

purposes only after determining that the bank's internal model and risk management systems meet the criteria in section III. of this appendix E. Such a determination may require on-site examinations of the systems. The Federal Reserve may require modification to an internal model as deemed necessary to ensure compliance, on a continuing basis, with the provisions of this appendix E. A bank's internal model will be subject to continuing review, both on- and off-site, by the Federal Reserve.¹¹

2. A bank should ensure that the level of sophistication of its internal model is commensurate with the nature and volume of the bank's trading activity in the risk factor categories covered by this appendix E and measures market risk as accurately as possible. In addition, the model should be adjusted to reflect changing portfolio composition and changing market conditions.

B. Qualitative Criteria

1. A bank using the internal models approach should have market risk management systems that are conceptually sound and implemented with integrity. Internal risk measurement models must be closely integrated into the day-to-day risk management process of the bank. For example, the risk measurement model must be used in conjunction with internal trading and exposure limits.

2. A bank must meet the following minimum qualitative criteria before using its internal model to measure its exposure to market risk.¹²

a. A bank must have a risk control unit that is independent from business trading units and reports directly to senior management of the bank. The unit must be responsible for designing and implementing the bank's risk management system and analyzing daily reports on the output of the bank's risk measurement model in the context of trading limits. The unit must conduct regular back-testing.¹³

b. Senior management must be actively involved in the risk control process. The daily reports produced by the risk management unit must be reviewed by a level of management with sufficient authority to enforce both reductions in positions taken by individual traders, as well as in the bank's overall risk exposure.

c. The bank must have a routine and rigorous program of stress-testing¹⁴ to

identify the effect of low-probability events on the bank's trading portfolio. Senior management must routinely review the results of stress-testing in the context of the potential effect of the events on bank capital and the appropriate procedures the bank should take to minimize losses. The policies of the bank set by management and the board of directors should identify appropriate stress-tests and the procedures to follow in response to the test results.

d. The bank must have established procedures for ensuring compliance with a documented set of internal policies and controls, as well as for monitoring the overall operation of the risk measurement system.

e. Not less than once a year, the bank must conduct, as part of its regular internal audit process, an independent review of the risk measurement system. This review must include both the activities of the business trading units and of the independent risk control unit of the bank.

f. Not less than once a year, the bank must conduct a review of its overall risk management process. The review must consider:

i. The adequacy of the documentation of the risk management system and process and the organization of the risk control unit;

ii. The integration of market risk measures into daily risk management and the integrity of the management information system;

iii. The process the bank employs for approving risk pricing models and valuation systems that are used by front- and back-office personnel;

iv. The scope of market risks captured by the risk measurement model and the validation of any significant changes in the risk measurement process;

v. The accuracy and completeness of position data, the accuracy and appropriateness of volatility and correlation assumptions, and the accuracy of valuation and risk sensitivity calculations;

vi. The verification process the bank employs to evaluate the consistency, timeliness, and reliability of data sources used to run internal models, including the independence of such data sources; and

vii. The verification process the bank uses to evaluate back-testing that is conducted to assess the model's accuracy.

C. Market Risk Factors

1. *Overview.* For regulatory capital purposes, a bank's internal risk measurement system(s) must use sufficient risk factors to capture the risks inherent in the bank's portfolio of on- and off-balance-sheet trading positions and must, subject to the following guidelines, cover interest rates, equity prices, exchange rates, commodity prices, and volatilities related to options positions in each risk factor category. The level of sophistication of the bank's risk factors must be commensurate with the nature and scope of the risks taken by the bank.

2. *Interest Rates.* a. A bank must use a set of market risk factors corresponding to interest rates in each currency in which it has material interest rate-sensitive on- or off-

balance-sheet positions. The risk measurement system must model the yield curve¹⁵ using one of a number of generally accepted approaches, for example, by estimating forward rates of zero coupon yields. The yield curve must be divided into various maturity segments in order to capture variation in the volatility of rates along the yield curve; there will typically be one risk factor corresponding to each maturity segment.

b. For material exposures to interest rate movements in the major currencies and markets, a bank must model the yield curve using a minimum of six risk factors.

However, the number of risk factors used should ultimately be driven by the nature of the bank's trading strategies.¹⁶ The risk measurement system must incorporate separate risk factors to capture spread risk.¹⁷

3. *Exchange rates.* A bank must use market risk factors corresponding to the exchange rate between the domestic currency and each foreign currency in which the bank has a significant exposure. The risk measurement system must incorporate market risk factors corresponding to the individual foreign currencies in which the bank's positions are denominated.

4. *Equity prices.* A bank must use market risk factors corresponding to each of the equity markets in which it holds significant positions. The sophistication and nature of the modeling technique for a given market must correspond to the bank's exposure to the overall market as well as to the bank's concentration in individual equity issues in that market. At a minimum, there must be a risk factor designed to capture market-wide movements in equity prices (such as a market index), but additional risk factors could track various sectors or individual issues.

5. *Commodity prices.* A bank must use market risk factors corresponding to each of the commodity markets in which it holds significant positions. The internal model must encompass directional risk, forward gap and interest rate risk, and basis risk.¹⁸ The

¹⁵ Generally, a yield curve is a graph showing the term structure of interest rates by plotting the yields of all instruments of the same quality by maturities ranging from the shortest to the longest available. The resulting curve shows whether short-term interest rates are higher or lower than long-term interest rates.

¹⁶ For example, a bank that has a portfolio of various types of securities across many points of the yield curve and that engages in complex arbitrage strategies would require a greater number of risk factors to capture interest rate risk accurately.

¹⁷ Spread risk refers to the potential changes in value of an instrument or portfolio arising from differences in the behavior of baseline yield curves, such as those for U.S. Treasury securities, and yield curves reflecting sector, quality, or instrument specific factors. A variety of approaches may be used to capture the spread risk arising from less than perfectly correlated movements between government and other interest rates, such as specifying a completely separate yield curve for non-government instruments (for example, swaps or municipal securities) or estimating the spread over government rates at various points along the yield curve.

¹⁸ Directional risk is the risk that a spot price will increase or decrease. Forward gap risk refers to the effects of owning a physical commodity versus owning a forward position in a commodity. Interest

¹¹ Banks that need to modify their existing modeling procedures to accommodate the requirements of this appendix E should, nonetheless, continue to use the internal models they consider most appropriate in evaluating risks for other purposes.

¹² If the Federal Reserve is not satisfied with the extent to which a bank meets these criteria, the Federal Reserve may adjust the multiplication factor used to calculate market risk capital requirements or otherwise increase capital requirements.

¹³ Back-testing includes *ex post* comparisons of the risk measures generated by the model against the actual daily changes in portfolio value.

¹⁴ Bank stress-testing should cover a range of factors that can create extraordinary losses or gains in trading portfolios or make the control of risk in those portfolios difficult. These factors include low-

probability events of all types, including the various components of market, credit, and operational risks.