The Development of Internal Models Approaches to Bank Regulation & Supervision: Lessons from the Market Risk Amendment

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Draft date: August 31, 2001

Abstract

Over the past decade, banks have devoted many resources to developing internal risk models for the purpose of better quantifying the risks they face and allocating economic capital. These efforts have been recognized and encouraged by bank regulators. For example, the 1997 Market Risk Amendment (MRA) to the Basel Capital Accord formally incorporates banks' internal, market risk models into regulatory capital calculations. That is, the regulatory capital requirements for banks' market risk exposures are explicitly a function of the banks' own value-at-risk estimates. A key component in the design and implementation of the MRA was the development of qualitative and quantitative standards that must be satisfied in order for banks' models to be used for regulatory capital purposes. In this paper, we examine the MRA and recent regulatory experience to draw out lessons for the design and implementation of internal models-based capital regimes for other types of risk.

I. Introduction

In June 1999, the Basel Committee on Banking Supervision issued a consultative paper, entitled "A New Capital Adequacy Framework", that outlines the three pillars to effective bank regulation: regulatory capital requirements, supervision, and market discipline. A key element of that document was the possible recognition of banks' internal risk ratings for the determination of capital requirements for credit risk. The new framework also raised the possibility of capital charges for interest rate and other risks being based on internal models. In short, the new framework clearly indicates that internal models currently play an important role in banks' own assessments of risks and, in the future, will do so in regulatory assessments of risk.

Over the last ten to fifteen years, financial institutions have significantly increased their use of econometric models to measure and manage their risk exposures. These developments have been both a product of and a driver of increased trading activities, increased emphasis on risk-adjusted returns on capital, and significant advances in finance and computer technology.

Given these developments, bank supervisors have also focused their attention on the use of such "internal models" for supervisory purposes such as the focus on banks' overall risk management systems. Supervisors have taken steps in using the "internal models" approach with the adoption of the Market Risk Amendment (MRA) to the 1988 Basel Capital Accord. The current regulatory framework (effective January 1998) applies to commercial banks whose trading activities account for more than 10% of total assets or are greater than $1 billion. The MRA capital requirements cover all assets in trading accounts (i.e., assets carried at current market value) and all foreign exchange and commodity positions, wherever located.

Regulatory concerns about market risk and how they have been addressed via the MRA should provide insight into the regulatory concerns about credit and other bank risks. A key component in the design and implementation of the MRA was the development of qualitative and quantitative standards that must be satisfied in order for banks' models to be used for regulatory capital purposes. These qualitative standards for bank risk management include independent risk control units and both internal and external audits. These standards also cover the integration of the models and quantitative methods into the management process as well as model reviews through "backtesting" and "stress-testing" exercises. The MRA also includes quantitative criteria such as capital requirements based on VaR estimates and explicit links to model performance via "backtesting."

We can draw lessons from the recent design and implementation of the MRA for the possible extension of an internal models approach to other risks. For example, the Basel committee recently issued a short note that found that models-based capital charges for market risk were sufficient to cover market losses, even in the stressed market conditions of the third and fourth quarters of 1998. Closer examination of this period (and the year earlier) as well as the reactions of banks and their regulators should give additional insight into the measures that must be set in place for possible extension of internal models approaches to other risk categories.

The development of the corresponding regulatory standards for credit and operational risk models will clearly be much more challenging than for market risk models. The design and implementation of the MRA, however, give us a framework to

discuss the prudential, model, and validation standards that will need to be developed for other internal models-based capital regimes.

II. The Market Risk Amendment: Theory and Implementation

A. Why is a models-based approach to capital requirements reasonable?

The overarching rationale for an internal models approach to capital requirements is to tailor the required capital to the actual risks faced by specific institutions. By linking regulatory capital requirements to bank-specific measures of risk, we should be able to create capital requirements that conform more closely to banks' actual risk exposures. By using banks' internal risk measurements (instead of uniform regulatory measures of risk exposure), the subsequent capital charges should more accurately reflect individual banks' true risk exposures.

Note that this approach is quite distinct from previous regulatory practice, which either did not acknowledge differences in bank risk characteristics or applied a common regulatory standard to all banks (i.e., 8% of risk-adjusted assets). Such an important change in regulatory and supervisory practice has required and will require much effort to design and implement successfully.

The internal models approach is consistent with the shift in supervisory interest from a focus on risk measurement to a more comprehensive evaluation of banks' overall risk management. Over the past several years, supervisors have placed increasing emphasis on banks' internal processes for measuring risks and for ensuring that capital, liquidity and other financial resources are adequate in relation to the organizations' risk profiles. As noted in a recent Federal Reserve supervisory letter (SR 99-18), supervisors

must evaluate whether a bank's internal capital adequacy analysis meaningfully ties the identification, measurement, monitoring and evaluation of risk to the institution's capital needs.

Since models are a natural way to examine these issues, banks and supervisors have moved in this direction. Since market risk is readily quantified and analyzed, this was the first area in which such modeling was put into place. Hence, market risk measures are currently more developed than those for other risks are, and prudential standards are more readily available, especially since the launch of Riskmetrics in the mid-1990's.

These risk measures, such as value-at-risk (VaR) estimates, should be useful for assessing the level of bank risk exposure at a point in time, but they will also be useful for monitoring risk exposures across time. The changes in these measures should provide supervisors with useful indicators. In addition, a capital charge based on internal models could provide supervisors with a consistent framework for making comparisons across institutions.

B. Details of the Market Risk Amendment

The current, U.S. capital rules for the market risk exposure of large, commercial banks, effective as of 1998, are explicitly based on VaR estimates. The rules cover a bank's total trading activity, which is all assets in a bank's trading account (i.e., assets carried at their current market value) as well as all foreign exchange and commodity positions wherever located in the bank. Any bank or bank holding company whose total trading activity accounts for more than ten percent of its total assets or is more than $1

billion must hold regulatory capital against their market risk exposure. The capital charge is to be calculated using the so-called "internal models" approach.

Under this approach, capital charges are based on VaR estimates generated by banks' internal, risk management models using the standardizing parameters of a ten-day holding period and 99 percent coverage. In other words, a bank's market risk capital charge is based on its own estimate of the potential loss that would not be exceeded with one- percent probability over the subsequent two-week period.

The actual market risk capital that a bank must hold at a point in time is the larger of the dollar value of its 10-day VaR estimate or a multiple of the average of the previous sixty days' estimates in dollar terms. Note that a charge for specific risk is also added. The regulatory multiplier is set to three, but it may increase as a function of the number of times that a bank's daily losses exceed its one-day VaR estimates. As described by Hendricks and Hirtle (1997), the regulatory multiplier adjusts the reported VaR estimates up to what regulators consider to be a minimum capital requirement reflecting their concerns regarding prudent capital standards and model accuracy. The regulatory multiplier explicitly links the accuracy of a bank's VaR model to its capital charge by varying over time.

The regulatory multiplier is a step function that depends on the number of exceptions observed over the last 250 trading days. Exceptions are defined as occasions when the one-day trading portfolio return is less than the corresponding one-day VaR estimate. The possible number of exceptions is divided into three zones. Within the green zone of four or fewer exceptions, a VaR model is deemed "acceptably accurate" to the regulators, and the multiplier remains at its minimum value of three. Within the

yellow zone of five to nine exceptions, the multiplier increases incrementally with the number of exceptions. Within the red zone of ten or more exceptions, the VaR model is deemed to be "inaccurate" for regulatory purposes, and the multiplier increases to its maximum value of four. The institution must also explicitly take steps to improve its risk management system.

C. Lessons from the Design and Implementation of the MRA

The design and implementation of the MRA should provide valuable lessons for how to structure internal model approaches for other risk categories. Specifically, the minimum qualitative requirements for internal market risk management and the quantitative requirements for model construction and backtesting are instructive. The qualitative requirements are perceived to be principals of sound risk management that should be in place, regardless of the type of risk being modeled. This section provides greater detail on these issues and alludes to their use for credit risk modeling.

Lessons from the design of the MRA

Although the quantitative criteria embodied in the MRA attracted much attention prior to its implementation, the qualitative criteria were potentially of greater importance from a regulatory standpoint. For example, the MRA requires that firms establish an independent risk control unit. That is, the unit in charge of gathering, processing and presenting internal risk measures must be independent of any single business unit and must report directly to senior management. Such an organizational structure would

provide safeguards against inappropriate actions, such as violations of trading limits and use of inaccurate or inappropriate market data sources.

Another qualitative requirement based on sound risk management principles is that the firm conduct annual, independent surveys of the risk control unit. Such audits, whether internal or external, are useful for maintaining objectivity in the risk measurement and management processes and can serve as a starting point for dialogue with examiners. Such audits should focus on issues such as the adequacy of documentation for of risk management systems, the setting and enforcement of market risk limits, the organization of the risk control unit and a review of the pricing models that feed output into the VaR models.

Another key qualitative requirement of the MRA is that the firm must integrate the output from their market-risk models into its daily risk management. This effort requires both well-functioning management information systems as well as serious effort on the part of senior management. For example, the firm should have clearly documented procedures for report generation and risk decision criteria. The procedures, by which this information is used to set, monitor, and ensure compliance with risk limits should also be clearly documented. This requirement, as well as the other qualitative requirements, serves to insure that sound risk management principles are in place in an institution and to encourage the improvement of the firm's risk management procedures.

Given that financial risk management is a quantitative exercise, the MRA contains several quantitative criteria that should also be embodied in internal model approaches for other risk categories. For example, in order to construct a capital requirement that is applicable across firms, regulators will require a certain degree of standardization of

model inputs. As described above, in the design of the MRA, regulators set standard parameters for the VaR percentile and the assumed portfolio holding period as well as certain others.

Beside parameter values for regulatory inputs, model assumptions are also of concern to regulators. With respect to VaR models, such issues as what risk factors are assumed to be independent and how options are incorporated into the model are very important to the accuracy of the reported VaR estimates. Within the MRA's supervisory framework, regulators require that such key modeling assumptions be clearly documented and justified. The sensitivity of the VaR estimates with respect to such assumptions should also be discussed and used to justify the firm's modeling decisions.

Analogous to examining a model's sensitivity to key assumptions, regulators insist that firms examine the model's performance under various scenarios. Examining model performance under standard conditions, which is known as "backtesting", is explicitly required, as described above. However, "stress-testing" exercises are crucial for gaining insight into the performance of a firm's risk management system in times of financial market crisis. For market risk, "stress" scenarios are readily generated and should be a standard part of a firm's analysis of its internal models. Such stress tests provide regulators with information that they are interested in because they focus more on downside risks. Stress testing will clearly be a key issue in implementing internal model approaches for other types of risks.

Lessons from the implementation of the MRA

The MRA's regulatory capital requirements for market risk exposure have been in effect in the U.S. since the start of 1998. From the regulatory experience during this period, two general sets of lessons have arisen.

The first lesson is the overriding importance of a firm's management culture to a successful implementation and the ongoing performance of a financial risk management system. While managing risk on a daily basis is a challenge, the sternest tests of risk management systems are in terms of crisis; as noted by Scholes (2000), "[p]lanning for crises is more important than VaR analysis." Thus, firms with actively involved management should have better performing risk management systems. An important way to gauge active management is with the firm's stress-testing philosophy. Firms that actively engage in forward-looking stress-testing exercises generally should have management that is planning for more likely future crisis scenarios and thus may be better prepared. For further discussion of stress-testing methodologies, see the report prepared by the Basel Committee on the Global Financial System (2000).

The second set of lessons is actual experience with the challenges associated with the empirical validation of VaR models. Certainly there are challenges with accounting for actual observed profits and losses arising from firms' market risk positions. However, such concerns can be directly addressed.

The greater challenge lies in the statistical tests used to determine the performance of firms' VaR estimates. The MRA's backtesting framework is based on the binomial test, which determines whether the observed frequency of VaR exceptions matches the expected frequency. Although this test is a reasonable starting point, it is problematic

because of its low power to detect inaccurate VaR estimates; that is, this test will indicate that a set of VaR estimates is accurate and acceptable too frequently. For further discussion of this point, see Kupiec (1995), Lopez (1999) and Berkowitz (2000). This flaw in the binomial test requires regulators to rely on other indicators of model performance to develop an informed opinion on the model's accuracy. For example, regulators can examine the magnitude of VaR exceptions to derive further information on model performance; see Lopez (1999), Berkowitz (1999), Berkowtiz and O'Brien (2000), and Lopez and Walter (2000) for discussion of such alternative tests.

Regarding actual firm performance, the BIS published a report in the fall of 1999 analyzing the performance of 40 banks in nine countries that were subject to the MRA requirements during the latter half of 1999. The report found that there were no cases of surveyed institutions experiencing trading losses over any ten-day consecutive period that exceeded their capital requirements, even though this was a particular volatile period in many financial markets. As to one-day exceptions, over half of the institutions reported none over the period. In a separate study, Berkowitz and O'Brien (2000) examine the one-day VaR estimates for U.S. commercial banks over the two-year implementation period of 1998 and 1999. Their preliminary analysis finds that nearly all VaR exceptions over this two-year period occur during the third quarter of 1998.

Clearly, these results are fine from a regulatory perspective; that is, regulatory capital requirements have been effective in protecting firms' capital against market risk losses. However, it raises an important issue regarding the tension between model accuracy and capital adequacy. If the goal is model accuracy, then VaR exceptions and losses should occur. In general, regulators would like capital requirements to be more

risk-sensitive and hence more accurate, but they would also feel comfortable with a "buffer" to help ensure capital adequacy. This tension will play a key role in the solutions developed for future internal-models approaches to regulatory capital.

III. Challenges for internal-model approaches for credit & other risks

Just as with market risk, regulators should be able to create capital requirements that conform more closely to banks' actual risk exposures by linking capital requirements to bank-specific measures of risk. By using banks' internal measures of credit and other risks, regulatory capital charges should more accurately reflect individual banks' true risk exposures. The design and implementation of the MRA outlined above provides valuable lessons for how to structure internal model approaches for these other risk categories. The quantitative requirements for model construction and backtesting and the minimum qualitative requirements for internal market risk management can be instructive.

As noted above, a key component in the design and implementation of the MRA was the development of qualitative and quantitative standards that must be satisfied in order for banks' models to be used for regulatory capital purposes. These standards can be thought of as addressing three general sets of regulatory concerns regarding the details of a capital framework based on internal models and the integrity of the internal models that were now being permitted to set regulatory capital.

Similar to the MRA, quantitative and qualitative standards for credit and other risks would likely need to address three general components: prudential standards defining the model-based estimate of risk to be used in the capital charge; modeling standards describing the elements that an acceptable risk model would incorporate; and

validation techniques to ensure that models estimates are reasonably accurate and comparable across institutions. Although much of the discussion that follows relates specifically to the development of an internal models-based capital requirement for credit risk, many if not all of these issues would also need to be addressed in order to develop an internal models approach for other risks.

Although banks' internal models have already been incorporated into the determination of capital requirements for market risk, credit and operational risk models are not a simple extension of their market risk counterparts for a few key reasons. Data for the calibration and validation of models and key inputs are much less available than for market risk since modeling horizons are much longer. Such models must also cover many more instrument types. Additionally, issues of data quality and price accuracy are much more prevalent for these modeling efforts since these data are much less standard across banks and across markets than for market risk.

Banks and researchers both often report that data limitations are one of the key impediments to the design and implementation of credit risk models. Most loans are not marked to market, as such the forecasts from a typical credit risk model are not derived from a projection of future prices based on a comprehensive record of historical prices.

The available data to estimate credit risk models is also severely limited because of the infrequent nature of default events and the longer-term time horizons used in measuring credit risk. Typically banks and model developers, in specifying model parameters, are required to use simplifying assumptions and proxy data.

Finally, the relative size of the banking book and the likelihood of bank solvency if modeled credit risk estimates are inaccurate underscore the need for a better understanding of a model's sensitivity to structural assumptions and parameter estimates.

The development of validation standards for credit and operational risk models is fundamentally more difficult than the development and implementation of the backtesting standards for market risk models. Where market risk models typically employ a horizon of a few days, credit risk models generally rely on a time frame of one year or more. These longer holding periods present problems to banks and supervisors in assessing the accuracy of these models. Additionally, a quantitative validation standard similar to that in the Market Risk Amendment would require an impractical number of years of data, spanning multiple credit cycles.

Recently, the Basel Supervisors Committee in a report specifically addressing credit risk modeling noted that risk modeling may indeed prove to result in better internal risk management, and may have the potential to be used in the supervisory oversight of banking organizations (Basel Committee on Banking Supervision 1999). The Committee concluded, however, that before an internal models approach could be used to determine regulatory capital requirements for credit risk, regulators would have to be confident that not only are these models being used to actively manage risk, but that they are also conceptually sound, empirically valid, and produce capital requirements that are comparable across institutions. This report concluded that at this time, significant issues with respect to data availability and model validation would need to be addressed before these objectives can be met.

Below we highlight some of the challenges that would need to be addressed in order to develop the quantitative qualitative standards that would accompany an internal models-based capital regime for credit or other risks.

A. Quantitative standards for credit and other risks

How to determine minimum capital requirements?

The first component of the MRA quantitative standards addresses how to determine the models-based minimum capital requirements. The basis for the MRA capital requirements is a risk measurement model that estimates the distribution of gains and losses on the bank's portfolio over some future time horizon. A regulatory capital requirement for credit or operational risk could be based on the output of banks' internal models in a similar fashion. As described above, the capital charge could be based on an estimate of a particular percentile of a credit or operational loss distribution over a given time horizon. Although these parameters would likely differ from those used in the market risk capital framework, the basic structure of the framework could be replicated.

These quantitative standards specified to establish the basic degree of stringency of the capital charge would need to be specified by regulators to ensure that the regulatory capital requirements provide a suitable degree of capital coverage and would be comparable across banks. Mirroring the some of the basic elements of the MRA outlined above, these quantitative standards would need to establish the appropriate definition of loss, planning horizon, and target loss percentile.

An obvious concern is how to measure losses? Two widely established practices have emerged in credit risk modeling, estimates of loss due solely to default, and

estimates of loss from credit migrations. These differences have been captured by so-called default-mode and mark-to-market (or mark-to-model) modeling approaches. A quantitative standard for credit risk broadly would need to specify whether the capital requirement would be based on a default mode or multi-state loss concept and additionally the horizon over which these losses should be measured. Some of the issues that would need to be addressed include the adoption of an approach that is potentially inconsistency with many banks' modeling practices as well as the potential inconsistency with a mark-to-market definition of loss and historical cost accounting.

The quantitative standards accompanying a models-based capital regime for other risks would also need to establish a horizon or holding period over which losses are estimated. Although the required capital for market risk under the MRA is calculated to an assumed ten-day holding period, credit and operational risk models typically employ holding periods of one or more years. These longer holding periods are consistent with the time it takes to recognize such losses and typical planning period for capital budgeting.

The loss definition and holding period standards are linked, since supervisors may face a tradeoff between the length of the planning horizon and the definition of loss. There are several alternatives that could be used in conjunction with either a default or multi-state loss definition, including a fixed horizon of one year, a fixed horizon of more than one year, and a "lifetime" horizon that would cover the maturity of credits in a bank's portfolio.

Again mirroring the MRA, one of the key prudential parameters a quantitative standard for an internal models approach would need to address is the specified target

loss percentile or confidence interval. As in the market risk setting, the capital charge could be calculated based on the level of losses at a specified percentile of the loss distribution (e.g., 99.9^{th} or 99.97^{th}). The specified percentile could be chosen so that, in conjunction with other parameters, the capital charge would provide the level of prudential coverage desired by the supervisory authorities.

Finally, standards for an internal models-based approach might also need to address the inclusion of a scaling factor. As noted earlier it has been asserted that the role of the scaling factor is to translate the model based estimates into a capital requirement that reflects both the accuracy of a bank's model and the desired capital coverage (Hendricks and Hirtle 1997). The inclusion of the regulatory scaling factor in the Market Risk Amendment has been often debated. At a minimum, the use of a scaling factor in a models-based capital regime for credit or other risks could again be a focal point.

What features of credit risk models need to be standardized?

The credit and operational risk models used to determine capital requirements would most likely also have to meet certain quantitative. Regulators face a trade off in establishing these standards. Given the current rapid state of evolution of these models, regulators need to recognize the risk of establishing standards that are highly restrictive. Although a certain degree of standardization is needed, there is great diversity of practice.

The quantitative standards could ensure greater consistency by requiring specific mathematical approaches or the use of certain approved models. At this time, however, there is little basis for concluding that one specific approach to credit risk modeling is uniformly better than all others in all situations. Such standards could either impede

future modeling advances or require frequent revisions to encompass innovations and advances in modeling.

Responding to the report by the Basel Committee on credit risk modeling practices, bankers argued that no one model type was suitable across all portfolios. Respondents noted that techniques used to measure credit risk in corporate loan portfolios, in trading and derivatives portfolios and in retail portfolios logically might be different from each other.

Although not specifically addressed earlier, the MRA also establishes quantitative standards for the data used to calibrate market risk models. The data used to calibrate credit and operational risk models should provide adequate historical coverage. The data should also be applicable to the specific business mix of the bank. With regard to historical coverage, quantitative standards would likely require that the data be sufficient to reflect credit cycle effects. With regard to bank-specific applicability, standards would need to establish that the data used to estimate model parameters are appropriate for the current composition of its portfolio. The development of comparable standards for credit and operational risk face a trade off between establishing an appropriate historical window and firm applicability.

What are appropriate validation procedures?

Unlike in the market risk setting, formal backtesting of credit risk model results may not feasible due to the length of a typical credit cycle and the resultant limited number of independent observations of actual outcomes. Lopez and Saidenberg (2000) discuss some of the challenges and limitations of backtesting credit risk models as well as

the limited methods available. As a result, quantitative standards for credit and operational risk model validation will likely have to draw on a combination of tests, at least until more internal data become available and more robust statistical methodologies are developed.

At this time quantitative standards for a model-based credit or operational risk regime would likely need to incorporate a range of possible alternatives. These alternatives include stress testing, sensitivity analysis, and test-deck exercises. Robust validation standards will be needed to ensure the integrity of any future internal models-based capital requirement. Even if regulators could be somewhat open minded as to the form of validation, the development of acceptable alternative approaches for validation is almost certainly one of the key be that will need to addressed before the implementation of other models-based capital requirements.

B. Qualitative standards for credit and other risks

The lessons learned from design and implementation of the MRA discussed above as well as the challenges of establishing meaningful quantitative model and validation standards highlight the importance of the accompanying qualitative standards.

Within the supervisory process, there has been growing emphasis on qualitative reviews of banks' methods for measuring, managing, and controlling risk. Supervisors also have developed significant experience assessing the integrity of banks' market risk models against a range of qualitative sound practice standards. In order to develop a models-based capital requirement for other risk, supervisors will likely need to place even greater reliance on banks' adherence to qualitative standards. This alone will require

a shift in supervisors' thinking and might delay the implementation of a models-based approach for credit and other risks.

Many of the issues addressed through MRA are even more relevant for the measurement and management of credit and operational risk especially the integration of these risk measurement procedures into management decision-making. Given that banks have long been in the credit business, many of these management procedures are in place and may only need to be updated. However, the move from traditional credit risk management to model-driven risk management could be difficult for management. For example, large institutions may have credit risk management procedures that are effective for traditional lending, but would need enhancement for credit trading and credit derivative activities

Building on the qualitative standards outlined above for the MRA of the, banks' use of credit and operational risk models for regulatory capital purposes would also likely be contingent upon their meeting a set of standards aimed at ensuring that the models are sound and implemented with integrity. Such qualitative standards could include compliance with a documented set of internal policies, controls, and procedures concerning the operation of risk measurement systems. These standards would also likely address the need for an independent risk control unit responsible for the design and implementation of a bank's model and a regular independent review of the models. Finally, the qualitative standards would almost certainly include a "use test" to ensure that the models used for regulatory capital are closely integrated into the risk management process of the bank.

IV. Conclusion

The trend in regulatory approach is toward more risk-focused capital charges and the unbundling of regulatory capital requirements. Growing regulatory capital arbitrage by banks requires the replacement of the 1988 Accord because it is not sufficiently risk sensitive. The increased emphasis on risk-sensitive capital requirements will require greater reliance on banks' internal risk assessments. For credit risk, the use external ratings to determine required capital would likely be just a first step. The use of banks' internal risk ratings to establish minimum capital requirements would be a further step in this direction. Such an approach should lead to an improvement in terms of risk sensitivity. An approach that links capital requirements to banks' internal risk ratings as well as other transaction characteristics will not be able to capture other important risk concerns such as single borrower, industry and country concentrations.

A full internal models approach is still down the road, but the lessons learned from the Market Risk Amendment will lay the foundation for such a future approach. The design and implementation of the MRA highlight some of the challenges of establishing quantitative model and validation criteria. They also highlight the importance of the accompanying qualitative standards. Both the quantitative and qualitative criteria are necessary to ensure model consistency across institutions, across national borders and across time.

Supervisors have accepted risk management and capital regulations based on probabilistic measures for market risk. The lessons learned from the design and implementation of the MRA suggest that before the adoption of additional models-based capital regimes, banks and supervisors will need to continue to push their thinking even

further along these lines, especially with respect to evaluation tools.

References

Basel Committee on Banking Supervision, 1999. "Credit Risk Modeling: Current Practices and Applications," Manuscript.

Basel Committee on Banking Supervision, 1999. "Performance of Models-Based Capital Charges for Market Risk," Manuscript.

Basel Committee on Banking Supervision, 2000. "Summary of Responses Received on the Report 'Credit Risk Modeling: Current Practices and Applications," Manuscript.

Basel Committee on the Global Financial System, 2000. "Stress Testing by Large Financial Institutions: Current Practice and Aggregation Issues," Manuscript.

Berkowitz, J., 1999. "Evaluating the Forecasts of Risk Models," FEDS Discussion Paper #11, Federal Reserve Board of Governors.

Berkowitz, J. and O'Brien, J., 2000. "The Performance of Large-Scale Portfolio Valuation Models," Manuscript, Federal Reserve Board of Governors.

Hendricks, D. and Hirtle, B., 1997. "Bank Capital Requirements for Market Risk: The Internal Models Approach," *Federal Reserve Bank of New York Economic Policy Review*, December 1-12.

Jackson, P. and Perraudin, W., 2000. "Regulatory Implications of Credit Risk Modeling," *Journal of Banking and Finance*, 24, 1-14.

Kupiec, P., 1995. "Techniques for Verifying the Accuracy of Risk Measurement Models," *Journal of Derivatives*, 3, 73-84.

Lopez, J.A., 1999. "Methods for Evaluating Value-at-Risk Estimates," Federal *Reserve Bank of San Francisco Economic Review*, 2, 3-15.

Lopez, J.A. and Saidenberg, M.R., 2000. "Evaluating Credit Risk Models," *Journal of Banking and Finance*, 24, 151-167.

Lopez, J.A. and Walter, C.A., 2000. "Evaluating Covariance Matrix Forecasts in a Value-at-Risk Framework," Manuscript, Economic Research Department, Federal Reserve Bank of San Francisco.

Scholes, M.S., 2000. "Crisis and Risk Management," *American Economic Review Papers and Proceedings*, 90, 17-21.