INTRODUCTION

Sensitivity to market risk reflects the degree to which changes in interest rates, foreign exchange rates, commodity prices, or equity prices can adversely affect a financial institution's earnings or capital. For most community banks, market risk primarily reflects exposure to changing interest rates. Therefore, this section focuses on assessing interest rate risk (IRR). However, examiners may apply these same guidelines when evaluating foreign exchange, commodity, or equity price risks. A brief discussion of other types of market risks is included at the end of this section.

Market risks may include more than one type of risk and can quickly impact a financial institution's earnings and the economic value of its assets, liabilities, and off-balance sheet items. In order to effectively manage IRR, each institution should have an IRR management program that is commensurate with its size and the nature, scope, and risk of its activities.

The adequacy of a bank's IRR program is dependent on its ability to identify, measure, monitor, and control all material interest rate exposures. To do this accurately and effectively, institutions need:

- Appropriate IRR policies, procedures, and controls;
- Sufficiently detailed reporting processes to inform senior management and the board of IRR exposures;
- Comprehensive systems and standards for measuring and monitoring IRR; and
- Appropriate internal controls and independent review procedures.

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TYPES AND SOURCES OF INTEREST RATE RISK

IRR can arise from a variety of sources and financial transactions and has many components including repricing risk, basis risk, yield curve risk, option risk, and price risk.

Types of Interest Rate Risk

Repricing risk reflects the possibility that assets and liabilities will reprice at different times or amounts and negatively affect an institution's earnings, capital, or general financial condition. For example, management may use non-maturity deposits to fund long-term, fixed-rate securities. If deposit rates increase, the higher funding costs would likely reduce net yields on fixed-rate securities.

Basis risk is the risk that different market indices will not move in perfect or predictable correlation. For example, LIBOR-based deposit rates may change by 50 basis points while prime-based loan rates may only change by 25 basis points during the same period.

Yield curve risk reflects exposure to unanticipated changes in the shape or slope of the yield curve. It occurs when assets and funding sources are linked to similar indices with different maturities. For example, a 30-year Treasury bond's yield may change by 200 basis points, but a 3-year Treasury note's yield may change by only 50-basis points during the same time period. This risk is commonly expressed in terms of movements of the yield curve for a type of security (e.g., a flattening, steepening, or inversion of the yield curve).

Option risk is the risk that a financial instrument's cash flows (timing or amount) can change at the exercise of the option holder, who may be motivated to do so by changes in market interest rates. Lenders are typically option sellers, and borrowers are typically option buyers (as they are often provided a right to prepay). The exercise of options can adversely affect an institution's earnings by reducing asset yields or increasing funding costs.

For example, assume that a bank purchased a 30-year callable bond at a market yield of 10 percent. If market rates subsequently decline to 8 percent, the bond's issuer will be motivated to call the bond and issue new debt at the lower market rate. At the call date, the issuer effectively repurchases the bond from the bank. As a result, the bank will not receive the originally expected yield (10 percent for 30 years). Instead, the bank must re-invest the principal at the new, lower market rate.

Price risk is the risk that the fair value of financial instruments will change when interest rates change. For example, trading portfolios, held-for-sale loan portfolios, and mortgage servicing assets contain price risk. When interest rates decrease, the value of an institution's mortgage servicing rights generally decrease because the total cash flows from servicing fees decline as consumers refinance. Because servicing assets are subsequently measured at fair value, or carried at amortized cost and tested for impairment, the fair value adjustment or any impairment is reflected in current earnings.

Sources of Interest Rate Risk

Funding sources may involve repricing risk, basis risk, yield curve risk, or option risk, and examiners should carefully evaluate all significant relationships between funding sources and asset structures. Potentially volatile or market-based funding sources may increase IRR, especially when matched to a longer-term asset portfolio.

For example, long-term fixed-rate loans funded by purchased federal funds may involve repricing risk, basis risk, or yield curve risk. As a result, interest rate movements could cause funding costs to increase substantially while asset yields remain fixed.

Derivative instruments may be used for hedging but can introduce complex IRR exposures. Depending on the specific instrument, derivatives may create repricing, basis, yield curve, option, or price risk.

Mortgage banking operations may create price risk within the loan pipeline, held-for-sale portfolio, and mortgage servicing rights portfolio. Interest rate changes affect not only current values, but also future business volumes and related fee income.

Fee income businesses may be influenced by IRR, particularly mortgage banking, trust, credit card servicing, and non-deposit product sales. Changing interest rates could affect such activities.

Product pricing strategies may introduce IRR, particularly basis risk or yield curve risk. Basis risk exists if funding sources and assets are linked to different market indices. Yield curve risk exists if funding sources and assets are linked to similar indices with different maturities.

Embedded options associated with assets, liabilities, and off-balance sheet derivatives can create IRR. Embedded options are features that provide the holder with the right, but not the obligation, to buy, sell, pay down, payoff, withdraw, or otherwise alter the cash flow of the instrument. The holder of the option can be the bank, the issuer, or a counterparty. Many instruments contain embedded options that can alter cash flows and impact the IRR profile of the institution, including:

- Non-maturity deposits: Depositors have the option to withdraw funds at any time.
- Callable bonds: The issuer has the option to redeem all or part of a bond before maturity (based on contractual call dates).
- Structured notes: Options can vary by the type of instrument and may include step-up features, interest rate caps and floors, and cash flow waterfall triggers.
- Wholesale borrowings: Lenders may have a call option (requiring banks to repay borrowings), or borrowing banks may have a put option (allowing them to prepay borrowings).
- Derivatives: Derivative owners may hold an option to purchase additional securities or to exercise an existing derivative contract.
- Mortgage loans: Borrowers may have the option to partially or fully prepay the loan.
- Mortgage-backed securities (MBS): Borrowers' options to prepay individual mortgage loans included in an MBS loan pool can shorten the life of a tranche of loans within a security.

Embedded options can create various risks, such as contraction risk, extension risk, and negative convexity. Contraction risk increases when rates decline and borrowers can refinance at a lower rate, forcing the bank to reinvest those funds at a lower rate. Extension risk increases when rates rise and borrowers become less likely to prepay loans, thereby locking banks into below-market returns. Convexity measures the curvature in the relationship between certain investment prices and yields and reflects how the duration of an instrument changes as rates change.

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RISK MANAGEMENT FRAMEWORK

The IRR management framework sets forth strategies and risk tolerances as established in the institution's policies and procedures that guide the identification, measurement, management, and control of sensitivity to market risk. The framework begins with sound corporate governance and covers strategies, policies, risk controls, measurements, reporting responsibilities, independent review functions, and risk mitigation processes.

The formality and sophistication of the IRR management program should correspond with an institution's balance sheet complexity and risk profile. Less complex programs may be adequate for institutions that maintain basic balance sheet structures, have moderate exposure to embedded options, and do not employ complicated funding or investment strategies. However, all institutions should clearly document their procedures, and senior management should actively supervise daily operations.

More complex institutions need more formal, detailed IRR management programs. In such cases, management should establish specific controls and produce sound analyses that address all major risk exposures. Internal controls at complex institutions should include a more thorough independent review and validation process for the IRR models employed, as well as more rigorous requirements for separation of duties.

At all institutions, management and the board should understand the IRR implications of their business activities, products, and strategies, while also considering their potential impact on market, liquidity, credit, and operational risks.

Board Oversight

Effective board oversight is the cornerstone of sound risk management. The board of directors is responsible for overseeing the establishment, approval, implementation, and annual review of IRR management strategies, policies, procedures, and risk limits. The board should understand and regularly review reports that detail the level and trend of the institution's IRR exposure.

The board or an appropriate board committee should review sensitivity to market risk information at least quarterly. The information should be timely and of sufficient detail to allow the board to assess senior management's performance in monitoring and controlling market risks and to assess management's compliance with board-approved policies.

In order to fulfill its responsibilities in this area, the board is expected to:

- Establish formal risk management policies, strategies, and risk tolerance levels;
- Define management authorities and responsibilities;
- Communicate its risk management strategies and risk tolerance levels to all responsible parties;
- Monitor management's compliance with board-approved policies;
- Understand the bank's risk exposures and how those risks affect enterprise-wide operations and strategic plans; and
- Provide management with sufficient resources to measure, monitor, and control IRR.

Senior Management Oversight

Senior management is responsible for ensuring that board-approved IRR strategies, policies, and procedures are appropriately executed. Management should ensure that risk management processes consider the impact that various risks, including credit, liquidity, and operational risks could have on IRR.

Management is responsible for maintaining:

- Appropriate policies, procedures, and internal controls that address IRR management, including limits and controls that ensure risks stay within board-approved tolerances;
- Comprehensive systems and standards for measuring IRR, valuing positions, and assessing performance;
- Adequate procedures for updating IRR measurement scenarios and documenting key assumptions that drive IRR analysis; and
- Sufficient reporting processes for informing senior management and the board of the level of IRR exposure.

IRR reports should provide sufficient aggregate information and supporting details to enable senior management and the board to assess the impact of market rate changes and the impact of key assumptions in the IRR model.

The Asset/Liability Committee (ALCO) or a similar senior management committee should actively monitor the IRR profile. The committee should have sufficient representation across major functions (e.g., lending, investment, and funding activities) that they can directly or indirectly influence the institution's IRR exposure.

Policies and Procedures

Policies and procedures should be comprehensive and govern all material aspects of an institution's IRR management process. IRR policies and procedures should:

- Address board and senior management oversight;
- Outline strategies, risk limits, and controls;
- Define general methods used to identify risk;
- Describe the type and frequency of monitoring and reporting;
- Provide for independent reviews and internal controls;
- Ensure that significant new strategies, products, and businesses are integrated into the IRR management process;
- Incorporate the assessment of IRR into institution-wide risk management procedures so that interrelated risks are identified and addressed; and
- Provide controls over permissible risk mitigation activities, such as hedging strategies and instruments, if applicable.

Interest Rate Risk Strategies

Management should develop IRR strategies that reflect board-approved risk tolerances and do not expose the bank to excessive risk. An institution's risk profile is a function of the bank's activities and products. For example, an institution's IRR strategy may be to maintain a short-term, non-complex balance sheet. In order to implement that strategy, management may hold loans and securities with short durations and minimal embedded options and fund the assets with nonmaturity deposits and short-term borrowings.

Some institutions may conduct borrowing and investment transactions (leverage strategies) that are separate from the bank's core operations. In a typical leverage strategy, management acquires short- or intermediate-term

wholesale funds or borrowings and invests those funds in longer-term bonds. Prior to implementing a leverage strategy, management should have the skills to understand, measure, and manage the risks. Management should be able to demonstrate a transaction's effect on the bank's risk profile and document that the exposure is within established risk limits.

Management should measure and document a strategy's effect on IRR exposure prior to implementation, periodically thereafter, and prior to any significant strategy changes. Institutions should consider stress testing all prospective strategies and ensure IRR exposures are within established risk limits.

Risk Limits and Controls

Risk limits should reflect the board's tolerance of IRR exposure by restricting the volatility of earnings and capital for given rate movements and applicable time horizons. Risk limits should be explicit dollar or percentage parameters. IRR exposure limits should be commensurate with the complexity of bank activities, balance sheet structure, and off-balance sheet items. At a minimum, limits should be expressed over one and two year time horizons, correspond to the internal measurement system's methodology, and appropriately address all key IRR risks and their effect on earnings and capital.

Examiners should carefully evaluate policy guidelines and board-approved risk limits. Institutions should establish limits that are neither so high that they are never breached, nor so low that exceeding the limits is considered routine and unworthy of action. Effective limits will provide management sufficient flexibility to respond to changing economic conditions, yet be stringent enough to prevent excessive risk-taking.

Policies should be in place to ensure excessive IRR exposures receive prompt attention. Controls should be designed to help management identify, evaluate, report, and address excessive IRR exposures. Policies should require management to regularly monitor risk levels, and controls should be altered as needed when economic conditions change or the board alters its risk tolerance level. Reports or stress tests that reflect significant IRR exposure should be promptly reported to the board (or appropriate board committee), and the board should review all risk limit exceptions and management's proposed actions.

Earnings-based risk limits may include volatility considerations involving:

- Net interest margin,
- Net interest income,
- Net operating income, and
- Net income.

Capital-based risk limits may include volatility considerations involving:

- Economic value of equity, and
- Other comprehensive income.

The board should provide staffing resources sufficient to ensure:

- Effective operation of measurement systems,
- Appropriate analytic expertise,
- Adequate training and staff development, and
- Regular independent reviews.

Risk Monitoring and Reporting

Management should report IRR in an accurate, timely, and informative manner. At least quarterly, senior management and the board should review IRR reports. Institutions that engage in complex or higher risk activities should assess IRR more frequently. At a minimum, IRR exposure reports should contain sufficient detail to permit management and the board to:

- Identify the source and level of IRR;
- Evaluate key assumptions, such as interest rate forecasts, deposit behaviors, and loan prepayments; and
- Determine compliance with policies and risk limits.

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INTEREST RATE RISK ANALYSIS

An effective risk management system must clearly quantify and timely report risks. Institutions should have sound IRR measurement procedures and systems that assess exposures relative to established risk tolerances. Such systems should be commensurate with the complexity of the institution. Although management may rely on third-party IRR models, they should fully understand the underlying analytics, assumptions, and methodologies of the models and ensure such systems and processes are incorporated appropriately in the strategic (long-term) and tactical (short-term) management of IRR exposures.

Management should conduct careful due diligence/pre-acquisition reviews to ensure they understand the IRR characteristics of new products, strategies, and initiatives. Management should also consider whether existing measurement systems can adequately capture new IRR

exposures. When analyzing whether or not a product or activity introduces new IRR exposures, management should consider that changes to an instrument's maturity, repricing, or repayment terms can materially affect a product's IRR characteristics. Institutions may be able to run alternative scenarios in their IRR models to test the effects of new products and initiatives. If an institution is unable to run alternative scenarios using existing models, they should use other methods to estimate the risk of new products, strategies, and initiatives. All institutions should ensure that the method(s) they use to evaluate new products and initiatives (running alternative scenarios in existing models or through other means), adequately captures potential market risks.

Management should consider earnings and the economic value of capital when evaluating IRR. Reduced earnings or losses can harm capital, liquidity, and the institution's reputation. Risk-to-earnings measurements are normally derived from simulation models that estimate potential earnings variability. Economic value of equity (EVE) measurements allow for longer-term earnings and capital analysis. The analysis may be useful for long-term planning and may also indicate a need for short-term actions to mitigate IRR exposure. Long term earnings-at-risk simulations (5 to 7 years) can be a helpful supplement to EVE measures, but they are not a replacement for EVE measurements.

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INTEREST RATE RISK MEASUREMENT METHODS

Institutions are encouraged to use a variety of measurement methods to assess their IRR profile. Regardless of the methods used, a bank's IRR measurement system should be sufficient to capture all material balance sheet items and to quantify exposures to both earnings and capital. The most common types of IRR measurement systems are:

- Gap Analysis,
- Duration Analysis,
- Earnings Simulation Analysis,
- Earnings-at-Risk,
- Capital-at-Risk, and
- Economic Value of Equity.

Gap Analysis

Gap analysis is a simple IRR methodology that provides an easy way to identify repricing gaps. It can also be used to estimate how changes in rates will affect future income. However, gap analysis has several weaknesses and is generally not sufficient as a financial institution's sole IRR measurement method. Gap analysis can be a first step in identifying IRR exposures and may serve as a reasonableness check for more sophisticated forms of IRR measurement, particularly in less complex institutions with simple balance sheets.

Gap analysis helps identify maturity and repricing mismatches between assets, liabilities, and off-balance sheet instruments. Gap schedules segregate rate-sensitive assets (RSA), rate-sensitive liabilities (RSL), and off-balance sheet instruments according to their repricing characteristics. Then, the analysis summarizes the repricing mismatches for defined time horizons. Additional calculations can then estimate the effect the repricing mismatches may have on net interest income.

A basic gap ratio is calculated as:

$$\frac{\text{RSA } ^{minus} \text{ RSL}}{\text{Average Earning Assets}}$$

Gap analysis may identify periodic, cumulative, or average mismatches, or it may show the ratio of RSA-RSL divided by average assets or total assets. However, using those denominators does not produce a standard gap ratio. They simply provide other ways of describing the degree of repricing mismatches.

A bank has a positive gap if the amount of RSAs repricing in a given period exceeds the amount of RSLs repricing during the same period. When a bank has a positive gap, it is said to be asset sensitive. Should market interest rates decrease, a positive gap indicates that net interest income would likely also decrease. If rates increase, a positive gap indicates that net interest income may also increase.

Conversely, a bank has a negative gap when the amount of RSLs exceeds the amount of RSAs repricing during the same period. When a bank has a negative gap, it is said to be liability sensitive, and a decrease in market rates would likely cause an increase in net interest income. Should interest rates increase, a negative gap indicates net interest income may decrease. While the terms asset and liability sensitive are generally used to describe gap results, they can also be used to describe the results of other models, or even the general IRR exposure of a bank.

The gap ratio can be used to calculate the potential impact on interest income for a given rate change. This is done by multiplying the gap ratio by the assumed rate change. The result estimates the change to the net interest margin.

For example, assume a bank has a 15 percent one-year average gap. If rates decline 2 percent, then the projected impact is a 30 basis point decline in the net interest margin (15 percent x 2 percent). This estimate assumes a static

balance sheet and an immediate, sustained interest rate shift.

Gap analysis has several advantages. Specifically, it:

- Identifies repricing mismatches,
- Does not require sophisticated technology,
- Is relatively simple to develop and use, and
- Can provide clear, easily interpreted results.

However, the weaknesses of gap analysis often overshadow its strengths, particularly for a majority of financial institutions. For example, gap analysis:

- Generally captures only repricing risk,
- Assumes parallel rate movements in assets and liabilities,
- Generally does not adequately capture embedded options or complex instruments,
- May not identify material intra-period repricing risks, and
- Does not measure changes in the economic value of capital.

Some gap systems attempt to capture basis, yield curve, and option risk. Multiple schedules (dynamic or scenario gap analysis) can show effects from non-parallel yield curve shifts. Additionally, sensitivity factors may be applied to account categories. These factors assume that coupon rates will change by a certain percentage for a given change in a market index. The market index is designated as the driver rate (sophisticated systems may use multiple driver rates). These sensitivity percentages, also called beta factors, may dramatically change the results.

Institutions can also use sensitivity factors in their gap analysis to refine non-maturity deposit assumptions. For example, management may determine that the cost of funds for money market deposit accounts (MMDA) will increase by 75 basis points whenever the six-month Treasury bill rate increases by one percent. Thus, management might consider only 75 percent of MMDA balances as rate sensitive for gap analysis. Management may expand its analysis by preparing gap schedules that assume different market rate movements and changing customer behaviors.

As noted above, gap analysis is generally not suitable as the sole measurement of IRR for the large majority of institutions. Only institutions with very simple balance sheet structures, limited assets and liabilities with embedded options, and limited derivative instruments and off-balance sheet items should consider relying solely on gap analysis for IRR measurements.

Duration Analysis

Duration analysis measures the change in the economic value of a financial instrument or position that may occur given a small change in interest rates. It considers the timing and size of cash flows that occur before the instrument's contractual maturity. Additional information on different types of duration analysis is included below and in the glossary.

Macaulay duration calculates the weighted average term to maturity of a security's cash flows. Duration, stated in months or years, always:

- Equals maturity for zero-coupon instruments,
- Equals less than maturity for instruments with payments prior to maturity,
- Declines as time elapses,
- Is lower for amortizing instruments, and
- Is lower for instruments with higher coupons.

Modified duration, calculated from Macaulay duration, estimates price sensitivity for small interest rate changes. An instrument's modified duration represents its percentage price change given a small change in interest rates.

Modified duration assumes that interest rate shifts will not change an instrument's cash flows. As a result, it does not estimate price sensitivity with an acceptable level of precision for instruments with embedded options (e.g., callable bonds or mortgages). Institutions with significant option risk should not rely solely upon modified duration to measure IRR.

Effective duration estimates price sensitivity more accurately than modified duration for instruments with embedded options and is calculated using valuation models that contain option pricing components. First, the user must determine the instrument's current value. Next, the valuation model assumes an interest rate change (usually 100 basis points) and estimates the instrument's new value based on that assumption. The percentage change between the current and forecasted values represents the instrument's effective duration.

All duration measures assume a linear price/yield relationship. However, that relationship actually is curvilinear, which means that large shifts in rates have a greater effect than smaller changes. Therefore, duration may only accurately estimate price sensitivity for rather small (up to 100 basis point) interest rate changes. Convexity-adjusted duration should be used to more

accurately estimate price sensitivity for larger interest rate changes (over 100 basis points).

Duration analysis contains significant weaknesses. Accurate duration calculations require significant analysis and complex management information systems. Further, duration only measures value changes accurately for relatively small interest rate fluctuations. Therefore, institutions must frequently update duration measures when interest rates are volatile or when any significant change occurs in economic conditions, market conditions, or underlying assumptions.

Earnings Simulation Analysis

Earnings simulation models (such as pro-forma income statements and balance sheets) estimate the effect of interest rate changes on net interest income, net income, and capital for a range of scenarios and exposures. Historically, comprehensive simulation models (both long- and short-term) were primarily used by larger, more complex institutions. Current technology allows less complex institutions to perform cost effective, comprehensive simulations of the potential impact of changes in market rates on earnings and capital.

A simulation model's accuracy depends on the use of accurate assumptions and data. Like any model, inaccurate data or unreasonable assumptions lead to inaccurate or unreasonable results.

A key aspect of IRR simulation modeling involves selecting an appropriate time horizon(s) for assessing IRR exposures. Simulations can be performed over any period and are often used to analyze multiple horizons identifying short-, intermediate-, and long-term risks. When using earnings simulation models, IRR exposures are often more accurate when projected over at least a two-year period. Using a two-year time frame better captures the full impact of important transactions, tactics, and strategies, which may be hidden by only viewing projections over shorter time horizons. Management should be encouraged to measure earnings at risk for each one-year period over their simulation horizon to better understand how risks evolve over time. For example, if the bank runs a two year simulation, one- and two-year simulation reports should be generated.

Longer-term earnings simulations of up to five to seven years may be recommended for institutions with material holdings of products with embedded options. Such extended simulations can be helpful for IRR analysis and economic value measurements. It is usually easier for an extended simulation model to identify when long-term mismatches occur (e.g., it can show that a bank is liability sensitive in years two, three, and four, but asset sensitive in years five, six, and seven), whereas EVE models aggregate the effect of such mismatches.

Institutions may vary their simulation rate scenarios based on factors such as pricing strategies, balance sheet compositions, hedging activities, etc. Simulation may also measure risks presented by non-parallel yield curve shifts.

Institutions can run static or dynamic simulations. Static models are based on current exposures and assume a constant balance sheet with no new growth. The models can also include replacement-growth assumptions where replacement growth is used to offset reductions in the balance sheet during the simulation period.

Dynamic simulation models may assume asset growth, changes in existing business lines, new business, or changes in management or customer behaviors. Dynamic simulation models can be useful for business planning and budgeting purposes. However, these simulations are highly dependent on key variables and assumptions that are difficult to project with accuracy over an extended period. Also, when management changes simulation scenarios, it may lose insights on the bank's current IRR positions. Dynamic simulations can provide beneficial information but, due to their complexity and multitude of assumptions, can be difficult to use effectively and may mask significant risks.

Projected growth assumptions in dynamic modeling often alter the balance sheet in a manner that reflects reduced IRR exposure. For example, if a liability-sensitive bank assumes significant growth in one-year adjustable rate mortgages or long-term liabilities and the growth targets are not met, management may have underestimated exposures to changing interest rates. Therefore, when performing dynamic simulations, institutions should also run static or no-growth simulations to ensure they produce an accurate, comparative description of the bank's IRR exposure.

Economic Value of Equity

Despite their benefits, both static and dynamic earnings simulations have limitations in quantifying IRR exposure. As a result, economic value methodologies should also be used to broaden the assessment of IRR exposures, particularly to capital.

Economic value methodologies attempt to estimate the changes in a bank's economic value of capital caused by changes in interest rates. A bank's economic value of equity represents the present value of the expected cash flows on assets minus the present value of the expected cash flows on liabilities, plus or minus the present value of the expected cash flows on off-balance sheet instruments.

Typically, an EVE model projects the value of a bank's economic capital for a base-case scenario, and then compares it to a stress scenario. These models go by various names and acronyms, such as EVE, MVE (Market Value of Equity), or NPV (Net Present Value).

In theory, an economic valuation approach has a broader scope than an earnings approach, since it captures all anticipated cash flows and is generally more effective in capturing embedded options. An economic valuation approach measures all estimated changes to the balance sheet and earnings, as opposed to gap models and earnings simulations, which generally measure shorter-term balance sheet and earnings projections. Economic valuation methods can be an effective supplement to short-term measures.

Many institutions can benefit from the use of economic value methods and should establish EVE risk limits and integrate economic valuation methods into their IRR measurement procedures. Because different EVE models calculate different base-case economic capital values for the same bank, limits should generally be based on the change of economic capital rather than absolute levels of economic capital. Accordingly, examiners should assess the relative changes in economic value of capital as a key indication of risk.

Most economic value models use a static approach where the analysis does not incorporate new business lines and all financial instruments are held until final payout or maturity. The analysis shows a snapshot of the risk inherent in a portfolio or balance sheet. However, this is not always the case as some models incorporate dynamic techniques that provide forward-looking estimates of economic value.

Because EVE estimates the future cash flows of the bank's financial instruments, the cash flows can be difficult to accurately quantify. This can be especially true for non-maturity deposits since the products generally have uncertain cash flows and durations. Consequently, estimating the value of these accounts can be difficult and requires the use of several assumptions. Management should be cautious when making EVE assumptions, as output errors can be more pronounced in long-term measurements. Examiners should consider the significance, accuracy, and sensitivity of underlying assumptions when assessing EVE models.

When modeling complex products with embedded options, the importance of data aggregation and stratification should not be overlooked. Complex or structured securities should be modeled on an individual basis, and homogenous balance sheet accounts should be aggregated by common IRR features. For example, loan portfolios, when possible, should be aggregated by product type, coupon, maturity, and prepayment volatility. For adjustable rate portfolios, modeling should include more IRR attributes, such as coupon reset dates and indexes; embedded caps and floors; and prepayment penalties.

Despite being different methodologies, earnings simulation and EVE models generally provide a consistent view of IRR trends. However, the two approaches may also generate divergent outcomes. In many cases, earnings simulation models provide shorter-term results and EVE models provide a much longer-term risk profile. These divergent outcomes can result from a variety of factors, such as the structure of the balance sheet, including the bank's derivative positions and off-balance sheet items, the interest rate environment, the timing of asset/liability mismatches, the sensitivity of funding sources to interest rate changes, and the volume of fixed- or floating-rate assets. Because many versions of each model type are available, management should ensure that the models used capture all significant risk factors.

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STRESS TESTING

Stress testing, which includes both scenario and sensitivity analysis, is an integral part of IRR management. Scenario analysis estimates possible outcomes given an event or series of events, while sensitivity analysis estimates the impact of change in one or only a few of a model's significant parameters.

Management should assess a range of alternative interest rate scenarios when conducting scenario analyses. The range should be sufficient to fully identify repricing, basis, and yield curve risks as well as the risk of embedded options. In many cases, static interest rate shocks consisting of parallel shifts in the yield curve of only plus and minus 200 basis points are not sufficient to adequately assess IRR exposure. Therefore, management should regularly assess a wide range of exposures across different periods, including changes in rates of greater magnitude (e.g., up and down 300 and 400 basis points). When conducting stress tests, management should give special consideration to financial instruments or markets where concentrations exist, as such positions may be difficult to unwind or hedge during periods of market stress. Management should compare stress test results against approved limits.

Management should ensure their scenarios are rigorous and consistent with the existing level of rates and the interest rate cycle. For example, in low-rate environments, scenarios involving significant declines in market rates can be deemphasized in favor of increasing the number and size of alternative rising-rate scenarios. Alternatively,

there may be instances where more extreme stress tests would be desirable.

Depending on a bank's IRR profile, stress scenarios should include:

- Instantaneous and significant rate changes,
- Substantial rate changes over time,
- Changes in the relationships between key market rates, and
- Changes in the shape or slope of the yield curve.

Not all financial institutions need to use the full range of the scenarios discussed above. Non-complex institutions (for instance, institutions with limited embedded options or structured products) may be able to justify running fewer or less intricate scenarios.

Management should run repricing risk scenarios regularly. When applicable, institutions should also run scenarios for other IRR risks, such as basis and yield curve risks. Institutions should assess these risk exposures at least annually or when the risk profile of a bank changes, for example, because of acquisitions, significant new products, or new hedging programs. If a bank shows material exposure to one of these risks, an appropriate scenario should be included in monthly or quarterly IRR monitoring. If an institution has relatively non-complex exposure to basis, yield curve, or options risk, management should document that the exposure is minimal. For example, management may document its assessment with a short narrative description of what percentage of assets and liabilities are tied to various indices and a description of the potential impact of the risks. These reports should typically be reviewed by the board at least annually.

Sensitivity analysis should be included in stress testing to help determine which assumptions have the most influence on a model's output. By identifying key assumptions, management, when necessary, can refine the assumptions to increase the accuracy of their models. The most significant variables can be tested by keeping all other variables constant, changing the variable in question, and comparing the results to the base-case scenario. Additionally, sensitivity analysis can be used to determine the conditions under which key business assumptions or model parameters break down or when IRR may be exacerbated by other risks or earnings pressures. When management includes assumptions based on strategic initiatives, it is imperative that they assess the impact of not meeting projections. (Refer to Sensitivity Testing - Key Assumptions for more details.)

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INTEREST RATE RISK MEASUREMENT SYSTEMS

The IRR measurement system should be appropriate for institution's risk profile. The measurement system should capture all material sources of IRR and generate meaningful reports for senior management and the board of directors. Management should ensure risks are measured over a relevant range of interest rate changes, including meaningful stress situations. Further, the measurement system must be subject to appropriate internal controls and periodic independent reviews. The IRR measurement process should be well documented and administered by individuals with sufficient technical knowledge.

IRR measurement systems can range from simple methods to sophisticated programs that include stochastic data modeling. (Stochastic modeling involves using one or more random variables in a model.) However, all measurement systems should use generally accepted financial concepts and risk measurement techniques and have an adequate level of transparency. If a third-party model is used, management should review the adequacy and comprehensiveness of the vendor's model-validations and internal control reviews. Also, management should consider the capabilities of the software to meet the institution's future needs and the adequacy of ongoing vendor support and training.

A bank's IRR measurement system is a critical part of its overall risk management process. Examiners rely heavily on the output of the measurement systems when assessing sensitivity to market risk. Accordingly, the review of such systems and their operation is a crucial element of the examination process. The review process should address the following items:

- Capabilities of the measurement system,
- Accuracy of system inputs,
- Reasonableness and documentation of material assumptions,
- Usefulness of system output/reports, and
- Adequacy of periodic variance analysis.

Measurement System Capabilities

The IRR measurement system should capture and reliably estimate all material risk exposures. Therefore, the system should consider all significant balance sheet categories, income statement items, and risk factors. For example, if an institution has material holdings of mortgage loans or mortgage-backed securities, then its measurement system should be able to adequately incorporate prepayment

projections. Likewise, if the bank has a mortgage banking operation that generates material fee income, its system should capture the rate sensitivity of this noninterest income.

When an institution develops an IRR model internally or considers acquiring a third-party model, management should assess its suitability by evaluating the model's ability to reasonably capture all relevant and material IRR exposures. Additionally, management should periodically re-evaluate the adequacy of a model in use as risk positions, strategies, and activities change.

To effectively use its IRR measurement system, management must fully understand the system's capabilities, limitations, quantitative methodologies, and use of assumptions.

System Documentation

Both purchased and internally developed systems should be supported by adequate documentation. System documentation should provide complete information regarding the factors discussed above. Management should be familiar with and retain all pertinent system documentation. Management should also review and maintain documentation of changes or upgrades to the model.

Adequacy of Measurement System Inputs

A model's accuracy depends on the assumptions and data used. Like any model, inaccurate data or unreasonable assumptions will render inaccurate results.

System data should accurately reflect the bank's current condition. When evaluating the adequacy of a model, management should consider the extent to which the model uses automated versus manual processes; whether the model has automated interfaces with the bank's core systems; and the funds, hardware, staff, and expertise needed to run and maintain the model.

Examination of the system's input process should focus on the procedures for inputting and reconciling system data, categorizing and aggregating account data, ensuring the completeness of account data, and assessing the effectiveness of internal controls and independent reviews.

The internal control process must be comprehensive enough to ensure that data inputs are accurate and complete prior to running the system and generating reports. The bank may input data manually, through data-extract programs, or a combination of both techniques. Internal control procedures should be established to ensure that input data, such as general ledger balances and contractual terms, are accurately captured. Institutions should verify system inputs by having experienced personnel reconcile the balances to the general ledger. This is often done using automated software that can identify and report exception items.

In addition to capturing account balances, institutions with complex balance sheets should use measurement systems that adequately capture the embedded market risk of all material on- and off-balance sheet activity. Most measurement systems allow for the input of the following contractual terms:

- Current balance,
- Contractual maturities,
- Principal and interest payments and frequencies,
- Coupon rates and repricing frequencies,
- Contractual caps and floors, and
- Contractual optionality (such as security or borrowing calls).

Account Aggregation

Account aggregation is the process of grouping together accounts of similar types and cash flow characteristics. This is an important component of the data input process as account aggregation improves the measurement system's efficiencies. Typically, loans of similar rate, maturity, and type (e.g., 6 percent, 30 year, residential loans) are aggregated. Grouping 6 percent, 30 year residential loans together may be appropriate, but grouping together 6 percent fixed-rate loans with 6 percent adjustable-rate loans is not.

The degree of account aggregation will vary from one institution to another. Institutions should ensure the model allows for a sufficient separation of accounts with significantly different cash flow patterns. For example, models that aggregate information based on Call Report data may not provide the granularity necessary for institutions with significant levels of embedded options. When applicable, institutions should ensure their systems have the ability to model highly structured instruments and bank-specific products.

Both contractual and behavioral characteristics should be considered when determining the cash flow patterns of accounts to aggregate. The process of determining which accounts are combined should be transparent, documented, and periodically reviewed. Furthermore, requests for changes to existing groups or new account aggregations should be formalized and documented. Institutions should maintain documentation disclosing the characteristics of

aggregated assets and liabilities (including all derivative instruments), and off-balance sheet items.

Assumptions

Assessing the reasonableness of assumptions is a critical part of reviewing an IRR measurement system. It is important that assumptions accurately reflect management's expectations regarding interest rates, customer behaviors, and local and macro-economic factors. Assumptions are typically derived using a combination of internal analysis and external sources. All material assumptions should be regularly updated and supported with thorough analysis and documentation.

IRR measurement systems rely on assumptions regarding key parameters, such as:

- Projected interest rates,
- Driver rate relationships,
- Non-maturity deposits, and
- Prepayments.

It is important that material assumptions be updated regularly to reflect the current market and operating environment. Furthermore, the process for developing material assumptions should be formalized and periodically assessed (at least annually for critical assumptions). This periodic assessment of the information and processes used to generate assumptions may prompt management to reevaluate its assumptions in order to better reflect current strategies or customer behaviors.

Sensitivity Testing - Key Assumptions

Proper IRR management requires an understanding of which assumptions have the greatest impact on results. Through sensitivity testing, management can identify the assumptions that have the most effect on model results. Documentation and monitoring should reflect the relative importance of assumptions. Sensitivity testing can also be used to identify less material assumptions, where assumption documentation, monitoring, and testing are less critical. Sensitivity testing can also be used to identify weaknesses in the model. For example, if an institution tested an assumption that was expected to have a critical impact on the model result, but instead found that it had little or no influence on the model output, further investigation would be warranted.

Sensitivity testing should only be applied to one assumption at a time and should test the effects of both large and small changes in an assumption on the model's overall output. For example, if an institution wanted to test the sensitivity of non-maturity deposit decay rates, it could alter its non-maturity deposit beta assumptions incrementally (up and down) in multiple scenarios (e.g., a 10, 25, and 50 percent increase/decrease from the base-case assumption). The revised results could then be compared to the base-case scenario. If a change in the assumption disproportionately impacts the model, then management should implement more robust assumption documentation, monitoring, and testing. Another sound practice when testing assumptions is to determine how extreme changes in key assumptions impact results and whether the results approach approved tolerance levels.

Conducting sensitivity testing on an annual basis is usually adequate for many institutions. However, more frequent tests should be performed if concerns are identified. Institutions should document the results of sensitivity testing and present the results to management and the board. The results of sensitivity testing should be considered when setting various assumptions. Management should conduct thorough due diligence before changing key assumptions that can materially alter model results. Key assumption changes should be properly documented and reviewed by the board.

Projected interest rate assumptions are a critical part of measuring IRR and may be generated by internal analysis or external sources. Internal interest rate forecasts, which may be derived from implied forward yield curves, economic analysis, or historical regressions, should be documented to support the assumptions used in the analysis. Key rate assumptions that should be considered include assumptions for general market rates, repricing rates, replacement interest rates, and discount rates.

Most institutions perform scenario analysis using deterministic interest rate yield curves. With the deterministic method, all interest rate scenarios are set by the user; that is, management selects the interest rate changes to simulate in the model. The deterministic method differs from the more complex and sophisticated stochastic method where multiple scenarios are generated using random path-dependent variables. (Further discussion of deterministic and stochastic methods may be found in the glossary.)

Analysis should be performed using a base-case interest rate scenario, as well as low-probability/high-risk scenarios, so that management can better estimate the impact to earnings and capital levels in stressed interest rate scenarios. The base-case interest rate scenario should be consistent with other forecasts used in the bank's overall planning process and should remain reasonably consistent across reporting periods. Any changes in the source of interest rate forecasts between reporting periods should be justified and documented.

Driver rates are used extensively in most income simulation and EVE models. The models capture the relationship between primary market interest rates (driver rates) and the rates of bank products. While there may be no direct connection between bank rates and the driver rate, the driver rate is chosen as a proxy for management's reaction to market changes. This frees management from needing to set rates explicitly for each loan or deposit type for each projected scenario. In most cases, bank rates are set to move in relation to the driver rate. The move may be referred to as a spread (when a specified number of basis points are added to or subtracted from a driver rate), or as a beta factor (when based on a percentage change in a driver rate). For example, management might specify that the rate paid on MMDAs will increase 75 basis points if the yield on one-year Treasury bills increases 100 basis points. By designating this relationship, pricing on all products linked to the driver rate will change to reflect the relationship built into the model. More complex systems may use a variety of driver rates tailored for different products. While most systems maintain static rate relationships, more sophisticated systems can alter relationships for different interest rate environments.

Spread or beta assumptions should be based on an analysis of the relationship between the product (e.g., MMDA) and the driver rate (e.g., federal funds rate). To determine the spread or beta, management can perform correlation or regression analysis to quantify the historical relationship between the product and driver rates.

Correlation analysis may also be used to determine the level of basis risk when instruments are tied to different indices. For instance, if an institution enters into a leveraging strategy that uses borrowed funds tied to LIBOR to invest in U.S. Treasury securities, correlation analysis can be performed to determine how closely the related rates move together. Less correlated instruments present greater basis risk.

Non-maturity deposit (NMD) rate sensitivity is typically one of the most critical and most difficult assumptions that management makes when measuring IRR exposure. The potential actions of management and customers need to be considered. Just as customers have control over the level and location of their deposit accounts, management has broad control over the rates paid on these accounts. In setting rates, management must take into account a wide array of factors, including local and national competition, the bank's funding needs, and the relative costs of alternative funding sources.

The assumptions modeled for NMDs should reflect both aspects of this relationship: management's control over rates and customers' control over their funds. Consideration should be given not only to historical correlation analysis, but also to management's intentions regarding future rate movements. If the measurement system has the capacity to reflect different assumptions for rising and falling rates, management should establish rate sensitivity assumptions for both scenarios.

Non-maturity deposits present a unique problem in EVE modeling because they lack contractual maturity dates. Generally an asset or liability must have a maturity date in order to be valued under present value methods. Therefore, in order to successfully model these accounts, an EVE model must use management's assumptions regarding the maturity of the accounts. The most common of these assumptions is the decay rate assumption. The decay rate reflects the amount of nonmaturity (and other) deposits that may be withdrawn or accounts closed in a given rate environment.

Management should use NMD assumptions that reflect institution-specific factors and avoid overreliance on industry estimates or default assumptions contained in off-the-shelf IRR models. Some institutions have difficultly measuring decay rates on NMDs due to limited historical data, acquisitions, mergers, or a lack of technical expertise. Industry averages provide approximations, but are often not the most accurate estimates because they are not tailored to the bank's products, pricing strategies, market, and experience. However, management can use industry estimates as a starting point until they develop adequate data sets. Industry estimates can also serve as a benchmarking tool to test the reasonableness of internal assumptions. Management should consider modeling different decay rates under various rate scenarios and, when appropriate, should consider engaging third parties to assist in determining NMD assumptions. Examiners should recognize that NMD decay rate are often imprecise, yet significant factors in IRR analysis.

Assumptions regarding NMDs are particularly critical in market environments in which customer behaviors may be atypical, or in which institutions are subject to heightened competition for such deposits. Generally, rate-sensitive and higher-cost deposits, such as brokered and Internet deposits, reflect higher decay rates than other types of deposits. Also, institutions experiencing or projecting lower capital levels that may trigger brokered and high interest rate deposit restrictions should adjust deposit assumptions accordingly.

Prepayment assumptions are important considerations when measuring optionality risk. Prepayment risk (or conversely, extension risk) on loans and mortgage-related securities are highly influenced by the direction of interest rates. Prepayment assumptions may also be affected by factors such as loan size, geographic area, credit score, and fixed versus variable rates. It is critical that assumptions

be reasonable for each rate scenario measured. For example, in an increasing rate environment, prepayment assumptions should typically reflect lower prepayments than in a declining rate environment.

Financial institutions may actively track internal prepayment data or obtain prepayment statistics from external sources. Management should consider the reliability and applicability of external data and be cognizant that market stress, externalities, or a change in the institution's condition may influence customer behaviors.

Management should ensure that assumptions are appropriate given the characteristics of the institution's various portfolios (i.e., prepayment speeds for a portfolio of five percent loans would likely differ from a portfolio of eight percent loans). In addition, proper aggregation of the assets is necessary before applying assumptions.
Documentation and support of all significant assumptions, including projected rates, spreads, customer behaviors, and NMD rates should be maintained and available for examiner review. Some measurement systems have only limited ability to change model assumptions, in which case documentation may be limited. Even in those cases, an analysis of the applicability of the embedded assumptions to the subject bank should be performed and maintained. More complex systems entail a vast array of assumptions, and thorough documentation of every assumption cannot be realistically expected. However, management should thoroughly support and document assumptions related to the most significant institution or model risks.

Measurement System Reports

Many measurement systems are capable of providing summary reports detailing key model assumptions. Examiners should review a copy of these reports when analyzing a measurement system.

Most asset/liability management systems offer an array of summary reports (such as a chart of accounts and account attribute reports) that aid management in reviewing measurement system assumptions. These reports may also provide information regarding the contractual terms and parameters that have been entered into the system for various account types and financial instruments.

If an institution is unable to provide assumption summaries, examiners should determine whether the absence of the report is due to measurement system limitations or bank personnel's lack of familiarity with system capabilities. Typically, measurement system user manuals will provide a list of reports that may be generated by the system.

Assumption summary reports are an important tool that management and examiners can use to ensure that reasonable assumptions have been entered into the measurement system. The reports can also be useful to examiners when management does not maintain adequate documentation of current assumptions. For example, when assumption summary reports are regularly produced and retained, examiners can compare current assumptions against historical assumption reports.

To ensure proper controls over significant assumption changes, management should establish procedures for reviewing the reasonableness of assumption changes and for approving those changes before they occur.

Measurement System Results

After data and assumptions have been input, the IRR measurement system performs calculations. The calculations measure the IRR in the bank's assets, liabilities, and off-balance sheet items. The measurement system should generate summary reports that highlight the bank's sensitivity to changes in market rates given various interest rate scenarios. These reports typically indicate the change in net income or net interest income and/or economic value of equity. Some systems may also provide a gap report highlighting asset/liability mismatches over various time horizons. More detailed reports may be available on some systems that can be used to test the reasonableness, consistency, and accuracy of the output. They may also assist the examiner in identifying or verifying the system's underlying assumptions.

Management should have formalized procedures in place for reviewing measurement system results and reporting to the board or a board committee. Reports provided to the board and senior management should be clear, concise, timely, and informative in order to assist the board and senior management in making decisions. The results of the measurement system should also highlight deviations from board-approved IRR exposure limits. Examiners should review follow-up actions and communication relevant to any material breaches in board-approved limits. Examiners should also review the presentations or analyses provided to senior management, board members, and the ALCO, as well as any relevant meeting minutes.

Variance Analysis

Variance analysis (also known as back-testing) can provide valuable insights into the accuracy and reasonableness of IRR models and is an integral part of the control process for IRR management. Variance analysis involves identifying material differences between actual and forecasted income statement and balance sheet amounts

and ascertaining the causes of the differences. Variances can be readily identified by direct comparison of the financial statements for a particular forecast period, or by using key financial indicators, such as net interest margin, cost of funds, or asset-yield comparisons.

Variance analysis can help management understand the primary reasons for material differences between projected and actual results. It can also provide a means to improve the precision of the IRR measurement system. Periodic variance analysis helps assure management and the board that the system is accomplishing its primary goal of providing meaningful information on the level of IRR. Variance analysis provides an opportunity for a deeper understanding of both the system and its results.

Variance analysis should be done periodically and no less frequently than annually. Further, management should document their analysis, highlighting any material variances, the primary cause of identified variances, and any proposed or implemented corrective actions.

Variances resulting from errors can be broken down into three major components: input, modeling, or assumption errors. When conducting variance analysis, management should attempt to pinpoint the cause of all material variances. Mathematical flaws, while relatively rare in widely available purchased systems, can occur. Other types of modeling errors can be caused by inaccurate data input, user unfamiliarity with the model, over-aggregation of account types, or the use of a model with insufficient capabilities.

Data errors can be minimized by strong internal controls and may be identified through selective transaction testing. Many models can compare the results of historical IRR simulations with actual financial results. Significant variances can help management identify, and subsequently correct, identified issues with the model setup, such as inappropriate account aggregations or the failure to include key account characteristics.

Assumption Variance Analysis

All IRR measurement systems rely heavily on a series of assumptions, and assessing their reasonableness is critical to ensuring the integrity of the measurement system results. Just as actual financial results can be expected to vary from forecasts, the assumptions that form the basis of that forecast can be expected to vary from actual events.

Institutions should have formalized procedures for periodically identifying material differences between assumed and realized values. Formal procedures help identify the key reasons for variances. Even if material financial variances are absent, the model's significant assumptions should be compared to actual performance. Compensating differences may have masked important variances. For example, an institution with a large mortgage portfolio may find that actual prepayment speeds were significantly higher than projected, but new loan production replaced the run-off. In this case, there may only be an immaterial variance in the ending loan balance, but a significant variance in projected vs. actual prepayments.

Given the large number of assumptions inherent in most measurement systems, a thorough review of every assumption during each measurement cycle is unrealistic. However, key assumptions should be checked against actual behaviors on a regular basis. Key assumptions include those dealing with interest rate movements, driver rates, non-maturity deposits, prepayment speeds, and account aggregations. Variance analysis should be used to identify the differences attributable to rate assumptions and other factors in order to better understand how those factors influenced modeled results.

Driver rate variances occur when the expected correlation between a bank rate and its driver rate does not act as predicted. Variance analysis is used to determine the significance of the difference and should address whether the difference is due to an inaccurate correlation between the subject and driver rate, or due to inappropriate spreads or beta factors. Ideally, the relationship between subject and driver rates should be documented, and the relationship should factor in historical correlations and management's intentions regarding future movements.

Non-maturity deposit assumptions may cause significant variances. If the measurement system forecast an increasing net interest margin in a rising rate environment, while the actual margin declined, the cause may involve NMD assumptions. Many models treat NMD rates as very insensitive to yield curve changes, while actual practices are to manage the rates more actively. This can lead to model measurements that show the bank as asset sensitive or neutral, when past performance shows it to be liability sensitive. Periodic variance analysis may identify this discrepancy and allow management to more effectively use the IRR measurement tool. *Note:* Examiners should recognize that models are forward looking; therefore the usefulness of historical variance analysis may be limited.

Prepayment speed variances occur when actual prepayments do not mirror those projected. Variances are not uncommon as the cash flows are difficult to model and predict; however, management should monitor prepayments and revise related assumptions if material variances occur.

Inappropriate account aggregation can also lead to significant variances. For example, when comparing

actual and modeled loan interest income, an institution may find that the model overestimated income in a falling rate environment because real estate loans with significantly different prepayment characteristics were aggregated together.

Many models measure static IRR, that is, what would happen to the current balance sheet if only interest rates changed. Other models incorporate management projections about asset and liability growth and changes in product mix. Variance analysis in the latter instance is complicated by the need to segregate variances due to balance sheet changes from those caused by rate movements.

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OTHER RISK FACTORS TO CONSIDER

Although IRR is the principal market risk taken by most financial institutions, other activities can significantly increase (or reduce) a bank's exposure and sensitivity to market risk.

Foreign exchange activities expose institutions to the price (exchange rate) risk that results from volatile currency markets. Exchange rates depend upon a variety of global and local factors that are difficult to predict, including interest rates, economic performance, central bank actions, and political developments.

Commodity activities involve using commodity contracts (including futures and options) to speculate or hedge. Commodity prices depend upon many factors and are very difficult to forecast.

Generally, institutions should only use foreign exchange or commodity activities to hedge or control specific market risks. Management, independent of the broker/dealer, should demonstrate expertise commensurate with the activities undertaken. In addition, management should produce documented analysis that clearly details the effectiveness of all foreign exchange and commodity hedging activities. The analysis should be prepared at least quarterly and presented to the board for its review. *Note:* Typical commodity hedging activities are significantly different from speculative commodity activities.

Equity trading and investing creates market risk exposure because changes in equity prices can adversely affect earnings and capital. The board and management have a responsibility to identify, measure, monitor, and control trading risks. Management should carefully monitor all equity investments, regularly evaluate the resulting market risk exposure, and provide timely reports to the board.

Foreign exchange, commodities, and equity trading requires a high level of technical and managerial expertise. The risk management and measurement systems needed to operate them effectively are likewise highly sophisticated and require rigorous monitoring and testing. Foreign exchange, commodity, or equity speculation, absent the necessary controls and sufficient capital, might be considered an unsuitable practice. When necessary, contact legal counsel or capital markets specialists in your region for additional guidance.

Interest Rate Risk Mitigation

Institutions can use several measures to mitigate IRR exposures. If risk measures fall outside approved tolerance guidelines and trigger corrective steps (which should be guided by approved policies), management might alter their balance sheet or engage in hedging activities. Hedging strategies often involve using complex derivative instruments and are not suitable for institutions lacking technical expertise. When any IRR mitigation strategy is considered, management should also consider other risks, such as credit, liquidity, and operational risks.

When implementing IRR mitigation techniques, the board and management should ensure that policies and approved strategies address:

- Analysis of market, liquidity, credit, and operating risks;
- Qualifications of personnel involved in implementing and monitoring hedging strategies;
- Permissible strategies and types of derivative contracts;
- Authority levels and titles of individuals approved to initiate hedging transactions and related authority limits;
- Risk limits for hedging activities such as position limits (gross and net), maturity parameters, and counterparty credit guidelines;
- Monitoring requirements for hedging activities, including ensuring activities fall within approved limits and management lines of authority; and
- Controls for ensuring management's compliance with technical accounting guidance that covers hedging activities.

Institutions should not use derivative instruments for hedging (whether or not hedge accounting is applied), unless the board and senior management fully understand the institution's strategy and the potential risks and benefits. Relying on outside consultants to assist with a hedging strategy does not absolve the board and senior management of their responsibility to understand and

oversee the risks of the activities. Hedging strategies should be designed to limit downside earnings exposure or manage income or EVE volatility. Activities conducted solely to generate additional income should not be considered hedging.

Altering the balance sheet is the most common method institutions use to modify their IRR position. However, this strategy may take time to implement and often cannot quickly correct significant exposures. For example, if a bank is liability sensitive and therefore exposed to rising interest rates, management may decide to reduce their retention of 30-year fixed-rate mortgages. Strategies may include increased sales (possibly for securitization) of longer-term mortgage products or pricing longer-term mortgages above market rates in order to reduce the volume of new loan originations. While this strategy may reduce IRR over time, this method can be slow in correcting material IRR imbalances and may not effect a timely reduction in risk exposures.

Institutions may also attempt to address exposures to rising interest rates by increasing longer-term deposit or borrowing levels. However, several factors may hinder the success of such strategies. There may be significant competition or limited demand for longer-term time deposits, and access to longer-term wholesale funding may be limited or offered on unfavorable terms. Additionally, embedded options (e.g., calls and step-up dates) in wholesale funding sources can present measurement challenges, and the cost of such funding can make this approach prohibitive unless there is a clear productive use for the funds.

Cash flow matching and duration matching are two typical hedging strategies. The goal of these strategies is to change a bank's IRR exposure to meet specific cash flow or duration targets. These strategies can be accomplished by altering the balance sheet composition or through the use of derivatives.

Some institutions refer to cash flow matching as matched funding. The bank matches the terms (rate or maturity) of funding and assets so that cash flows will reprice or mature simultaneously and interest rate changes will not significantly influence net cash flow. Cash flow matching can be difficult for small institutions due to the wide range of cash flows in most financial assets.

With a duration matching strategy, management may attempt to match the duration of a pool of assets with the duration of a pool of liabilities. The use of interest rate derivatives or options might also be used to modify or offset the duration of an existing pool of assets or liabilities. The goal is to match the effective durations of the pools in order to limit the net changes in fair values of the pools, rather than matching the specific cash flows. Duration matching is not a perfect strategy and may result in imperfect hedging from a cash flow perspective and can cause exposure to different kinds of risk (such as yield curve and basis risk).

Derivative instruments are available to hedge IRR. These instruments include, but are not limited to, swaps, amortizing swaps, basis swaps, futures, forwards, caps, options, floor options, and collars. The most common derivatives used to hedge IRR are swaps and forwards. In a pay-fixed swap transaction, a stream of fixed interest payments from a commercial loan may be contractually exchanged for a stream of floating-rate payments. This swap effectively shortens the duration of the commercial loan portfolio by reducing the asset/liability mismatch and improves profitability in a rising-rate environment. Conversely, the bank could lengthen the effective duration of its floating-rate deposits by entering into a swap where a floating-rate stream of payments is exchanged for a fixed-rate payment stream.

Institutions that use hedging activities should understand the true impact of a hedge (whether it actually decreases risks), and understand its impact on earnings and capital. All derivatives require fair value accounting adjustments, which may result in earnings and capital volatility. While management may utilize hedges to reduce certain risks in their portfolio, analysis of the hedges should consider the impact of related accounting adjustments on earnings and capital.

Each institution using derivatives should establish an effective process for managing related risks. The level of formality in this process should be commensurate with the activities involved and the level of risk approved by senior management and the board.

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INTERNAL CONTROLS

Establishing and maintaining an effective system of internal controls and independent reviews is critical to the risk management process and the general safety and soundness of the bank. Institutions should have adequate internal controls to ensure the integrity of their IRR management process. These controls should promote reliable financial reporting and compliance with internal policies and relevant regulations. Internal control policies and procedures should address appropriate approval processes, adherence to exposure limits, reconciliations, reporting, reviews, and other mechanisms designed to provide a reasonable assurance that the bank's IRR management objectives are achieved. Internal control policies and procedures should clearly define management authorities and responsibilities and identify the individuals

and committees responsible for managing sensitivity to market risk.

A sound control environment should also ensure adequate separation of duties in key elements of the risk management process to avoid potential conflicts of interest. Institutions should have clearly defined duties that are sufficiently independent from position-taking functions of the bank. Additionally, IRR exposures should be reported directly to senior management and the board of directors. The nature and scope of such safeguards should reflect the type and structure of the bank, the volume and complexity of IRR incurred by the bank, and the complexity of its transactions and commitments. More complex institutions should have an independent unit responsible for the design and administration of the bank's IRR measurement, monitoring, and control functions.

Independent Reviews

Regular independent reviews of its IRR management process are an important element of a bank's internal control system. Internal reviews of the IRR measurement system should include assessments of the assumptions, parameters, and methodologies used. Such reviews should seek to understand, test, and document the current measurement process, evaluate the system's accuracy, and recommend solutions to any identified weaknesses. The independent review should be tailored to the type and complexity of an institution's activities and encompass the standards and desirable scope discussed below. Regardless of the depth of the independent review, the findings of the review should be reported to the board no less frequently than annually, along with a summary of the bank's IRR measurement techniques and management practices.

Independent Review Standards

The purpose of an independent review is to ensure that the IRR measurement and management processes are sound. Regardless of whether the review is performed by internal staff or external entities, it is important these parties be independent of any operational responsibility for the measurement and management processes. They should not perform any of the routine internal control functions such as reconciling data inputs, developing assumptions, or performing variance analysis.

Independent reviews should be performed at least annually. The scope, responsibility, and authority for the reviews should be clearly documented and encompass all material aspects of the measurement process. The scope of the independent review should generally be defined by the internal audit staff and approved by the audit committee. However, subject to board approval, it is acceptable for another department of the bank, separate from the group that measures IRR, to define, perform, and document the independent review. A bank's review processes should meet the following minimum standards:

- Independence - Parties performing the independent review should not be involved in the day-to-day IRR measurement/management process. Institutions may use internal staff, an outsourcing arrangement, or a combination of the two to independently review the measurement system. Management may find that the internal audit department, or other staff independent of the measurement system, has the knowledge and skills to perform certain aspects of the review while using external resources for other areas. When the assessment of the measurement system is outsourced, senior management and the board should ensure that the procedures used meet the same standards required of a satisfactory internal review.
- Skills and Knowledge - Senior management and the board must ensure that individuals performing the independent review have the knowledge and skills to competently assess the measurement system and its control environment.
- Transparency - The procedures used in the independent review of the measurement system should be clearly documented, and work papers should be available to management, auditors, and examiners for review. Senior management should ensure that they have access to work papers even when external parties perform the review.
- Communication of Results - Procedures should be established for reporting independent review findings at least annually to the board or board-delegated committee.

Scope of Independent Review

Independent reviews provide a way to assess the adequacy of a bank's IRR measurement system. The level and depth of the independent reviews should be commensurate with the bank's risks and activities. More complex institutions should have a more rigorous independent review process. Less complex institutions may rely upon less formal reviews. At a minimum, each institution should have procedures in place to independently review the input process, assumptions used, and system output reports.

System-input reviews should evaluate the adequacy and appropriateness of:

- The knowledge and skills of individuals responsible for input to the measurement system;
- The reconciliation of the measurement system's data

to the bank's general ledger;
- The rules and methods of account aggregation used in the measurement system;
- The accuracy of contractual terms captured within the measurement system; and
- The source, completeness, accuracy, and procedures for external data feeds.

Assumption reviews should evaluate the following issues:

- The process of developing assumptions for all material asset, liability, and off-balance sheet exposures;
- The process for reviewing and approving key assumptions;
- The periodic review of assumptions for relevance, applicability, and reasonableness; and
- The completeness of assumption analysis and its supporting documentation.

System output and reporting assessments should include coverage of the following:

- Inclusion of a sufficiently broad range of potential rate scenarios,
- Accuracy of the IRR measurement and assurance that all material exposures are captured,
- Timeliness and frequency of reporting to management and the board,
- Compliance with operating policies and approved risk limits,
- Performance and documentation of variance analyses (back-testing), and
- Translation of model output into understandable management reports that support decision making.

Theoretical and Mathematical Validations

The degree to which calculations in an IRR model should be validated depends on the complexity of an institution's activities and IRR model. The complexity of many measurement systems demands specialized knowledge and skills to verify the mathematical equations. Less complex institutions using simpler, vendor-supplied IRR models can satisfy some, but not all, validation requirements with independent attestation reports from the vendor.

Management should periodically discuss with vendors what validation and internal control process assessments have been conducted. The vendor should provide documentation showing a credible, independent third party has performed such assessments. Vendors should be able to provide appropriate testing results to show their product works as expected. They should also clearly indicate the model's limitations, assumptions, and where the product's use may be problematic. Such disclosures, exclusive of confidential or proprietary information, should contain useful insights regarding a model's functionality and outputs. However, a certification or validation report from a vendor is only one component of a bank's independent review and should not be used as a substitute for an overall validation review. Management is still responsible for any aspect of the process under their control, such as data input, assumption changes, etc.

As part of the validation process, management should ensure that the software and mathematics of the IRR model function as intended. Many community institutions use largely standardized, vendor-provided models. In such cases, the validations provided by vendors can be used to support the accuracy of the model. For models that are customized to an individual institution or in situations where vendors are unable or unwilling to provide appropriate certifications or validations, management is responsible for validating the accuracy of the model's mathematics and soundness of the software.

Additionally, vendor models may be customized by an institution for its particular circumstances. Management should document and justify the institution's customization choices as part of the validation process. If vendors provide input data or assumptions, their relevance to the bank's situation should be evaluated and approved. Institutions should obtain information regarding the data (e.g., vendor-derived assumptions) used to develop the model and assess whether the data is representative of the institution's situation.

Complex institutions or those with significant IRR exposures may need to perform more in-depth validation procedures of the underlying mathematics. Validation practices could include constructing a similar model to test assumptions and outcomes or using an existing, well-validated benchmark model, which is often a less costly alternative. The benchmark model should have theoretical underpinnings, methodologies, and inputs that are very close to those used in the model being validated. More complex institutions have used benchmarking effectively to identify model errors that could distort IRR measurements. The depth and extent of the validation process should be consistent with the degree of risk exposures.

Model certifications and validations commissioned by vendors can be a useful part of an institution's efforts to evaluate the model's development and conceptual soundness. Although many vendors offer services for process verification, benchmarking, or back-testing, the services are usually separate engagements. Each institution should ensure these engagements meet its

internal policy requirements for validations and independent reviews.

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EVALUATING SENSITIVITY TO MARKET RISK

Component Review

Under the *Uniform Financial Institutions Rating System*, the sensitivity to market risk component reflects the degree to which changes in interest rates, foreign exchange rates, commodity prices, or equity prices can adversely affect a financial institution's earnings or economic capital. When evaluating this component, consideration should be given to: management's ability to identify, measure, monitor, and control market risk; the institution's size; the nature and complexity of its activities; and the adequacy of its capital and earnings in relation to its level of market risk exposure.

For many institutions, the primary source of market risk arises from nontrading positions and their sensitivity to changes in interest rates. In some larger institutions, foreign operations can be a significant source of market risk. For some institutions, trading activities are a major source of market risk.

Market risk is rated based upon, but not limited to, an assessment of the following evaluation factors:

- The sensitivity of the financial institution's earnings or the economic value of its capital to adverse changes in interest rates, foreign exchanges rates, commodity prices, or equity prices;
- The ability of management to identify, measure, monitor, and control exposure to market risk given the institution's size, complexity, and risk profile;
- The nature and complexity of interest rate risk exposure arising from nontrading positions; and
- Where appropriate, the nature and complexity of market risk exposure arising from trading and foreign operations.

Rating Sensitivity to Market Risk

Institutions rated 1 have well-controlled market risk and there is minimal potential that the earnings performance or capital position will be adversely affected. Risk management practices are strong for the size, sophistication, and market risk accepted by the institution. The level of earnings and capital provide substantial support for the degree of market risk taken by the institution.

Institutions rated 2 have adequately controlled market risk and there is only moderate potential that the earnings performance or capital position will be adversely affected. Risk management practices are satisfactory for the size, sophistication, and market risk accepted by the institution. The level of earnings and capital provide adequate support for the degree of market risk taken by the institution.

Institutions rated 3 need to improve market risk control or there is significant potential that the earnings performance or capital position will be adversely affected. Risk management practices need to be improved given the size, sophistication, and level of market risk accepted by the institution. The level of earnings and capital may not adequately support the degree of market risk taken by the institution.

Institutions rated 4 have unacceptable market risk control or there is high potential that the earnings performance or capital position will be adversely affected. Risk management practices are deficient for the size, sophistication, and level of market risk accepted by the institution. The level of earnings and capital provide inadequate support for the degree of market risk taken by the institution.

Institutions rated 5 have unacceptable control of market risk or the level of market risk taken by the institution is an imminent threat to its viability. Risk management practices are wholly inadequate for the size, sophistication, and level of market risk accepted by the institution.

Examination Standards and Goals

The following documents provide additional guidance for managing IRR:

- Joint Agency Policy Statement on Interest Rate Risk,
- Interagency Advisory on Interest Rate Risk Management, and
- Interagency Advisory on Interest Rate Risk Management Frequently Asked Questions.

Interagency Policy Statement on Interest Rate Risk

In 1996, the FDIC and the other Federal banking regulators adopted the Sensitivity to Market Risk component of the Uniform Financial Institutions Rating System and issued a Joint Agency Policy Statement on IRR (Policy Statement). The Policy Statement identifies the key elements of sound IRR management and describes prudent principles and practices for each of these elements. It emphasizes the importance of adequate oversight by a bank's board of directors and senior management as well

as the importance of comprehensive risk management processes. The Policy Statement also describes the critical IRR-related factors that affect the Agencies' evaluation of an institution's capital adequacy

Interagency Advisory-Interest Rate Risk Management

In January 2010, the Agencies issued updated guidance to clarify supervisory expectations for IRR management set forth in the 1996 Policy Statement. The Interagency Advisory on Interest Rate Risk Management (Advisory) re-emphasizes the importance of effective corporate governance, policies and procedures, risk measurement and monitoring systems, stress testing, and internal controls related to IRR exposures. The Advisory indicates financial institutions should manage IRR commensurate with their complexity, risk profile, business model, and scope of operations. Additionally, the Advisory highlights that effective IRR management involves not only the identification and measurement of IRR, but also appropriate risk mitigation strategies that may be used to control IRR if exposure levels warrant corrective steps.

In January 2012, the agencies published supplemental guidance addressing Frequently Asked Questions (FAQs) on the 2010 Advisory. The FAQs provides additional clarification on topics such as determining model appropriateness; defining meaningful stress scenarios; analyzing yield curve, basis, and option risk, as well as using no-growth measurement scenarios. The FAQs also describe effective procedures for model validations and calculation of non-maturity deposit decay assumptions.

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EXAMINATION PROCESS

FDIC examination procedures follow a risk-focused framework that incorporates the guidelines outlined in the 1996 Policy Statement and the 2010 Advisory (including the FAQs guidance) to efficiently allocate examination resources. The scope of an examination should consider a bank's IRR exposure relative to earnings and capital, the complexity of on- and off-balance sheet exposures, and the strength of risk management processes.

Examiners can identify material exposures and risks by reviewing the following items (most of which are available during off-site analysis):

- Prior examination findings,
- Interest Rate Risk Standard Analysis (IRRSA),
- Net interest margin and net operating income trends,
- Board or committee minutes,
- Bank IRR analysis,
- Independent review or audit findings,
- Related bank policies and procedures,
- Balance sheet and account data,
- Strategic and business plans,
- Product pricing guidelines, and
- Derivatives activities.

Citing Examination Deficiencies

Material weaknesses in risk management processes, or high levels of IRR exposure relative to capital, require corrective action. Such actions may include recommendations or directives to:

- Raise additional capital;
- Reduce levels of IRR exposure;
- Strengthen IRR management expertise;
- Improve IRR management information and measurement systems; or
- Take other measures or combination of actions, depending on the facts and circumstances of the individual bank.

If an examiner determines that IRR weaknesses warrant the listing of a contravention of regulatory guidance in the Report of Examination, the 1996 Policy Statement should be cited as the source guidance. Examiners may reference the Advisory or the FAQs document in supporting comments. A contravention of the interagency guidelines detailed in Appendix A of Part 364 may also be warranted for institutions with seriously deficient IRR programs.

Pursuant to Appendix A (II.E.) of Part 364, an institution should:

- Manage interest rate risk in a manner that is appropriate to the size of the institution and the complexity of its assets and liabilities; and
- Provide for periodic reporting to management and the board of directors regarding interest rate risk with adequate information for management and the board of directors to assess the level of risk.

Note: Accepting a reasonable degree of IRR is a fundamental part of banking that significantly affects profitability and shareholder values. Although risks must be properly managed, exceptions to established IRR policies and limits occasionally occur. Examiners should not automatically criticize relatively minor exceptions to established policies or internal limits if an institution has appropriate, formal processes for monitoring, reviewing, and approving exceptions.

Additionally, examiners are reminded that, if weaknesses in a model or its assumptions are identified that render its

results unreliable, report comments supporting the assigned rating should not rely on (or, at a minimum, should qualify any use of) the resulting data.

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MARKET RISK GLOSSARY

Deterministic Rate Scenarios

Deterministic modeling techniques allow management to specify the direction, amount, and timing of future interest rates in order to measure the potential impact the changes may have on earnings and capital. The following items are examples of commonly used deterministic interest rate scenarios:

- **Rate Shock Scenario** – In this scenario, rate changes are immediate and sustained. For example, in a plus 300 basis point scenario, the full effect of the rate increase would be administered in the first period measured and remain in effect for all periods.
- **Rate Ramp Scenario** – In this scenario, rate changes are applied gradually over the measured period. For example, when measuring the effects of a 300 basis point rate increase during a 12-month period, rates would be increased 25 basis points each month.
- **Stair Step Scenario** – In this scenario, rate changes are administered at less frequent intervals over the measured period. For instance, in a 300 basis point increasing rate environment measured over a two-year time period, rates may be increased 50 basis points each quarter of the first year and 25 basis points each quarter of the second year.

Non-parallel Yield Curve Shifts

A shift in the yield curve in which yields do not change by the same number of basis points for every maturity. When running various interest rate scenarios, management may set non-parallel shifts in a manner similar to deterministic rate scenarios (rate shock, rate ramp, or stair step). The scenarios often have a pivot point on the yield curve from which longer-term and shorter-term rates change in different amounts.

Static Models

Static simulation models are based on current exposures and assume a constant, no-growth balance sheet. In order to simulate no growth in balance sheet accounts, some static models assume that all principal cash flows from a particular account are reinvested back into that same account. This assumption is sometimes referred to as replacement growth.

Dynamic Models

Dynamic simulation models rely on detailed assumptions regarding changes in existing business lines, new business, and changes in management and customer behavior. The assumptions change the existing balance sheet to reflect expected business changes.

Stochastic Models

Stochastic modeling consists of the modeling of an uncertain variable over time using a random selection process. It recognizes that market variables, such as interest rates, exhibit a general trend (drift) and some degree of volatility around that trend. Stochastic models provide a framework for the evaluation of the impact of embedded options in financial instruments.

Constraints are usually imposed so that the model is representative of current market conditions. For example, if Treasury securities are priced using interest rate paths, a constraint may be imposed so that the average present value derived from all the paths must equal the observed market price of the Treasury securities. In such a case, the model can also be classified as a Stochastic No Arbitrage Model.

Monte Carlo Simulation

A Monte Carlo simulation randomly generates a large sample set of values from a reasonable population of variables such as an interest rate. The stochastic model provides a framework for the evolution of the variable, and a Monte Carlo simulation is an application of that stochastic model. The randomness in games of chance is similar to how Monte Carlo simulation selects values at random to simulate a model. When you turn a roulette wheel, you know that one number within a range of numbers will come up, but you do not know which number will come up for any particular turn. The same concept applies with a Monte Carlo simulation where the variables (e.g., interest rates, security prices) have a known range of values but an uncertain value for any particular time. Monte Carlo simulations can take into account returns, volatility, correlations, and other factors. Monte Carlo programs can generate millions of different scenarios by randomly changing a component for each run or iteration. Monte Carlo simulation allows the banker to simulate thousands of market-like scenarios and learn the probability of a particular outcome or a range of outcomes. Assume that the investment portfolio is run through 20,000 simulations, projecting 20,000 separate scenarios over a two-year period, and acceptable results occur 16,000 times. This means that there is an 80 percent probability

that the portfolio will perform at an acceptable level. Like any financial model, the results are sensitive to underlying assumptions. The number of runs or simulations is also important. For example, a Monte Carlo model with only 500 iterations captures fewer possible scenarios than one that runs 50,000 iterations.

Spread Types

- **Static Spread –** Basis points, that when added to a set of implied forward rates, discounts the cash flows of an instrument back to its observed market value. For an instrument without embedded optionality, the static spread is the best measure of return in excess of the risk-free rates provided by that instrument. For instruments with embedded optionality, it may be useful to calculate a static spread only as a starting point for comparison with a more appropriate mark-to-market spread measure, such as the option adjusted spread.
- **Option Adjusted Spread (OAS) –** Basis points, that when added to a set of interest rates discounts the cash flows of an instrument back to its observed market value. This measure only applies to instruments with embedded optionality. The static spread applies to instruments without embedded optionality. For example, consider a mortgage-backed security, which typically contains an embedded prepayment option. Assume the static spread is 75 basis points. The OAS would be less than the static spread of 75 basis points because the volatility of interest rates reflected in an OAS framework assigns more value to the borrower's prepayment option, thus reducing the value to the MBS investor.
- **OAS Process** – In a stochastic valuation model, the average value generated by all the interest rate paths must equal the currently observed price of the security. The initial computation in the model is based on an assumed spread. The security value derived is compared to the observed.

Duration Calculations

Macaulay duration calculates the weighted average term to maturity of a security's cash flows. Assume a bond with three years remaining to maturity, bearing a 5 percent coupon rate paid annually, when a 10 percent yield is required.

Macaulay Duration Calculation
3 year bond, 5% coupon, 10% yield

Year	Payment	PV x	T	PVxT
1	$50	$45.5 x	1 =	$45.5
2	$50	$41.3 x	2 =	$82.6
3	$1,050	$788.9 x	3 =	$2,366.7
Total		$875.7		$2,494.8

T = Time period payment is received

Macaulay Duration: 2,494.8 / 875.7 = 2.85 years

Modified duration, calculated from Macaulay duration, estimates price sensitivity for small interest rate changes.

Modified Duration Calculation
3 year bond, 5% coupon, 10% yield
Macaulay Duration = 2.85 years

$$\frac{\text{Macaulay Duration}}{1 + (\text{Yield} / n)} = 2.85 / 1.10$$

n = coupons per year

Modified Duration = 2.59%

The following formula can be used to estimate the percentage change in a bond's price:

$$\Delta\ \% = -\text{Modified Duration} \times \Delta\ \text{Yield} \times 100$$

Note: The minus sign recognizes the inverse relationship of price and yield.

For a 100 basis point change in rates, the estimated change in price is equal to the modified duration. In other words, using a modified duration of 2.59 percent, the price of a bond would change approximately 2.6 percent for every 100 basis point change in rates. If rates changed by only 50 basis points, the bond would change approximately 1.3 percent.

$\Delta\%$ = Modified Duration x Δ Yield x 100
= 2.59% x 50bp x 100
= 2.59% x .5
= 1.295%

The following formula can be used to estimate the dollar change in price:

$\Delta\$$ = minus Price x Modified Duration x Δ Yield x 100

If the price of the bond had been $875.66, then its approximate change in value (price), if rates changed by 50bp, would be ($875.66) x 1.295% = ($11.34).

If rates fell, the estimated value would be $887.00, while if rates rose the estimated value would fall to $864.32.

Duration-based price forecasts are generally precise when used with small rate changes (1 to 5 basis points). However, the accuracy of the forecasts decline when larger rates changes (especially 100 basis points or more) are involved. The reason for the declining accuracy of price forecasts relates to the non-linear relationship between prices and yields (a.k.a., convexity).

Convexity

Option-free financial instruments display positive convexity. When rates decline, a positively convexed instrument's price increases at an increasing rate. When rates rise, a positively convexed instrument's price decreases at a decreasing rate.

Negative convexity causes the duration of a security to lengthen when rates rise and shorten when rates fall. Instruments that contain embedded options demonstrate negative convexity. When rates decline, a negatively convexed instrument's price increases at a decreasing rate. When rates rise, the price of a negatively convexed instrument will decline at an increasing rate.

For example, the value of the treasury security changes relatively less in value in comparison to the sample mortgage security, which declines more significantly. However, as yields decrease, the treasury security gains value at an increasing rate, while the mortgage security gains only modestly. As interest rates decline, the likelihood increases that borrowers will refinance (exercise prepayment option). Therefore, the value of a mortgage security does not increase at the same rate or magnitude as a decline in interest rates.

Effective Duration and Effective Convexity

Effective duration and effective convexity are used to calculate the price sensitivity of bonds with embedded options. The calculations provide an approximate price change of a bond given a parallel yield curve shift. Measures of modified duration and convexity do not provide accurate calculations of price sensitivity for bonds with embedded options. Effective duration and convexity provide a more accurate view of price sensitivity since the measures allow for cash flows to change due to a change in yield. Formula:

Effective Duration = $(V_- - V_+)/(2V_0 \times \Delta Y)$
Effective Convexity = $(V_+ + V_- - 2V_0)/(2V_0 \times \Delta Y)^2$

Where, ΔY = Change in market interest rate used to calculate new values:

V_+ = Price if yield is increased by Change Y
V_- = Price if yield is decreased by Change Y
V_0 = Initial price per $100 of par value

Assume: a three-year callable bond's current market value is $98.60 ($V_0$); that interest rates are projected to change by 100 basis points (Y); that the price of this bond given a 100 basis point increase in rates is $96.75 ($V_+$); and that the price of this bond given a 100 basis point decrease in rates is $99.98 ($V_-$).

To calculate effective duration and convexity:

Effective Duration =
$(99.98 - 96.75)/(2(98.60)(.01)) = 1.64$
Effective Convexity =
$96.75 + 99.98 - 2(98.60) \div (2(98.60)(.01))^2 = -23.83$

If we assume interest rates increase 100 basis points, the approximate price change due to effective duration is the following:

Percentage Price Change = -Effective Duration x Yield Change
Percentage Change in Price = -1.64 x .01 = -1.64%

The approximate price change due to effective convexity is the following:

½ x Effective Convexity x (Yield Change)²
½ x -23.83 x $(0.01)^2$ x 100 = -0.12%

Thus this bond's price would be expected to decrease by about 1.76 percent given a 100 bps rise in rates:

Effective Duration	=	-1.64%
Effective Convexity	=	-0.12%
		-1.76%