

The following is a review of the Operational Risk and Resilience principles designed to address the learning objectives set forth by GARP®. Cross-reference to GARP assigned reading—Federal Deposit Insurance Corporation.

READING 54

SUPERVISORY GUIDANCE ON MODEL RISK MANAGEMENT

Study Session 8

EXAM FOCUS

This is a very specific reading on managing model risk from the perspective of a bank (or other financial institution). It begins with defining model risk and how to manage it. It then discusses the development and implementation of a model. In the concluding section on model validation, be familiar with the details surrounding the three elements of a strong validation process.

MODULE 54.1: MODEL RISK MANAGEMENT

LO 54.a: Describe model risk and explain how it can arise in the implementation of a model.

A model involves the use of concepts from statistics, economics, finance, and mathematics together with assumptions that are used to transform input data into potentially useful quantitative outputs. There are three distinct parts to a model: (1) *information inputs* to deal with data and assumptions, (2) *processing* to convert inputs to estimates, and (3) *reporting* to convert estimates into applied information. Models attempt to mimic real life, but due to cost-benefit constraints, models must resort to some simplifying assumptions. As a result, models will never be completely accurate and model risk will always be present.

Model risk raises the possibility of (negative) outcomes resulting from poor decisions made from using inaccurate model outputs. Such outcomes include financial and reputational losses. Model risk can arise in two distinct ways:

1. The model has significant errors and produces faulty outputs. Errors could be introduced anywhere from the initial design to the final implementation. Seemingly innocent modifications to simplify complex issues may end up sacrificing the accuracy of the outputs. In addition, the expression “garbage in, garbage out” holds in

terms of the quality of the output being a function of the quality of the inputs and assumptions.

2. The model is not used properly, not used for its intended purpose, or used out of context. For example, models that were formerly appropriate may no longer be appropriate for new products or changed market environments. Therefore, it is crucial for those in charge to understand the limitations and/or purposes of the original model.

Effective Model Risk Management Elements

LO 54.b: Describe elements of an effective model risk management process.

Managing model risk requires the identification of all relevant risks and attempts to quantify the exposure. The amount of model risk is dependent on how complicated the model is, the level of uncertainty with its inputs and assumptions, and its potential impact on users. Additionally, risk must be analyzed not just for stand-alone models but also in aggregate for models that are related or used in conjunction with other models.

The notion of an “effective challenge” of models is fundamental to managing model risk. It is necessary to have an in-depth, third-party, and unbiased evaluation of the model by individuals with strong technical skills who can determine the weaknesses of the model and its assumptions and propose effective solutions. To be effective, the individuals involved in the challenge should be completely independent from model development to avoid a self-review threat. Finally, there should be a robust follow-through process of issues identified during the challenge. This would require the support and authority of upper management.

Other methods of managing model risk include setting restrictions on the use of models, analyzing model performance, continually calibrating and improving models, and placing model output in the context of other relevant information (as a check on the reasonability of the output).

The potential impact (or materiality) of the model is a key element that will drive the level of risk management. If there is a potentially significant impact on the firm’s profits and/or financial position, then the risk management process must be much more detailed and comprehensive.

Best Practices for Model Development and Implementation

LO 54.c: Explain best practices for the development and implementation of models.

At the outset, development of a model should have a clearly stated objective that is congruent with the model’s eventual use. All the background information supporting the model needs to be thoroughly described, noting relevant strengths and weaknesses. The developers need to be satisfied that the model is logical and based on technically-

correct mathematical theories. In addition, a comparison of the model with other alternative models may serve as a “reasonability check” on the model’s logic.

During development, it is crucial to ensure that the data and assumptions are robust and are relevant for the model. Any data proxies, data that is not representative, or adjustments to data (e.g., from external data sources) need to be clearly documented and made clear to users. That way users can judge for themselves the usefulness of the data.

Testing is a key component of model development to ensure the model is working as planned. Testing involves assessing the precision of the model, proving the model’s strength and consistency, and using input amounts over a reasonable range to assess the model. At the same time, potential weaknesses in the model or circumstances where the model does not work must be noted. Testing should occur in both normal states and extreme (stressed) market states. This would include unusual (but still plausible) conditions. In addition, if the given model’s outputs are used as inputs for other models, then an analysis of the other models is required. There should also be proper documentation, analysis, and summary of the testing process.

The testing process may vary given the type of the model and the context in which the model is used. In a quantitative context, the use of sampling introduces potential error in making conclusions. To avoid making Type I (rejecting null hypothesis when it is true) or Type II (failing to reject null hypothesis when it is false) testing errors when relying on a single test, multiple tests should be utilized in model development.

Although the testing process is focused on the quantitative aspects, the qualitative aspects must not be overlooked. For example, quantitative outputs might be taken and tempered with subjective and/or nonquantitative elements to make the outputs relevant. Care must be taken to ensure that any alterations have a reasonable or logical basis and are clearly documented. Additionally, a robust internal control system (involving both individuals and computers) will promote an effective model development and implementation process.



MODULE QUIZ 54.1

1. Which component of a model deals with converting estimates into useful or applied information?
 - A. Information inputs.
 - B. Processing.
 - C. Reporting.
 - D. Transformational.
2. Which of the following statements regarding model risk is correct?
 - A. Shortcuts and simplifications will increase model risk.
 - B. Managing model risk requires proper segregation of duties.
 - C. With the appropriate procedures and tools, model risk can be eliminated.
 - D. Like many other risks, model risk has both an upside and a downside component.
3. Which of the following items is least likely to be a key consideration when testing models?
 - A. Testing for potential weaknesses.
 - B. Testing with extreme values as inputs.

- C. Testing under normal market conditions.
- D. Testing other models that rely on the subject model.

MODULE 54.2: MODEL VALIDATION PROCESS

LO 54.d: Describe elements of a strong model validation process and challenges to an effective validation process.

Model validation involves a series of steps to ensure that models are achieving their intentions. There needs to be a segregation of duties, for example, in that those individuals who develop the models should generally not be the same ones to validate it. Some exceptions may apply in areas that are overly technical or specialized, but in those instances, there must be a rigorous and objective review of such validation.

Three elements of a strong validation process are (1) evaluation of conceptual soundness, (2) ongoing monitoring, and (3) outcomes analysis.

Evaluation of Conceptual Soundness

This step is an overall quality check on the model, which involves analyzing all the documentation and live test results that backup the construction of the model. The documentation of the development process should be analyzed prior to using the model as well as analyzed throughout the validation process. If a model undergoes significant change, the documentation of such developments should also be reviewed.

Therefore, the model development process must be well-documented in terms of formulation, major assumptions, computations, and inputs. A proper validation process would thoroughly examine the documentation and perform supplemental testing, if appropriate. In terms of specifics, evaluating the significant assumptions and factors chosen and their effect on the outputs of the model is important. Additionally, the data underlying the model needs to be assessed for relevance and for ensuring it is representative when attempting to model specific portfolio assets or economic environments. That is especially the case when the data is external or is being used to model for new business ventures.

Sensitivity analysis should be performed as part of validation. It can be done for single variables by testing a range of changes in values for inputs and then examining the corresponding outputs to ensure they are reasonable. Testing can be expanded to multiple variable changes at the same time to check for any previously unknown interrelationships between the variables. Finally, the testing can be in the form of stress testing, which takes on extreme values to determine if the model still functions properly or to determine at what point the model loses effectiveness or accuracy. Should it be determined that a model is not working properly, then a plan must be in place to make amendments to the model, limiting the use of the model, or even replacing the model.

The nonquantitative aspects of model development must also be validated to ensure that any subjective assessments made in model development make sense and have appropriate backup and documentation.

Ongoing Monitoring

Ongoing monitoring attempts to determine whether the model needs any changes, additional developments, or replacement. Once the model is put into use, monitoring begins and should be done on a frequent basis, taking into account factors such as the purpose of the model and the risk exposures involved. Process verification and benchmarking should be part of the monitoring process.

Process verification looks at data inputs to ensure they remain error-free and complete. When implementing a model, the computer code must be verified for accuracy and there must exist an internal control to ensure computer code can only be changed by authorized individuals and that all changes be recorded for potential future audit. Process verification is very important in context of system integration because model processing takes in different data sources and eventually transfers processed data for data storage and reporting purposes. Also, within the firm, some users will develop their own spreadsheets or databases for quantitative analysis purposes, which are fraught with model risk. Ultimately, as the data changes with time, the corresponding systems need to be updated accordingly.

The same kinds of tests used for developing models would also be applicable for monitoring. The same goes for sensitivity analysis as part of monitoring. The monitoring process would review any overrides together with the supporting documentation. Human judgment is important and may necessitate the overriding of output from a model. The existence of overrides does suggest problems with the performance of the model and requires a deeper understanding for why the overrides are occurring, especially if the overrides are frequent. In some cases, it means the model needs to be amended or completely overhauled.

Benchmarking compares a model's inputs and outputs with other comparable data or models. If there are significant variances between the model's outputs and benchmarks, then the question is whether such variances fall within an acceptable range. If the variances between the model and benchmark are small, then it suggests the model is reliable, but it should not be thought of as absolute confirmation. On the other hand, the existence of significant variances does not automatically mean that the model is faulty; it could be that the benchmark uses a different methodology and therefore is not a good comparison.

Outcomes Analysis

The validation process must also examine the outputs from the model in context of what actually happened. Frequently, there is a determination of the level of precision of the estimates as a means of assessing the performance of the model. If it is determined through outcomes analysis that the model is weak, then the model must be revised.

Outcomes analysis includes both quantitative and qualitative methods; as an example of the latter, expert judgment is used to assess whether the results are logical. Whichever method is used should be based on the nature of the model, its level of complexity, the availability of data, and the level of model risk to the firm. Testing must

be tailored to the specific circumstances and should include multiple tests since a single test will have inherent limitations and therefore most likely be insufficient.

Parallel outcomes analysis considers that models are frequently amended for new information or because they are not effective. Such analysis involves a side-by-side examination of the first model and the amended model's estimates to the actual outcomes. If the amended model is not noticeably better than the first model, then further amendments to the model are required before fully replacing the first model.

Backtesting looks at the variances between the actual results and the estimates from the model. The time period under examination is different from that used in developing the model but is consistent with the model's forecast horizon. Confidence intervals are established based on the model estimates; results that lie beyond the intervals are considered significant and must be monitored. The point is to ascertain whether the outliers resulted from not including important factors in the model or whether there were errors in the model specification. Assessing value at risk (VaR) is a good example of backtesting, although only one value (e.g., 5% VaR) could be supplemented with other values (e.g., 1% VaR) to consider the possibility for larger losses.

Unfortunately, trying to understand backtesting results is usually a complex task of reviewing many forecasts in various economic environments and various time periods. Although statistical testing is used, the difficulty lies in selecting the right tests and how to decipher the results.

Long forecasting periods require backtesting which comes with the inherent disadvantage of obtaining the right amount of data. In such instances, there needs to be additional testing over shorter periods. "Early warning" signals that measure model performance on a more timely basis could be used to supplement backtesting.

Should the results of outcomes analysis show major problems or poor performance with the models, then amendments and/or reconstruction may be required. In the case of significant changes and reconstruction, validation is required prior to implementation.

Vendor and Other Third-Party Products

Vendor products are very commonly used; they can range from providing data to full models. They make the validation process trickier because the modeling activities are external and some parts of the modeling may be confidential. As a result, the validation process will need to be changed somewhat from that used for internally developed models. For example, vendors need to provide details regarding the construction of their models to ensure that the model is appropriate for the user. In addition, testing results would need to be provided by the vendor to demonstrate that the models are effective at what they are supposed to do. Because the use of an external model may mean limited access to information on coding and implementation, the validation process will likely have to focus more on sensitivity analysis and benchmarks. If a vendor model is modified to suit the institution's needs, then the modifications should be noted and explained during the validation process. Overall, in-depth knowledge of

the vendor product is necessary from the perspective of the institution's internal controls.



MODULE QUIZ 54.2

1. Backtesting is most appropriately classified in which element of the validation process?
 - A. Evaluation of conceptual soundness.
 - B. Ongoing monitoring.
 - C. Outcomes analysis.
 - D. Postvalidation review.
2. Comparing a model's inputs and outputs to estimates from other data or models is best described as:
 - A. benchmarking.
 - B. ongoing monitoring.
 - C. process verification.
 - D. sensitivity analysis.

KEY CONCEPTS

LO 54.a

Model risk raises the possibility of (negative) outcomes resulting from poor decisions made using inaccurate model outputs. Model risk can arise in two distinct ways: (1) the model has significant errors and produces faulty outputs, and (2) the model is not used properly, not used for its intended purpose, or used out of context.

LO 54.b

Managing model risk requires the identification of all relevant risks and attempts to quantify the exposure. The amount of model risk is dependent on how complicated the model is, the level of uncertainty with its inputs and assumptions, and its potential impact on users.

Other methods of managing model risk include setting restrictions on use of models, analyzing model performance, continually calibrating and improving models, and placing model output in the context of other relevant information.

LO 54.c

At the outset, development of a model should have a clearly stated objective that is congruent with the model's eventual use. All the background information supporting the model needs to be thoroughly described, noting relevant strengths and weaknesses.

Testing is a key component of model development to ensure the model is working as planned. Although the testing process is focused on the quantitative aspects, the qualitative aspects must not be overlooked.

LO 54.d

Three elements of a strong model validation process are (1) evaluation of conceptual soundness, (2) ongoing monitoring, and (3) outcomes analysis.

Evaluation of conceptual soundness is an overall quality check on the model, which involves analyzing all the documentation and live test results that backup the construction of the model. A proper validation process would thoroughly examine the documentation and perform supplemental testing, if appropriate. Sensitivity analysis should also be performed as part of validation and it can be done for single or multiple variables.

Ongoing monitoring attempts to determine whether the model needs any changes, additional developments, or replacement. Process verification and benchmarking should be part of the monitoring process. Process verification looks at data inputs to ensure they remain error-free and complete. Benchmarking compares a model's inputs and outputs with other comparable data or models. If there are significant variances between the model's outputs and benchmarks, then the question is whether such variances fall within an acceptable range.

The validation process must also examine the outputs from the model in context of what actually happened. Parallel outcomes analysis considers that models are frequently amended for new information or because they are not effective.

Backtesting looks at the variances between the actual results and the estimates from the model. The time period under examination is different from that used in developing the model but is consistent with the model's forecast horizon. Confidence intervals are established based on the model estimates; results that lie beyond the intervals are considered significant and must be monitored.

ANSWER KEY FOR MODULE QUIZZES

Module Quiz 54.1

1. **C** The reporting component essentially transforms estimates into useful business information. In contrast, the processing components transforms inputs into estimates. (LO 54.a)
2. **B** A proper “effective challenge” of models is a key part of managing model risk and would require proper segregation of duties. In that regard, the model development process and the critical review of the model must be done by different parties in order to maintain proper independence and objectivity. (LO 54.b)
3. **C** Although testing is done under normal market conditions, a more accurate statement would be that testing is done under a wide variety of market conditions, including those that are unusual or extreme. Testing for potential weaknesses, using extreme values as inputs, and testing other models that use the outputs of the subject model as inputs are all important considerations when testing models. (LO 54.c)

Module Quiz 54.2

1. **C** Backtesting is a specific type of outcomes analysis. (LO 54.d)

2. A Ongoing monitoring is the general term used to describe various activities that constitute the second key aspect of the validation process. Those activities include benchmarking, process verification, and sensitivity analysis. However, benchmarking is the specific term that applies to comparing a model's input and outputs to relevant estimates. (LO 54.d)

The following is a review of the Operational Risk and Resilience principles designed to address the learning objectives set forth by GARP®. Cross-reference to GARP FRM Part II Operational Risk and Resilience, Chapter 16.

READING 55

CASE STUDY: MODEL RISK AND MODEL VALIDATION

Study Session 8

EXAM FOCUS

This short reading provides contextual importance to model risk management. For the exam, focus on the sources of model risk, approaches to model risk management, and what the presented case studies teach us about model risk management.

MODULE 55.1: MODEL RISK AND MODEL VALIDATION

Model Risk Exposure

LO 55.a: Define a model and describe different ways that financial institutions can become exposed to model risk.

Models are sophisticated tools used widely in finance. An example of a financial model is the value at risk (VaR) computation. Various definitions exist for models, such as the U.S. Federal Reserve's model risk guidance definition, from Supervision and Regulation 11-7: "The term *model* refers to a quantitative method, system, or approach that applies statistical, economic, financial, or mathematical theories, techniques, and assumptions to process input data into quantitative estimates."¹

In other words, a model generates an estimate or forecast using a set of inputs, an underlying theory, and under a certain set of assumptions. The inputs can be quantitative as well as qualitative. It is critical to recognize that the estimate or forecast (i.e., the model output) is not definitive, but rather subject to estimation error.

Model risk can occur in the following two types:

1. *Execution risk* refers to the risk of models not functioning as intended due to errors in input data or in coding of the model.

2. *Conceptual errors* arise when the assumptions are invalid (i.e., they do not represent reality) or when incorrect modeling techniques are used.

Conceptual errors are more difficult to identify. A model that works in some economic environments may not perform well when used in other environments. Model assumptions and limitations should be documented and effectively communicated to users. For example, risk measurement models often rely on correlations between portfolio assets as an input. Correlation estimates from normal times often underestimate correlations during more volatile market conditions. Model validation techniques will verify whether the model is performing as expected.

Model Risk Management

LO 55.b: Describe the role of the model risk management function and explain best practices in the model risk management and validation processes.

A **model risk management (MRM)** team comprises of experts who are independent of the original model developers and are charged with mitigating model risk. MRM teams set the standards for model documentation, data quality, and model version control. Not all models pose the same organizational risks. Cost-benefit considerations call for more scrutiny for those models that pose a higher level of risk. Therefore, models can be assigned to risk tiers.

The level of model risk tier depends on (1) materiality of model output (e.g., dollar value of loss if the model fails), (2) model complexity, (3) whether the model will be client facing, and (4) whether the model is used for regulatory compliance. The highest tiers of model risk require more frequent validation (usually every 2–3 years) and comprehensive backtesting for reliability of model output. Regardless of their risk tier, all models should be reviewed annually regarding changes in the environment, input data quality, and other important elements such that there are no material changes that would affect model performance.

Additionally, MRM teams review the periodic model performance reports prepared by model owners. It is important that MRM should be a continuous, ongoing process rather than a scheduled, periodic review to limit the damage done by models that no longer generate reliable forecasts. The existence of an MRM team should not result in complacency among the model users and developers, who are the first line of defense against unnecessary risk that the institution is exposed to.

Model Risk Case Studies

LO 55.c: Describe lessons learned from the three case studies involving model risk.

Gaussian Copula and CDO Pricing

In the 2000s, David X. Li developed a collateralized debt obligation (CDO) pricing model known as the **Gaussian copula function**. Li assumed that markets were efficient

and, therefore, credit default swap (CDS) prices, which were used for the model, were correctly set by the market. The model used current CDS prices to infer correlations among assets in a collateral pool known as the Gaussian constant (recall that lower correlations among assets in a collateral pool indicate a lower risk for the CDO). The model was quickly adopted by major market participants, and its use became entrenched—without regard for the model's limitations.

Historical correlations of residential mortgage defaults tended to be low; homeowners do not systematically default together. However, as housing prices fell in 2008, CDS prices started shooting up (reflecting higher credit risk and higher correlations). The model incorporated changing correlations with a lag, leading to a collapse in the CDO market. Essentially, the model encouraged both quantitative analysts and their managers to ignore that the real world is full of randomness, uncertainty, and noise.

MRM in this context would aim to increase the transparency regarding assumptions and limitations of this CDO pricing model. Given that the model users lacked the necessary quantitative background, effective communication would have been critical to minimize the misuse of the model.

The Barclays Acquisition of Lehman Brothers' Assets and Spreadsheet Error

The recent global financial crisis was triggered by the collapse of Lehman Brothers, at the time, the fourth-largest investment bank in the United States. During the liquidation of Lehman Brothers, Barclays made an offer to purchase some of Lehman's assets and trading positions. A few hours before the deadline to submit bids to the bankruptcy court, Barclays sent a spreadsheet consisting of 1,000 rows to their lawyers at Cleary Gottlieb indicating the positions that they wanted to purchase as well as those they did not want.

The 179 positions that Barclays was not interested in were in hidden rows. To conform to the bid submission guidelines, a junior law associate converted the spreadsheet into a PDF—unaware that the hidden rows were now revealed. The mistake was realized several days later—after the bid was approved, requiring Barclays to file a legal motion to exclude those contracts.

This is an example of an implementation error. The spreadsheet is not a model, but the failure to delete the unneeded rows posed a large potential loss to the user of the software.

NASA Mars Orbiter

The Mars Orbiter is an example of a rather innocuous mistake, which led to the loss of a \$125 million satellite. In this case, the engineering team at Lockheed Martin used English units of measurement (commonly used in the United States), while NASA's convention was to use the metric system. This mistake in measurement of model inputs led to the loss of a multi-million-dollar satellite.

MRM, in this context, would have rigorously tested all assumptions and inputs. Oftentimes, small mistakes result in losses—some of those losses, however, can be quite

large. The case for rigor of MRM, often considered to be a bureaucratic hurdle, cannot be overstated.



MODULE QUIZ 55.1

1. Which one of the following items is least likely associated with a model?
 - A. Qualitative inputs.
 - B. Mathematical theories.
 - C. Precise output.
 - D. Assumptions.
2. Which of the following statements describes model execution risk?
 - A. Inaccurate model inputs.
 - B. Model coding that is consistent with model assumptions.
 - C. Inappropriate model assumptions.
 - D. Incorrect modeling techniques.
3. What is the most likely reason for the failure of the Gaussian copula function to price CDOs?
 - A. Model computation error.
 - B. Inappropriate model for the task.
 - C. Invalid model assumption.
 - D. Invalid use of model output.
4. The Barclays bankruptcy court bid for Lehman assets most likely suffered from:
 - A. ongoing monitoring.
 - B. improper model use.
 - C. invalid model assumptions.
 - D. implementation error.
5. The failure of NASA's Mars Orbiter mission can be directly attributed to:
 - A. model inaccuracy.
 - B. model assumptions.
 - C. incorrect model choice.
 - D. incorrect model inputs.

KEY CONCEPTS

LO 55.a

Models generate an estimate or forecast using a set of inputs under a certain set of assumptions. Two types of model risk are (1) execution risk and (2) conceptual errors.

LO 55.b

A model risk management (MRM) team sets the standards for model documentation, data quality, and model version control consistent with the model's risk tier. The model risk tier depends on (1) materiality of model output, (2) model complexity, (3) whether the model will be client facing, and (4) whether the model is used for regulatory compliance.

LO 55.c

The model risk case studies presented in this reading highlight the risk of using models given (1) invalidity of assumptions, (2) implementation error, or (3) input measurement error.

ANSWER KEY FOR MODULE QUIZ**Module Quiz 55.1**

1. **C** Model outputs are forecasts or estimates, which are not precise. Model inputs can be qualitative or quantitative. Also, models rely on a set of assumptions, and use economic and mathematical theories. (LO 55.a)
2. **A** Execution risk arises due to errors in input data or in coding of the model. (LO 55.b)
3. **C** The Gaussian copula function relied on the Gaussian constant input, which was based on an assumption of static (constant) asset correlations in a collateral pool. (LO 55.c)
4. **D** The failure to delete spreadsheet rows representing assets that Barclays did not want to bid on represented an implementation error. (LO 55.c)
5. **D** The units of measurement for model inputs were inaccurate, which led to the failure of the model and a very large loss. (LO 55.c)

¹ <https://www.federalreserve.gov/supervisionreg/srletters/sr1107.htm>.

The following is a review of the Operational Risk and Resilience principles designed to address the learning objectives set forth by GARP®. Cross-reference to GARP assigned reading—Schuermann.

READING 56

STRESS TESTING BANKS

Study Session 8

EXAM FOCUS

This reading focuses on the use of bank stress testing to determine if liquidity and capital are adequate. The discussion focuses primarily on capital adequacy but notes that the issues are similar with respect to liquidity. For the exam, understand the details of the 2009 Supervisory Capital Assessment Program (SCAP), the first stress testing required after the 2007–2009 financial crisis. Also, be able to explain the issue of coherence in stress testing and describe the challenges with modeling the balance sheet using stress tests in the context of the stress test horizon. Finally, understand the differences in disclosure between United States and European stress tests and the way that stress test methodologies and disclosure have changed since the 2009 SCAP.

MODULE 56.1: STRESS TESTING

In the wake of the 2007–2009 financial crisis, regulators and other policymakers realized that standard approaches to risk assessment, such as regulatory capital ratio requirements, were not sufficient. At that point, supervisory **stress testing** became a popular tool for measuring bank risk. There was a “pop-quiz” quality to the post-financial crisis stress tests. They were difficult to manipulate because they were sprung on banks at short notice. As a result, the information provided by the stress tests to regulators and the market was truly new. This allowed financial markets to better understand bank risks and, as a result, regain a level of trust in the banking sector.

The goal of stress testing, as well as capital/liquidity and “economic capital/liquidity” (i.e., internal, bank-specific) models, is to assess how much capital and liquidity a financial institution needs to support its business (i.e., risk taking) activities. It is relatively easy for banks to swap out of lower risk assets and into higher risk assets. Stress testing provides clarity about the true risk and soundness of banks.

Stress testing is an old tool that banks and other firms have used to examine risk. It asks the question, “What is the institution’s resilience to deteriorating conditions?” and simulates financial results given various adverse scenarios. Stresses are generally of two basic types: scenarios or sensitivities. An example of a scenario is a severe recession. An example of sensitivity is a significant increase in interest rates. Risk

managers can stress test the sensitivity of a single position or loan or an entire portfolio.

Supervisory Capital Assessment Program (SCAP)

LO 56.a: Describe the evolution of the stress testing process and compare the methodologies of historical European Banking Association (EBA), Comprehensive Capital Analysis and Review (CCAR), and Supervisory Capital Assessment Program (SCAP) stress tests.

In the wake of the financial crisis, there was much uncertainty about the soundness of the U.S. banking system. Regulators needed to assess the capital strength of financial institutions. If there was a gap between what a bank needed in terms of capital and what it had, regulators had to find a credible way to “fill the hole.” The 2009 U.S. bank stress test, known as the **Supervisory Capital Assessment Program (SCAP)**, was meant to serve that purpose. It was the first macro-prudential stress test after the 2007–2009 financial crisis. Macro-prudential regulation focuses on the soundness of the banking system as a whole (i.e., focuses on systematic risks) while micro-prudential regulation focuses on the safety and soundness of the individual institution.

At this point the federal government planned to infuse equity capital into banks that were undercapitalized based on stress testing. The Treasury intended to borrow money and “downstream” it as equity in banks via the Treasury’s Capital Assistance Program (CAP). If banks could not convince investors to fill the hole (i.e., infuse banks with needed equity capital), current investors would be diluted by the government’s equity investment. In the end, 19 SCAP banks were required to raise \$75 billion within six months. The undercapitalized banks raised \$77 billion of Tier 1 common equity and did not need to draw on the CAP funds.

Prior to 2009, stress testing was relatively simple. Figure 56.1 summarizes the differences in stress testing pre-SCAP and post-SCAP.

Figure 56.1: Comparison of Stress Testing Pre-SCAP and Post-SCAP

Pre-SCAP	Post-SCAP
Primarily assessed exposure to single-shocks (e.g., volatility increases OR interest rate increases OR increasing unemployment).	Considers broad macro-scenarios and market-wide stresses with multiple factors occurring/changing at once, as evidenced in the 2007–2009 financial crisis.
Focused on specific bank products or business units (e.g., lending or trust).	Focuses on the whole firm, a more comprehensive look at the effect of the stress scenarios on the institution.
Typically focused on earnings shocks (i.e., losses) but not on capital adequacy.	Explicitly focuses on capital adequacy. Considers the post-stress common equity threshold to ensure that a bank remains viable.
Focused exclusively on losses.	Focuses on revenues, costs, and projected losses.
Stress testing was static in nature.	Stress testing is now dynamic and path dependent.

**PROFESSOR'S NOTE**

We will compare and contrast SCAP, CCAR, and EBA stress tests later in this reading.

Challenges in Designing Stress Tests

LO 56.b: Explain challenges in designing stress test scenarios, including the problem of coherence in modeling risk factors.

One of the challenges of designing useful stress tests is **coherence**. The sensitivities and scenarios must be extreme but must also be reasonable or possible (i.e., coherent). Problems are inherently multi-factored, making it more difficult to design a coherent stress test. For example, an increase in volatility can lead to credit markets freezing. High unemployment and falling equity prices often go hand-in-hand. It is not sufficient to specify one potential problem (i.e., risk factor) because the others do not remain fixed. The supervisor's key challenge is to specify the joint outcomes of all relevant risk factors.

Additionally, not everything goes bad at once. For example, if some currencies are depreciating, others must be appreciating. If there is a “flight to quality,” there must also be safe haven assets in the stress model. So while it is important to look at, for example, what happens if U.S. Treasury debt becomes riskier and is no longer a safe haven, the model would at the same time have to identify the “risk-free” asset(s) in which capital would flee under those circumstances.

The problem is even greater when designing stress scenarios for marked-to-market portfolios of traded securities and derivatives. Risk is generally managed with a value at risk (VaR) system. Hundreds of thousands of positions in the trading book must be mapped to thousands of risk factors, tracked on a daily basis. The data that results is

used to estimate volatility and correlation parameters. It is very difficult to find coherent outcomes in such a complex, multi-dimensional universe.

The 2009 SCAP tested rather simple scenarios with three variables: growth in GDP, unemployment, and the house price index (HPI). Historical experience was used for the market risk scenario (i.e., the financial crisis—a period of “flight to safety,” the failure of Lehman, and higher risk premiums). While the market risk scenario did not test for something new, the overall framework achieved coherence of financial and other stresses of the time period.

One thing to note is that prior to 2011 all supervisory stress tests imposed the same scenarios on all banks (i.e., a one-size-fits-all approach to stress testing). In recognition of the problem, the 2011 and 2012 Comprehensive Capital Analysis and Review (CCAR) asked banks to submit results from their own stress scenarios in addition to the supervisory stress scenario in an attempt to reveal bank-specific vulnerabilities. This was an important step forward from the 2009 SCAP as it gave supervisors a sense of what banks think are the high risk scenarios. This provides regulators with not only bank-specific (i.e., micro-prudential) insight but also improves macro-prudential supervision as it highlights common risks across banks that may have been underemphasized or unnoticed before.



MODULE QUIZ 56.1

1. Which of the following changes in stress testing was not the result of the 2009 Supervisory Capital Assessment Program (SCAP)?
 - A. Banks are now required to provide the results of their own scenario stress tests.
 - B. Stress scenarios are now broader in nature.
 - C. Stress testing now focuses on the whole firm.
 - D. Stress testing now focuses on revenues, costs, and projected losses.

MODULE 56.2: CHALLENGES IN MODELING LOSSES AND REVENUES

LO 56.c: Explain challenges in modeling a bank's revenues, losses, and its balance sheet over a stress test horizon period.

Current stress tests are based on macro-scenarios (e.g., unemployment, GDP growth, the HPI). One concern is how to translate the macro-risk factors employed in stress testing into micro (i.e., bank-specific) outcomes related to revenues and losses. Supervisors need to map from macro-factors into intermediate risk factors that drive losses in specific products and geographic areas. Although not limited to these products, geographic differences are especially important in modeling losses in both commercial and residential real estate lending.

Credit card losses are particularly sensitive to unemployment figures. For example, unemployment was 12.9% in Nevada in July 2011, 3.3% in North Dakota, and the national unemployment rate was 9.1%. Credit card loss rates varied dramatically from region to region during this period. The geographic diversity with respect to macro-factors makes a “one-size-fits-all” stress testing regime less meaningful.

Geography is not the only difference supervisors must contend with. Risks affect different asset classes in different ways. For example, during recessions people buy fewer automobiles overall. However, if a person needs a car during a recession, he is more likely to buy a used car. Thus, if default rates increase, loss given default (LGD) (i.e., loss severity) may not increase as much.

The business cycle also affects different industries at different times. Consider the airline industry versus the healthcare industry during a recession. Airplanes are collateral for loans to airlines. If the airline industry is depressed, the bank gets stuck with collateral that is very difficult to sell except at extremely depressed prices. Healthcare is somewhat recession-proof but that doesn't mean the bank can transform an airplane it is stuck with into a hospital. These factors increase the difficulty of mapping broader macro-factors to bank-specific stress results.

Modeling revenues over a stress test horizon period is much less developed than modeling losses. The 2009 SCAP did not offer much clarity on how to calculate revenue during times of market stress. The main approach to modeling revenue is to divide a bank's total income into interest and noninterest income. The yield curve can be used to estimate interest income, and it can reflect credit spreads during stress testing scenarios; however, it remains unclear how bank profitability is directly influenced by the net impact of changing interest rates. Estimating noninterest income, which includes fees and service charges, is even more difficult to model. This is alarming given the steady increase in noninterest income among U.S. banks.

Challenges in Modeling the Balance Sheet

The typical stress test horizon is two years. Over this period, both the income statement and balance sheet must be modeled to determine if capital is adequate post-stress. Generally speaking, capital is measured as a ratio of capital to assets. There are different types of capital (e.g., Tier 1 and Tier 2) but in general (and for the sake of simplicity), capital can be defined as common equity. **Risk-weighted assets (RWAs)** are computed based on the Basel II risk weight definitions. For example, agency securities have a lower risk weight than credit card loans.

In a stress model, the beginning balance sheet generates the first quarter's income and loss from the stressed scenario, which in turn determines the quarter-end balance sheet. At that point, the person modeling the risk must consider if any assets will be sold or originated, if capital is depleted due to other actions such as acquisitions or conserved as the result of a spin-off, if there are changes made to dividend payments, if shares will be repurchased or issued (e.g., employee stock or stock option programs), and so on. These decisions make modeling the balance sheet over the stress horizon quite difficult. The stress model doesn't determine if it would be a good time to sell a subsidiary or lower dividend payments.

The challenges of balance sheet modeling exist under both static and dynamic modeling assumptions. The bank must maintain its capital (and liquidity) ratios during all quarters of the stress test horizon. At the end of the stress horizon the bank must estimate the reserves needed to cover losses on loans and leases for the next year. This means that a two-year horizon stress test is actually a three-year stress test (i.e., a T-

year stress test requires the bank to estimate required reserves to cover losses for T+1 years).

Stress Test Comparisons

Disclosure was a significant feature of the 2009 SCAP. It disclosed projected losses for each of the 19 participating banks for eight asset classes. It also disclosed resources the bank had to absorb losses other than capital (e.g., pre-provision net revenue and reserve releases if available). This high level of disclosure created transparency. It allowed investors and the market to check the severity of stress tests and to comprehend stress test outcomes at the individual bank level. Before the 2009 SCAP, banks only reported realized losses, not forecasted losses (i.e., possible losses given the stress scenario).

The 2011 CCAR required only that macro-scenario results be published, not bank level results. This differed dramatically from the 2009 SCAP requirements. The market had to figure out whether a bank had passed the test or not (i.e., market participants had to “do the math” themselves). For example, if a bank increased its dividend, it was assumed by the market to have “passed” the stress test. However, the 2012 CCAR disclosed virtually the same amount and detail of bank level stress data as the 2009 SCAP (i.e., bank level loss rates and losses by major asset classes).

The regulatory asset classes are:

1. First and second lien mortgages.
2. Commercial and industrial (C&I) loans.
3. Commercial real estate loans.
4. Credit card lending.
5. Other consumer loans.
6. Other loans.

One of the key contributions of the CCAR was that in both 2011 and 2012 the CCAR required banks to submit the results of their own scenarios, both baseline and stress, not just supervisory stress test results. The Fed also reported dollar pre-provision net revenue (PPNR), gains and losses on available-for-sale and held-to-maturity securities, and trading and counterparty losses for the six institutions with the largest trading portfolios. These firms were required to conduct the trading book stress test. The numbers that were reported were supervisory estimates, not bank estimates, of losses under the stress scenario.

In contrast, the 2011 European Banking Authority (EBA) Irish and 2011 EBA European-wide stress tests, both disclosed after the CCAR, contained considerable detail. In the Irish case, the report contained a comparison of bank and thirdparty estimates of losses. The EBA data was available in electronic, downloadable form. Ireland needed credibility, having passed the Committee of European Bank Supervisors (CEBS) stress test in July 2010 only to need considerable aid four months later. In general, the faith in European supervisors was harmed and only by disclosing detailed information on bank-by-bank, asset-class, country, and maturity bucket basis could the market

interpret the data and draw its own conclusions about individual bank risks. Figure 56.2 summarizes the differences among the various stress test regimes.

Figure 56.2: Comparison of Macro-Prudential Stress Tests

Stress Test	Methodologies	Disclosure	Findings
SCAP (2009). All banks with \$100 billion or more in assets as of 2008 year end were included.	Tested simple scenarios with three dimensions, GDP growth, unemployment, and the house price index (HPI). Historical experience was used for the market risk scenario (i.e., the financial crisis—a period of “flight to safety,” the failure of Lehman, and higher risk premiums). A “one-size-fits-all” approach.	First to provide bank level projected losses and asset/product level loss rates.	19 SCAP banks were required to raise \$75 billion within six months. The undercapitalized banks actually raised \$77 billion of Tier 1 common equity and none of the banks were forced to use the Treasury’s Capital Assistance Program funds.
CCAR (2011)	In recognition of “one-size-fits-all” stress testing, CCAR asked banks to submit results from their own baseline and stress scenarios.	Only macro-scenario results were published.	
CCAR (2012)	Banks were again asked to submit their own baseline and stress test results.	Similar in detail to SCAP 2009—bank level and asset/product level loss rates disclosed.	

EBA Irish (2011)	Similar in design to EBA Europe 2011.	Comparison of bank and third party projected losses; comparison of exposures by asset class and geography. Data is electronic and downloadable.	After passing the 2010 stress tests, 2011 stress tests revealed Irish banks needed €24 billion. Greater disclosure in 2011 resulted in tightening credit spreads on Irish sovereign and individual bank debt.
EBA Europe (2011). [formerly the Committee of European Bank Supervisors (CEBS)] 90 European banks were stress tested.	Specified eight macro-factors (GDP growth, inflation, unemployment, commercial and residential real estate price indices, short and long-term government rates, and stock prices) for each of 21 countries. Specified over 70 risk factors for the trading book. It also imposed sovereign haircuts across seven maturity buckets.	Bank level projected losses. Comparisons of exposures by asset class and geography. Data is electronic and downloadable.	Eight banks were required to raise €2.5 billion.

The key benefit of greater disclosure is transparency. Transparency is especially important in times of financial distress. However, during “normal” times, the costs of disclosure may outweigh the benefits. For example, banks may “window dress” portfolios, making poor long-term investment decisions to increase the likelihood of passing the test. Traders may place too much weight on the public information included in stress test disclosure and be disincentivized to produce private information about financial institutions. This harms the information content of market prices and makes prices less useful to regulators making policy decisions.

One thing to note is that prior to the CCAR 2011 requirements, all supervisory stress tests imposed the same scenarios on all banks (i.e., a one-size-fits-all approach to stress testing). In recognition of the problem, the 2011 and 2012 CCAR asked banks to submit results from their own scenarios in addition to the supervisory stress scenario in an attempt to reveal bank-specific vulnerabilities.



MODULE QUIZ 56.2

- Piper Hook, a bank examiner, is trying to make sense of stress tests done by one of the banks she examines. The stress tests are multi-factored and complex. The bank is using multiple extreme scenarios to test capital adequacy, making it difficult for Hook to interpret the results. One of the key stress test design challenges that Hook must deal with in her examination of stress tests is:
 - multiplicity.
 - efficiency.
 - coherence.

- D. efficacy.
2. Greg Nugent, a regulator with the Office of the Comptroller of the Currency, is presenting research on stress tests to a group of regulators. He is explaining that macro-variable stress testing can be misleading for some banks because of geographical differences in macro risk factors. He gives the example of the wide range of unemployment rates across the United States following the 2007–2009 financial crisis. Which type of loan did Nugent most likely identify as having losses tied to unemployment rates?
- A. Residential real estate loans.
 - B. Credit card loans.
 - C. Commercial real estate loans.
 - D. Industrial term loans.
3. A risk modeler has to make assumptions about acquisitions and spinoffs, if dividend payments will change, and if the bank will buy back stock or issue stock options to employees. These factors make it especially challenging to:
- A. get a CAMELS rating of 2 or better.
 - B. determine if the bank has enough liquidity to meet its obligations.
 - C. meet the Tier 1 equity capital to risk-weighted assets ratio.
 - D. model a bank's balance sheet over a stress test horizon.
4. One of the key differences between the 2011 CCAR stress test and the 2011 EBA Irish stress test is that the:
- A. CCAR did not require banks to provide results from their own stress scenarios.
 - B. EBA Irish did not find any banks in violation of capital adequacy requirements.
 - C. CCAR required disclosure of macro-level, not bank level, scenario results.
 - D. EBA Irish allowed for 1-year stress horizons.

KEY CONCEPTS

LO 56.a

After the 2007–2009 financial crisis, it was clear that traditional risk measures such as regulatory capital ratios were insufficient. Supervisory stress-testing became an important risk-assessment tool at that point.

The goal of stress testing is to assess how much capital and liquidity a financial institution needs to support its business (i.e., risk taking) activities.

The 2009 U.S. bank stress test, known as the Supervisory Capital Assessment Program (SCAP), was the first macro-prudential stress test after the 2007–2009 financial crisis.

Disclosure was a significant feature of the 2009 SCAP. This high level of disclosure lead to transparency and allowed investors and the market the ability to check the severity of the stress tests and the outcomes of the stress at the individual bank level.

In 2011, CCAR required only macro-scenario results be published, not bank level results, differing significantly from the 2009 SCAP requirements. The 2012 CCAR disclosed virtually the same amount and detail of bank level stress data as the 2009 SCAP. The EBA Irish and the EBA Europe required significant disclosures as well. The disclosures were needed to increase trust in the European banking system.

LO 56.b

One of the challenges regulators face is designing coherent stress tests. The sensitivities and scenarios must be extreme but must also be reasonable and possible (i.e., coherent). Problems are inherently multi-factor, making it more difficult to design a coherent stress test.

LO 56.c

Current stress tests are based on macro-scenarios (i.e., unemployment, GDP growth, the HPI). One concern is how to translate the macro-risk factors employed in stress tests into micro (i.e., bank specific) outcomes related to revenues and losses. Supervisors must be able to map from macro-factors into intermediate risk factors that drive losses in specific products and geographic areas.

In a stress model, the starting balance sheet generates the first quarter's income and loss from the stressed scenario, which in turn determines the quarter-end balance sheet. The bank must maintain its capital (and liquidity) ratios during all quarters of the stress test horizon, typically two years.

ANSWER KEY FOR MODULE QUIZZES**Module Quiz 56.1**

1. A The 2009 U.S. bank stress test, known as the Supervisory Capital Assessment Program (SCAP), was the first macro-prudential stress test after the 2007–2009 financial crisis. (LO 56.a)

Module Quiz 56.2

1. C One of the challenges of designing useful stress tests is coherence. The sensitivities and scenarios must be extreme but must also be reasonable or possible (i.e., coherent). Problems are inherently multi-factored, making it more difficult to design a coherent stress test. Hook is dealing with the possibly incoherent results of the bank's stress tests. (LO 56.b)
2. B Credit card losses are particularly sensitive to unemployment figures. For example, unemployment was 12.9% in Nevada in July 2011, 3.3% in North Dakota, and the national unemployment rate was 9.1%. Credit card loss rates varied dramatically from region to region during this period. Residential mortgages are affected by unemployment as well but people are generally more likely to quit paying credit card bills before mortgages. (LO 56.c)
3. D In a stress model, the starting balance sheet generates the first quarter's income and loss from the stressed scenario, which in turn determines the quarter-end balance sheet. At that point, the person modeling the risk must consider if any assets will be sold or originated, if capital is depleted due to other actions such as acquisitions or conserved as the result of a spin-off, if there are changes made to dividend payments, if shares will be repurchased or issued (e.g., employee stock

or stock option programs), and so on. This makes it challenging to model the balance sheet over the stress horizon. (LO 56.c)

4. C The 2011 CCAR required banks to provide results from their own stress scenarios but the EBA Irish did not. After the 2011 EBA Irish tests, €24 billion was required to increase the capital of several banks. The 2011 CCAR, unlike the SCAP and the 2012 CCAR, only required the disclosure of macro-level scenario results. The EBA Irish did not change the stress horizon from two years to one year. (LO 56.c)

The following is a review of the Operational Risk and Resilience principles designed to address the learning objectives set forth by GARP®. Cross-reference to GARP assigned reading—Crouhy, Galai, and Mark, Chapter 17.

READING 57

RISK CAPITAL ATTRIBUTION AND RISK-ADJUSTED PERFORMANCE MEASUREMENT

Study Session 9

EXAM FOCUS

This reading covers the application of the risk-adjusted return on capital (RAROC) approach to the allocation of economic capital. The application of a hurdle rate for capital budgeting decisions as well as an adjusted version of the traditional RAROC approach is also presented. For the exam, know the differences between economic capital and regulatory capital, and be able to compute RAROC for capital budgeting as well as adjusted RAROC. Also, be familiar with the qualitative concepts discussed, such as reasons for using economic capital to allocate risk capital, the benefits of RAROC, and best practices in implementing the RAROC approach.

MODULE 57.1: RISK-ADJUSTED RETURN ON CAPITAL

Risk Capital, Economic Capital, and Regulatory Capital

LO 57.a: Define, compare, and contrast risk capital, economic capital, and regulatory capital, and explain methods and motivations for using economic capital approaches to allocate risk capital.

Risk capital provides protection against risk (i.e., unexpected losses). In other words, it can be defined as a (financial) buffer to shield a firm from the economic impact of risks taken. Should a disastrous event occur, those impacts could otherwise jeopardize the firm's financial security and its ability to remain a going concern. In short, risk capital provides assurance to the firm's stakeholders that their invested funds are safe. In most cases, risk capital and **economic capital** are treated synonymously, although an alternative definition of economic capital exists (discussed further in LO 57.c):

economic capital = risk capital + strategic risk capital

On the other hand, there are at least three distinct differences between risk capital and **regulatory capital** as follows:

1. Unlike risk capital, regulatory capital is relevant only for regulated industries such as banking and insurance.
2. Regulatory capital is computed using general benchmarks that apply to the industry. The result is a minimum required amount of capital adequacy that is usually far below the firm's risk capital.
3. Assuming that risk capital and regulatory capital are the same for the overall firm, the amounts may be different within the various divisions of the firm. From a risk capital allocation perspective, one solution is to allocate the greater of risk capital and regulatory capital to a certain division.



PROFESSOR'S NOTE

We will examine the regulatory capital charges for credit, market, and operational risk in Reading 60.

Given that Basel III requirements are sufficiently robust, it is probable that in certain areas (e.g., securitization), regulatory capital will be substantially higher than risk/economic capital. Although the two amounts may conflict, risk/economic capital must be computed in order to determine the economic viability of an activity or division. Assuming that regulatory capital is substantially higher than risk/economic capital for a given activity, then that activity will potentially move over to shadow banking (i.e., unregulated activities by regulated financial institutions) in order to provide more favorable pricing.

Using Economic Capital Approaches

From the perspective of financial institutions, the motivations for using economic capital are as follows:

- *Capital is used extensively to cushion risk.* Compared to most other nonfinancial institutions, financial institutions can become highly leveraged (i.e., riskier) at a relatively low cost simply by accepting customer deposits or issuing debt. All of this may occur without having to issue equity. Additionally, many of the financial institutions will participate in transactions involving derivatives, guarantees, and other commitments that only require a relatively small amount of funding but always involve some risk. As a result, all of the firm's activities must be allocated an economic capital cost.
- *Financial institutions must be creditworthy.* A unique aspect of financial institutions is that their main customers are also their main liability holders. Customers who deposit funds to a financial institution will be concerned about the default risk of the financial institution. With over-the-counter (OTC) derivatives, the concern is counterparty risk. As a result, a sufficient amount of economic capital must be maintained to provide assurance of creditworthiness.
- *There is difficulty in providing an external assessment of a financial institution's creditworthiness.* It is challenging to provide an accurate credit assessment of a

financial institution because its risk profile is likely to be constantly evolving. For example, an institution may engage in complicated hedging and derivatives transactions that could rapidly impact its liquidity. Therefore, having a sufficient store of economic capital could mitigate this problem and provide assurance of financial stability.

- *Profitability is greatly impacted by the cost of capital.* Economic capital is similar to equity capital in the sense that the invested funds do not need to be repaid in the same manner as debt capital, for instance. In other words, economic capital serves as a reserve or a financial cushion in case of an economic downturn. As a result, economic capital is more expensive to hold than debt capital, thereby increasing the cost of capital and reducing the financial institution's profits. A proper balance between holding sufficient economic capital and partaking in risky transactions is necessary.

Risk-Adjusted Return on Capital

LO 57.b: Describe the RAROC (risk-adjusted return on capital) methodology and its use in capital budgeting.

The **risk-adjusted return on capital (RAROC)** methodology provides users with information pertaining to the risk-adjusted performance of the firm and its business units as opposed to merely the “raw” performance numbers. In measuring economic performance, this methodology involves allocating risk capital to the firm’s business units and to specific transactions.

Benefits of RAROC include:

1. Performance measurement using economic profits instead of accounting profits. Accounting profits include historical and arbitrary measures such as depreciation, which may be less relevant.
2. Use in computing increases in shareholder value as part of incentive compensation (e.g., scorecards) within the firm and its divisions. The flexibility of RAROC may also allow for deferred/contingent compensation or clawbacks for subsequent poor performance.
3. Use in portfolio management for buy and sell decisions and use in capital management in estimating the incremental value-added through a new investment or discontinuing an existing investment.
4. Using risk-based pricing, which will allow proper pricing that takes into account the economic risks undertaken by a firm in a given transaction. Each transaction must consider the expected loss and the cost of economic capital allocated. Many firms use the “marginal economic capital requirement” portion of the RAROC equation for the purposes of pricing and determining incremental shareholder value.

LO 57.c: Compute and interpret the RAROC for a project, loan, or loan portfolio and use RAROC to compare business unit performance.

The necessary amount of economic capital is a function of credit risk, market risk, and operational risk. The RAROC for a project or loan can be defined as risk-adjusted return divided by risk-adjusted capital. The basic RAROC equation is as follows:

$$\text{RAROC} = \frac{\text{after-tax expected risk-adjusted net income}}{\text{economic capital}}$$

There is a tradeoff between risk and return per unit of capital with the numerator acting as return and the denominator acting as risk. For example, a business unit's RAROC needs to be greater than its cost of equity in order to create shareholder value.

Furthermore, measures such as return on equity (ROE) or return on assets (ROA) are based on accounting book values only, and therefore are unable to account for the relevant risks. RAROC has two specific adjustments to these measures. In the numerator, it deducts expected loss (the risk factor) from the return. In the denominator, it replaces accounting capital with economic capital.

The underlying principles of the RAROC equation are similar to two other common measures of risk/return: (1) the Sharpe ratio, which equals: $(\text{expected return} - \text{risk-free rate}) / \text{standard deviation}$, and (2) the net present value (NPV), which equals the discounted value of future expected after-tax cash flows. The discount rate for the NPV is a risk-adjusted expected return that uses beta (captures systematic risk only) from the capital asset pricing model (CAPM). In contrast to NPV, RAROC takes into account both systematic and unsystematic risk in its earnings figure.

A more detailed RAROC equation to use for capital budgeting decisions is as follows:

$$\text{RAROC} = \frac{\left(\begin{array}{l} \text{expected revenues} - \text{costs} - \text{expected losses} \\ - \text{taxes} + \text{return on economic capital} \pm \text{transfers} \end{array} \right)}{\text{economic capital}}$$

where:

- *Expected revenues* assume no losses and *costs* refer to direct costs. *Taxes* are computed using the firm's effective tax rate and *transfers* include head office overhead cost allocations to the business unit as well as transactions between the business unit and the Treasury group, such as borrowing and hedging costs.
- *Expected losses (EL)* consist mainly of expected default losses (i.e., loan loss reserve), which are captured in the numerator (i.e., higher funding cost) so there is no adjustment required in the denominator. Expected losses also arise due to market, operational, and counterparty risks.
- *Return on economic capital* refers to the return on risk-free investments based on the amount of allocated risk capital.
- *Economic capital* includes both risk capital and strategic risk capital.

Risk capital serves as a buffer against unexpected losses. It is the amount of funds that the firm must hold in reserve to cover a worst-case loss (an amount over the expected

loss) at a specific confidence level that is usually 95% or more. Therefore, it is very similar to the annual value at risk (VaR).

Strategic risk capital pertains to the uncertainty surrounding the success and profitability of certain investments. An unsuccessful investment could result in financial losses and a negative reputational impact on the firm. Strategic risk capital includes goodwill and burned-out capital.

- **Goodwill** is the excess of the purchase price over the fair value (or replacement value) of the net assets recorded on the balance sheet. A premium price may exist because of the existence of valuable but unrecorded intangible assets.
- **Burned-out capital** represents the risk of amounts spent during the start-up phase of a venture that may be lost if the venture is not pursued because of low projected risk-adjusted returns. The venture may refer to a recent acquisition or an internally generated project. Burned-out capital is amortized over time as the strategic failure risk decreases.

Finally, firms may allocate risk capital to any unused risk limits (e.g., undrawn amounts on a line of credit) because risk capacity could be utilized any time. If risk capacity is utilized, the firm would then have to adjust the risk capital amount.

As mentioned, economic capital is designed to provide a cushion against *unexpected losses* at a specified confidence level. The confidence level at which economic capital is set can be viewed as the probability that the firm will be able to absorb unexpected losses over a specified period. A simple example can help illustrate the concept of unexpected loss and how it is equal to the risk capital allocation. Assume for a given transaction that the expected loss is 20 basis points (bps) and the worst-case loss is 190 bps at a 95% confidence level over one year. Based on this information, the unexpected loss is 170 bps (excess of worst-case loss over expected loss). There is also still a 5% probability that the actual loss will exceed 190 bps.

EXAMPLE: RAROC calculation

Assume the following information for a commercial loan portfolio:

- \$1.5 billion principal amount
- 7% pre-tax expected return on loan portfolio
- Direct annual operating costs of \$10 million
- Loan portfolio is funded by \$1.5 billion of retail deposits; interest rate = 5%
- Expected loss on the portfolio is 0.5% of principal per annum
- Unexpected loss of 8% of the principal amount, or \$120 million of economic capital required
- Risk-free rate on government securities is 1% (based on the economic capital required)
- 25% effective tax rate
- Assume no transfer pricing issues

Compute the RAROC for this loan portfolio.

Answer:

First, calculate the following RAROC components:

$$\text{Expected revenue} = 0.07 \times \$1.5 \text{ billion} = \$105 \text{ million}$$

$$\text{Interest expense} = 0.05 \times \$1.5 \text{ billion} = \$75 \text{ million}$$

$$\text{Expected loss} = 0.005 \times \$1.5 \text{ billion} = \$7.5 \text{ million}$$

$$\text{Return on economic capital} = 0.01 \times \$120 \text{ million} = \$1.2 \text{ million}$$

Then, apply the RAROC equation:

$$\text{RAROC} = \frac{(105 - 10 - 75 - 7.5 + 1.2 + 0) \times (1 - 0.25)}{120} = 8.56\%$$

Therefore, maintenance of the commercial loan portfolio requires an after-tax expected rate of return on equity of at least 8.56%.

Note that for capital budgeting projects, *expected* revenues and losses should be used in the numerator since the analysis is being performed on an ex ante (or before the fact) basis. In contrast, for performance evaluation purposes on an ex post (or after the fact) basis, *realized* (or actual) revenues and losses should be used.

**MODULE QUIZ 57.1**

1. Which of the following statements regarding the risk-adjusted return on capital (RAROC) methodology is correct?
 - A. In the context of performance measurement, RAROC uses accounting profits.
 - B. In the numerator of the RAROC equation, expected loss is added to the return.
 - C. If a business unit's cost of equity is greater than its RAROC, then the business unit is not adding value to shareholders.
 - D. RAROC is useful for determining incentive compensation but it lacks the flexibility to consider deferred or contingent compensation.

2. Assume the following information for a commercial loan portfolio:
 - \$1.2 billion principal amount
 - 6% pre-tax expected return on loan portfolio
 - Direct annual operating costs of \$8 million
 - Loan portfolio funded by \$1.2 billion of retail deposits; interest rate = 4%
 - Expected loss on the portfolio is 0.4% of principal per annum
 - Unexpected loss of 7% of the principal amount
 - Risk-free rate on government securities is 1%
 - 30% effective tax rate
 - Assume no transfer pricing issues

Based on the information provided, which of the following amounts is closest to the RAROC?

- A. 9.33%.
- B. 10.03%.
- C. 12.33%.

D. 14.66%.

MODULE 57.2: RAROC, HURDLE RATE, AND ADJUSTED RAROC

RAROC for Performance Measurement

LO 57.d: Explain challenges that arise when using RAROC for performance measurement, including choosing a time horizon, measuring default probability, and choosing a confidence level.

Time Horizon

In computing RAROC, the focus so far has been on one period (i.e., one-year time horizon) since it is convenient from a business planning cycle perspective and it represents the probable amount of time needed for a firm to recover from a significant unexpected loss. At the same time, it is possible to look at multi-period RAROC to obtain a more accurate RAROC measure for longer-term transactions and loans. One issue that arises is how much economic capital to allocate if the risk of a transaction changes dramatically in subsequent periods. For example, using an averaging method would give rise to periods of overcapitalization and periods of undercapitalization.

Risk capital could be thought of as the firm's one-year VaR at a specific confidence level (e.g., 95% or 99%). For both credit risk and operational risk, no adjustments are required from one-year VaR to compute risk capital. For market risk, short time horizons such as one day (risk monitoring) or 10 days (regulatory capital) require adjustments to determine the correct one-year risk capital allocation.

One basic approach is the "square root of time" rule whereby one-year VaR is estimated by multiplying the one-day VaR by the square root of 252 business days in the year. This approach needs to be fine-tuned by considering that even in a worst-case scenario, the firm might only be able to reduce its risk to a core risk level to retain its status as a financially viable business for the rest of the year. Furthermore, the computation must also factor in the time needed to lower the current risk level to the core risk level (i.e., "time to reduce"). That amount of time corresponds to the relative liquidity (during difficult market conditions) of the firm's investment positions taken. As a result, a large amount of time may be required for a reasonable liquidation of the positions.

EXAMPLE: Risk capital for market risk

Assume the following information where the core risk level is below the current risk level:

- Daily value at risk (VaR) = 80
- Core risk level = 60
- Days needed to reduce current risk level to core risk level = 10 (i.e., risk reduction of 2 VaR per day)

- Number of business days per year = 252

Compute the required risk capital as a percentage of annualized VaR.

Answer:

Risk capital =

$$\begin{aligned} \text{square root} & \left\{ \begin{array}{l} \text{sum of squares +} \\ \text{core risk level squared} \times (\text{number of business days per year} -) \\ \text{days needed to reduce current to core} \end{array} \right\} \\ & = \text{square root} \left\{ \begin{array}{l} (80^2 + 78^2 + 76^2 + 74^2 + 72^2 + 70^2 + 68^2 + 66^2 + 64^2 + 62^2) + \\ [60^2 \times (252 - 10)] \end{array} \right\} \\ & = \text{square root} [50,740 + (3,600 \times 242)] \\ & = \sqrt{921,940} = 960.18 \end{aligned}$$

Note that annualized VaR = $80 \times \text{square root of } 252 = 1,269.96$

Therefore, the risk capital required is approximately 75.6% of annualized VaR (= $960.18 / 1,269.96$).

There is a lot of subjectivity in selecting the time horizon for RAROC calculation purposes. A longer time horizon could be selected to account for the full business cycle; it may not always increase the risk capital required since the confidence level required to maintain a firm's solvency will fall as the time horizon is increased. A key consideration with the selection of a time horizon is the fact that risk and return data for periods over one year is likely to be of questionable reliability.

Default Probability

A **point-in-time (PIT)** probability of default could be used to compute short-term expected losses and to price financial instruments with credit risk exposure. A **through-the-cycle (TTC)** probability of default is more commonly used for computations involving economic capital, profitability, and strategic decisions.

A firm's rating is more likely to change when analyzed under the PIT approach versus the TTC approach. As a result, the TTC approach results in a lower volatility of economic capital versus the PIT approach. From time to time, it is advisable to compare the result of PIT versus TTC for RAROC computations at a stable portion of the economic cycle and at the lowest portion of the cycle.

Confidence Level

In computing economic capital, the confidence level chosen must correspond with the firm's desired credit rating. A high rating such as AA or AAA would require a confidence level in excess of 99.95%, for example. Choosing a lower confidence level will reduce the amount of risk capital required/allocated and it will impact the risk-adjusted performance measures. The reduction may be dramatic if the firm is primarily exposed to operational, credit, and settlement risks where large losses are rare.

Hurdle Rate for Capital Budgeting Decisions

LO 57.e: Calculate the hurdle rate and apply this rate in making business decisions using RAROC.

Similar to internal rate of return (IRR) analysis, the use of a **hurdle rate** (i.e., after-tax weighted average cost of equity capital) is compared to RAROC in making business decisions. In general, the hurdle rate should be revised perhaps once or twice a year or when it has moved by over 10%.

The hurdle rate, h_{AT} , is computed as follows:

$$h_{AT} = \frac{[(CE \times R_{CE}) + (PE \times R_{PE})]}{(CE + PE)}$$

where:

CE = market value of common equity

PE = market value of preferred equity

R_{CE} = cost of common equity (could be derived from the capital asset pricing model [CAPM])

R_{PE} = cost of preferred equity (yield on preferred shares)

Recall that the CAPM formula is as follows:

$$R_{CE} = R_F + \beta_{CE}(R_M - R_F)$$

where:

R_F = risk-free rate

R_M = expected return on market portfolio

β_{CE} = firm's common equity market beta

Once the hurdle rate and the RAROC are calculated, the following rules apply:

- If RAROC > hurdle rate, there is value creation from the project and it should be accepted.
- If RAROC < hurdle rate, there is value destruction from the project and it should be rejected/discontinued.

Obviously, a shortcoming of these rules is that higher return projects that have a RAROC > hurdle rate (accepted projects) also come with high risk that could ultimately result in losses and reduce the value of the firm. In addition, lower return projects that have a RAROC < hurdle rate (rejected projects) also come with low risk that could provide steady returns and increase the value of the firm. As a result, an adjusted RAROC measure should be computed.

Adjusted RAROC

LO 57.f: Compute the adjusted RAROC for a project to determine its viability.

RAROC should be adjusted to consider systematic risk and a consistent hurdle rate.

$$\text{Adjusted RAROC} = \text{RAROC} - \beta_E (\text{R}_M - \text{R}_F)$$

where:

R_F = risk-free rate = hurdle rate

R_M = expected return on market portfolio

β_E = firm's equity beta

$(\text{R}_M - \text{R}_F)$ = excess return over risk-free rate to account for the nondiversifiable systematic risk of the project

Therefore, the revised business decision rules are as follows:

- If adjusted RAROC > R_F , then accept the project.
- If adjusted RAROC < R_F , then reject the project.

EXAMPLE: Adjusted RAROC

Suppose RAROC is 12%, the risk-free rate is 5%, the market return is 11%, and the firm's equity beta is 1.5. Use ARAROC to **determine** whether the project should be accepted or rejected.

Answer:

$$\begin{aligned}\text{Adjusted RAROC} &= \text{RAROC} - \beta_E (\text{R}_M - \text{R}_F) \\ &= 0.12 - 1.5(0.11 - 0.05) = 0.12 - 0.09 = 0.03\end{aligned}$$

The project should be rejected because the ARAROC of 3% is less than the risk-free rate of 5%.



MODULE QUIZ 57.2

1. Which of the following statements regarding the computation of economic capital is correct?
 - I. Selecting a longer time horizon for RAROC calculations is preferable because risk and return data is more reliable with more time.
 - II. Choosing a lower confidence level will not likely reduce the amount of risk capital required if the firm has little exposure to operational, credit, and settlement risks.
 - A. I only.
 - B. II only.
 - C. Both I and II.
 - D. Neither I nor II.
2. Which of the following statements regarding the choice of default probability approaches in computing economic capital is correct?
 - A. A through-the-cycle (TTC) approach should be used to price financial instruments with credit risk exposure.
 - B. A point-in-time (PIT) approach is more commonly used for computations involving profitability and strategic decisions.
 - C. A TTC approach is more likely to result in a lower volatility of capital compared to the PIT approach.

- D. A firm's rating will not change when analyzed under the PIT approach versus the TTC approach.

MODULE 57.3: DIVERSIFICATION BENEFITS AND RAROC BEST PRACTICES

Risk Capital and Diversification

LO 57.g: Explain challenges in modeling diversification benefits, including aggregating a firm's risk capital and allocating economic capital to different business lines.

The overall risk capital for a firm should be less than the total of the individual risk capitals of the underlying business units. That is because the correlation of returns between the business units is likely to be less than +1. Such risk reduction due to diversification effects over risk types and business activities is very difficult to measure in practice. Instead of using an extremely high overall confidence level for the firm, the various business units may use lower confidence levels to avoid an excessively high aggregate risk capital amount.

For example, assume a firm is subject to only the following four types of risk (risk capital amounts are provided for each risk):

- Market risk = \$400
- Credit risk = \$300
- Liquidity risk = \$200
- Operational risk = \$500

Aggregate risk capital for the firm could be as high as \$1,400 assuming a perfect correlation (i.e., sum of the four risk capital amounts). Or it could be as low as \$734 assuming zero correlation (square root of the sum of squares of the four risk capital amounts). In taking into account the diversification effects, the firm's overall VaR should be computed as some value between \$734 and \$1,400, which is a very wide range. In addition, there is a lot of subjectivity involved in allocating the diversification benefits back to the business units in a fair manner especially since the allocation will impact the respective business units' performance measures (i.e., reduction of risk capital required).

It makes sense that a business unit with earnings or cash flows that are highly correlated to the overall firm would need to be allocated more risk capital than a business unit with earnings or cash flows that are negatively correlated (assuming similar volatility). Having business lines that are countercyclical in nature allows the overall firm to have stable earnings and to attain a given desired credit rating using less risk capital. In practice, the easiest allocation method is a pro-rata allocation based on stand-alone risk capital amounts.

For example, assume the following information pertaining to a business unit that engages in only two activities, A and B:

- Activity A alone requires \$50 of risk capital.
- Activity B alone requires \$60 of risk capital.
- Activities A and B together require a total of \$90 of risk capital.

Stand-alone capital looks at each activity independently and ignores any diversification benefits. Therefore, the stand-alone capital for Activities A and B are \$50 and \$60, respectively. The stand-alone capital for the business unit is \$90.

Fully diversified capital takes into consideration the diversification benefits, which equal \$20 ($= \$50 + \$60 - \90). For simplicity, the diversification benefit can be done on a pro-rata basis as follows: $(\$20 \times \$50) / \$110 = \9.1 is allocated to Activity A and $(\$20 \times \$60) / \$110 = \10.9 is allocated to Activity B. Therefore, Activities A and B have fully diversified capital of \$40.9 and \$48.1, respectively. Fully diversified capital should be used to determine a firm's solvency and to determine the minimum amount of risk capital required for a given activity.

Marginal capital is the extra capital needed as a result of a new activity added to the business unit. Diversification benefits are fully considered. The marginal risk capital for Activity A is \$30 ($= \$90 \text{ total} - \$60 \text{ for Activity B}$) and the marginal risk capital for Activity B is \$40 ($= \$90 \text{ total} - \$50 \text{ for Activity A}$). Total marginal risk capital (\$70) is below the full risk capital of the business unit (\$90). The general method for computing marginal capital of a new activity is to start with the total risk capital required for the business unit minus all of the risk capital required for the other activities. Marginal capital is useful for making active portfolio management and business mix decisions; such decisions need to fully consider diversification benefits.

In a performance measurement context, stand-alone risk capital is useful to determine incentive pay and fully diversified risk capital is useful to determine the incremental benefit due to diversification. In allocating the diversification benefits, caution must be taken especially since correlations between the risk factors usually change over time. In a more extreme situation such as a market crisis, correlations could move to -1 or +1, thereby reducing diversification benefits.

RAROC Best Practices

LO 57.h: Explain best practices in implementing an approach that uses RAROC to allocate economic capital.

Recommendations for implementing a RAROC approach are as follows.

Senior Management

The management team (including the CEO) needs to be actively involved with the implementation of a RAROC approach within the firm and promote it as a means of measuring shareholder value creation. The emphasis should be on the level of profits earned by the firm in relation to the level of risks taken as opposed to merely earning as much profit as possible.

Communication and Education

The RAROC process needs to be clearly explained to all levels of management of the firm in order to have sufficient “buy in” from management. Specifically, the process of allocating economic capital to the various business units needs to be fair and transparent in order to minimize the common concerns of excessive economic capital attribution to a given business unit. An open dialogue and debate with the various business unit leaders of issues concerning how economic capital is computed would also be helpful.

Ongoing Consultation

There are key metrics that impact the computation of economic capital. A committee consisting of members from the various business units as well as the risk management group should review these metrics periodically in order to promote fairness in the capital allocation process.

Metrics involving credit risk include: probability of default, credit migration frequencies, loss given default, and credit line usage given default. The metrics will change with time and will need to be updated accordingly. The historical period over which the metrics are adjusted is debatable—a shorter period may result in fluctuating economic capital amounts and a longer period may result in more stable amounts.

Metrics involving market risk focus on volatility and correlation, and should be updated at least monthly. Metrics involving operational risk are not as defined as they are for credit and market risk, so therefore, involve a significant amount of subjectivity and debate. Other key metrics, like core risk level and time to reduce, should be updated annually.

Data Quality Control

Information systems collect data (e.g., risk exposures and positions) required to perform the RAROC calculations. The data collection process should be centralized with built-in edit and reasonability checks to increase the accuracy of the data. In subdividing the general duties surrounding data, the RAROC team should be responsible for the data collection process, the computations, and the reporting. The business units and the accounting department should be responsible for putting controls in place to ensure the accuracy of the data being used for the RAROC calculations.

Complement RAROC With Qualitative Factors

A qualitative assessment of each business unit could be performed using a four-quadrant analysis. The horizontal axis would represent the expected RAROC return and the vertical axis would represent the quality of the earnings based on the importance of the business unit’s activities to the overall firm, growth opportunities, long-run stability and volatility of earnings, and any synergies with other business units. There are four resulting possibilities:

- Low quality of earnings, low quantity of earnings: the firm should try to correct, reduce, or shut down the activities of any of its business units in this category.

- Low quality of earnings, high quantity of earnings (managed growth): the firm should maintain any business units that currently produce high returns but have low strategic importance to the firm.
- High quality of earnings, low quantity of earnings (investment): the firm should maintain any business units that currently produce low returns but have high strategic value and high growth potential.
- High quality of earnings, high quantity of earnings: the firm should allocate the most resources to business units in this category.

Active Capital Management

Business units should submit their limit requests (e.g., economic capital, leverage, liquidity, risk-weighted assets) quarterly to the RAROC team. The RAROC team performs the relevant analysis and sets the limits in a collaborative manner that allows business units to express any objections. Senior management will then make a final decision. The Treasury group will ensure the limits make sense in the context of funding limits. The restriction placed on a firm's growth due to leverage limitations helps promote the optimal use of the limited amount of capital available.



MODULE QUIZ 57.3

1. Which of the following statements regarding best practices in implementing a RAROC approach is correct?
 - A. A successful RAROC approach is focused on maximizing profits earned by the firm.
 - B. A restriction on the firm's growth due to leverage limitations may result in higher profits.
 - C. The data collection process throughout the firm should be decentralized to allow the various business units to ensure the utmost accuracy of data.
 - D. Metrics involving credit risk, market risk, and operational risk to compute economic capital are generally clearly defined and may be computed objectively.

KEY CONCEPTS

LO 57.a

Risk capital is a buffer to shield a firm from the economic impacts of the risks that it takes (i.e., protect against unexpected losses). In short, it provides assurance to the firm's stakeholders that their invested funds are safe.

In most cases, risk capital and economic capital are identical; however, strategic risk capital may be added to economic capital as follows:

$$\text{economic capital} = \text{risk capital} + \text{strategic risk capital}$$

Regulatory capital is relevant only for regulated industries such as banking and insurance. It is computed using general benchmarks that apply to the industry. Assuming that risk capital and regulatory capital are the same for the overall firm, the amounts may be different within the various divisions of the firm.

For financial institutions, there are four major reasons for using economic capital to allocate risk capital:

- Capital is used extensively to cushion risk.
- Financial institutions must be creditworthy.
- Difficulty in providing an external assessment of a financial institution's creditworthiness.
- Profitability is greatly impacted by the cost of capital.

LO 57.b

Benefits of using the risk-adjusted return on capital (RAROC) approach include:

1. Performance measurement using economic profits instead of accounting profits.
2. Use in computing increases in shareholder value as part of incentive compensation (e.g., scorecards) within the firm and its divisions.
3. Use in portfolio management for buy and sell decisions and use in capital management in estimating the incremental value-added through a new investment or discontinuing an existing investment.
4. Using risk-based pricing, which will allow proper pricing that takes into account the economic risks undertaken by a firm in a given transaction.

LO 57.c

The basic RAROC equation is as follows:

$$\text{RAROC} = \frac{\text{after-tax expected risk-adjusted net income}}{\text{economic capital}}$$

A more detailed RAROC equation for capital budgeting decisions is as follows:

$$\text{RAROC} = \frac{\left(\begin{array}{l} \text{expected revenues} - \text{costs} - \text{expected losses} \\ -\text{taxes} + \text{return on economic capital} \pm \text{transfers} \end{array} \right)}{\text{economic capital}}$$

LO 57.d

In computing RAROC, the focus is often on a one-year time horizon. However, it is possible to look at multi-period RAROC to obtain a more accurate RAROC measure for longer-term transactions and loans. One issue that arises is how much economic capital to allocate if the risk of a transaction changes dramatically in subsequent periods.

There is a lot of subjectivity in selecting the time horizon for RAROC calculation purposes. A longer time horizon could be selected to account for the full business cycle, for example. A key consideration with the selection of a time horizon is the fact that risk and return data for periods over one year is likely to be of questionable reliability.

A point-in-time (PIT) probability of default could be used for short-term expected losses and to price financial instruments with credit risk exposure. A through-the-cycle (TTC) probability of default is more commonly used for computations involving economic capital, profitability, and strategic decisions.

In computing economic capital, the confidence level chosen must correspond with the firm's desired credit rating. Choosing a lower confidence level will reduce the amount of risk capital required/allocated and it will impact risk-adjusted performance measures.

LO 57.e

The hurdle rate is computed as follows:

$$h_{AT} = \frac{[(CE \times R_{CE}) + (PE \times R_{PE})]}{(CE + PE)}$$

Once the hurdle rate and the RAROC are calculated, the following rules apply:

- If RAROC > hurdle rate, there is value creation from the project and it should be accepted.
- If RAROC < hurdle rate, there is value destruction from the project and it should be rejected/discontinued.

LO 57.f

RAROC should be adjusted to take into account systematic risk and a consistent hurdle rate as follows:

$$\text{Adjusted RAROC} = \text{RAROC} - \beta_E (R_M - R_F)$$

LO 57.g

The overall risk capital for a firm should be less than the total of the individual risk capitals of the underlying business units. This is because the correlation of returns between business units is likely to be less than +1.

A business unit with earnings or cash flows that are highly correlated to the overall firm should be allocated more risk capital than a business unit with earnings or cash flows that are negatively correlated (assuming similar volatility). Having business lines that are countercyclical in nature allows the overall firm to have stable earnings and to attain a given desired credit rating using less risk capital.

LO 57.h

The management team needs to be actively involved with the implementation of a RAROC approach within the firm and promote it as a means of measuring shareholder value creation.

The RAROC process needs to be clearly explained to all levels of management of the firm in order to have sufficient "buy in" from management.

A committee consisting of members from the various business units as well as the risk management group should periodically review the metrics that impact economic capital calculations in order to promote fairness in the capital allocation process.

The RAROC team should be responsible for the data collection process, the computations, and the reporting. The business units and the accounting department

should be responsible for putting controls in place to ensure the accuracy of the data being used for the RAROC calculations.

A qualitative assessment of each business unit could be performed using a four-quadrant analysis. The horizontal axis would represent the expected RAROC return and the vertical axis would represent the quality of the earnings based on the importance of the business unit's activities to the overall firm, growth opportunities, long-run stability and volatility of earnings, and any synergies with other business units.

Business units should submit their limit requests (e.g., economic capital, leverage, liquidity, risk-weighted assets) quarterly to the RAROC team. The RAROC team performs the relevant analysis and sets the limits in a collaborative manner that allows business units to express any objections.

ANSWER KEY FOR MODULE QUIZZES

Module Quiz 57.1

- 1. C** The cost of equity represents the minimum rate of return on equity required by shareholders. Therefore, if RAROC is below the cost of equity, then there is no value being added.

Response A is not correct because RAROC uses economic profits, not accounting profits. Response B is not correct because in the numerator of the RAROC equation, expected loss is deducted from the return. Response D is not correct because RAROC has the flexibility to consider deferred or contingent compensation. (LO 57.c)

- 2. B** Unexpected loss ($\$1.2 \text{ billion} \times 7\% = \84 million) is equal to the amount of economic capital required. The return on economic capital is then $\$84 \text{ million} \times 1\% = \0.84 million . Also, expected revenues = $0.06 \times \$1.2 \text{ billion} = \72 million ; interest expense = $0.04 \times \$1.2 \text{ billion} = \48 million ; expected losses = $0.004 \times \$1.2 \text{ billion} = \4.8 million .

$$\text{RAROC} = \frac{\left(\begin{array}{l} \text{expected revenues} - \text{costs} - \text{expected losses} \\ \hline - \text{taxes} + \text{return on economic capital} \pm \text{transfers} \end{array} \right)}{\text{economic capital}}$$

$$\text{RAROC} = \frac{(72 - 8 - 48 - 4.8 + 0.84 + 0) \times (1 - 0.3)}{84} = 10.03\%$$

(LO 57.c)

Module Quiz 57.2

- 1. B** Choosing a lower confidence level will not likely reduce the amount of risk capital required if the firm has little exposure to operational, credit, and settlement risks. The reduction would be much more dramatic only if the firm has significant exposure to such risks because large losses would be rare.

In selecting a time horizon for RAROC calculations, risk and return data for periods over one year is likely to be of questionable reliability. (LO 57.d)

2. C A firm's rating is more likely to change when analyzed under the point-in-time (PIT) approach compared to the through-the-cycle (TTC) approach. As a result, the TTC approach results in a lower volatility of economic capital compared to the PIT approach.

A PIT approach should be used to price financial instruments with credit risk exposure and to compute short-term expected losses. A TTC approach is more commonly used for computations involving profitability, strategic decisions, and economic capital. (LO 57.d)

Module Quiz 57.3

1. B A restriction on the firm's growth due to leverage limitations may result in higher profits because it requires the firm to be "creative" and to optimize a scarce resource (the limited amount of capital available).

Response A is not correct. A successful RAROC approach is focused on the level of profits earned by the firm in relation to the level of risks taken. Response C is not correct. The data collection process should be the responsibility of the RAROC team; the process should be centralized with built-in edit and reasonability checks to increase the accuracy of the data. Response D is not correct. Metrics involving operational risk are not as defined as credit and market risk, therefore, there is often a significant amount of subjectivity involved in the computations.(LO 57.h)