does not give a full literature survey of all VaR-related research. Rather, it summarises a selection of papers that have specifically looked at the empirical performance of different VaR models in various circumstances. The summaries are IOSCO's and have not been reviewed by the papers' authors. Further relevant papers may be found in the compilations of VaR-related articles published by Risk Publications (*VAR, Understanding and Applying Value at Risk*, September 1997) and in the Journal of Derivatives (Spring 1997).

Alexander and Leigh. Journal of Derivatives, Spring 1997. *'On the covariance Matrices used in Value at Risk Models'*.
Generated covariance matrices and tested the performance of different parametric models on equity indices and US$ exchange rates. Found that an exponentially-weighted parametric model would in many cases be classed as 'Red Zone' under the Basle backtesting framework - although for US equities this type of model performed best in the operational evaluation.

Darryl Hendricks, FRBNY Economic policy review, April 1996. *'Evaluation of Value-at-Risk Models using Historical Data'*.
Applied different types of VaR model, using different data window lengths and different confidence levels, to 1000 randomly chosen FX portfolios. Concluded that in almost all cases the approaches cover the risk they are intended to cover; that the approaches produce risk estimates that do not differ greatly in average size; but that at a 99% confidence level, only a long-window historical simulation approach covered 99% of actual outcomes, with other approaches tending to cover around 98.2-98.5% of outcomes; that VaRs generated by these other approaches would need to be increased by 10-15% to achieve perfect 99% coverage, and that outcomes which lie in the 1% tail are typically 30-40% bigger than the model's VaR.

Jackson, Maude & Perraudin, Journal of Derivatives, Spring 1997. *'Bank Capital and Value at Risk'*.
Examined the performance of different VaR models (with different data window lengths and holding periods) using actual fixed income, FX and equity security portfolios of a large bank. Found that simulation based VaR techniques yielded more accurate measures of tail probabilities than the parametric approaches, where actual losses exceeded the model's 99% cut off much more than 1% of the time. A longer data window did help to reduce the tail probability bias, whereas weighting schemes (in which more recent returns are given a higher weighting than the more lagged ones) tended to increase it. Comparing the model-generated 99% capital with actual losses, the historical simulation approach tended to produce a capital surplus more often and in larger amounts. However, if the capital requirement were calculated using the Basle approach of the 60-day average 10-day VaR multiplied by 3, none of the portfolios under any of the approaches would have had a single loss outlier; indeed a multiplier of 2.5 would suffice.

James M. Mahoney. Conference paper of September 1996.
Explores which method best forecasts 1 day VaRs at a variety of confidence levels. Selects random currency portfolios and random equity portfolios. Concluded that historical simulation was more accurate for randomly chosen portfolios, particularly at higher confidence levels. However, suggested that for intentionally hedged portfolios, VaR estimates may understate the true value at risk.

Marshall and Siegel. Journal of Derivatives, Spring 1997. *'Value at Risk: Implementing a Risk Measurement Standard'*.
Looked at the variation in VaR outputs produced by different users of the same model (Risk Metrics) using the same test portfolios and the same parameters of risk (one-day, 95% confidence). Concluded that certain instruments - generally the more complex kind - gave rise to significant 'implementation risk', i.e. the risk of significant variations in outputs unrelated to the model being used. Differences in the underlying valuation of instruments was sometimes (but not always) the driving factor behind variations.

Matt Pritsker, Risk Publications, 1996. *'Evaluating Value-at-Risk Methodologies: Accuracy Versus Computational Time'*.
This paper examines six VaR methods, and compares their computational requirement and their accuracy when the sole source of inaccuracy is errors in approximating non-linearity. Simulations using portfolios of foreign exchange options show fairly wide variation in accuracy and unsurprisingly wide variation in computational time. The paper also presents a method for using order statistics to create confidence intervals for the errors and as a percentage of the true value at risk for each VaR method.

Tanya Styblo Beder. Financial Analysts Journal. September / October 1995. *'VAR: Seductive but Dangerous'*.
Applied 8 VaR calculations to 3 hypothetical portfolios. Used historical simulation with two different data bases and two holding periods (1 day and two weeks), and Monte Carlo simulation with two sets of correlation estimates and the same two holding periods. Also applied two confidence levels (95% and 99%). At the extreme, the resulting estimates of VaRs differed by up to 14 times. However, where the parameters were constrained, the differences were much less significant.