Risk Model Validation, Risk Aggregation, Risk Capital & Derivatives

Liquidity Risk

- **Liquidity** is defined in many ways in financial markets. In general, an asset is liquid if it is "close to cash." This means that the asset can be sold quickly, cheaply, and without moving the price "too much." A market is liquid if positions can be unwound quickly, cheaply (i.e., at low transactions costs), and without undue price deterioration.

Liquidity Risk

Liquidity has two essential properties, which relate to two essential forms of risk.

- **Transactions liquidity** deals with financial assets and financial markets.
- **Funding liquidity** is related to an individual's or firm's creditworthiness.

Liquidity Risk

- Risks associated with liquidity include:

  Transactions (or **market**) **liquidity risk** is the risk that the act of buying or selling an asset will result in an adverse price move.

  Funding liquidity risk or **balance sheet risk** results when a borrower's credit position is either deteriorating or is perceived by market participants to be deteriorating. It also occurs when the market as a whole deteriorates. Under these conditions, creditors may withdraw credit or change the terms of credit (e.g., increase the required collateral for the loan). The position may, as a result, be unprofitable or may need to be unwound. Balance sheet risks are higher when borrowers fund longer term assets with shorter term liabilities. This is called a **maturity mismatch**.

Liquidity Risk

- **Measuring Market Liquidity**

  Factors such as tightness, depth, and resiliency are characteristics used to measure market liquidity.

Tightness (or **width**) refers to the cost of a round-trip transaction, measured by the bid-ask spread and brokers' commissions. The narrower the spread, the tighter it is. The tighter it is, the greater the liquidity.

Depth describes how large an order must be to move the price adversely. In other words, can the market absorb the sale? The market can likely absorb a sale by an individual investor without an adverse price impact. However, if a large institution sells, it will likely adversely impact the price.

Resiliency refers to the length of time it takes lumpy orders to move the market away from the equilibrium price. In other words, what is the ability of the market to bounce back from temporary incorrect prices?

Liquidity Risk

- Liquidity risks are introduced when bid-ask spreads fluctuate, when the trader's own actions impact the equilibrium price of the asset (called **adverse price impact**) and when the price of an asset deteriorates in the time it takes a trade to get done (called **slippage**)

Liquidity Risk

- **Exogenous liquidity** refers to the bid-ask spread not being affected by the individual trades made by investors. This is more likely to be the case when the trades are relatively small.

  Endogenous liquidity refers to when a given trade can influence the liquidity risk of the trade (i.e., a trader submitting a buy or sell order that increases the spread). If an investor attempts to purchase a large block of an asset, for example, the buy order may have an impact on the spread and increase the cost over that indicated by the initial bid-ask prices. This can also happen when an investor tries to liquidate an asset.

Liquidity Risk

- This type of endogeneity problem is more likely in illiquid markets and when the trade is large relative to the market. In summary, for endogenous markets, if a trader attempts to liquidate (buy) a large position,
  the trader should expect the bid (ask) price to fall (increase) and the bid-ask spread to widen. The trader should include such a market reaction when estimating liquidity costs and risks. In both the endogenous and exogenous case, the bid-ask spread is still a function of the factors already mentioned (the number of traders, the standardization of the asset, low transactions
  costs, etc)

- Liquidity is a function of the type of market and its characteristics. It depends on factors such as the number of traders in the market, the frequency and size of trades, the time it takes to
carry out a trade, the cost, and the risk of the transaction not being completed. It also depends on the type of asset and the degree to which the asset is standardized.
- A less standardized asset will have higher liquidity risk. A forward contract has much more liquidity risk than a futures contract, for example, because the forward contract is not a standardized contract.
Over-the-counter (OTC) derivatives of all types usually have relatively high liquidity risk.

- **Liquidity risk** is the risk of an adverse change in the value of the collateral and can be of particular concern to the lender. Even if the lender is less concerned with the credit risk of a counterparty given the security of collateral, the lender is still exposed to the risk of collateral illiquidity and to the value of the collateral declining during the repo term. Especially during times of market turbulence the value of collateral can decline
  significantly and its liquidity can dry up. This risk can be mitigated with the use of haircuts,
  margin calls, reducing the term of the repo, and accepting only higher quality

Recall… Market Microstructure

- In order to understand transactions liquidity risk, it is important to understand market microstructure fundamentals. These fundamentals are:

  Trade processing costs. The first cost is associated with finding a counterparty in a timely fashion. In addition, processing costs, clearing costs, and the costs of settling trades must also be considered. These costs do not typically increase liquidity risk except in circumstances, either natural or man-made, where the trading infrastructure is affected.

  Inventory management. Dealers provide trade immediacy to market participants. The dealer must hold long or short inventories of assets and must be compensated by price concessions. This risk is a volatility exposure.

- **Adverse selection.** There are informed and uninformed traders. Dealers must differentiate between liquidity or noise traders and information traders. Information traders know if the price is wrong. Dealers do not know which of the two are attempting to trade and thus must be compensated for this lemons risk through the bid-ask spread. The spread is wider if the dealer believes he is trading with someone who knows more than he does. However, the dealer does have more information about the flow of trading activity (i.e., is there a surge in either buy or sell orders).

  Differences of opinion. It is more difficult to find a counterparty when market participants agree (e.g., the recent financial crisis where counterparties were afraid to trade with banks because everyone agreed there were serious problems) than when they disagree. Investors generally disagree about the correct or true price on an asset and about how to interpret new information about specific assets.

Risk Aggregation

- Risk aggregation involves identifying the individual risk types and making certain choices in aggregating those risk types. Classification by risk types (market, credit, operational, and business) may be approximate and prone to error. For example, the definitions of risk types may differ across banks or within a given bank, which complicates the aggregation process

Risk Aggregation

- Even though one or more of the previously mentioned four risk types may be found at the same time within a given bank portfolio, the portfolio will often be represented by one risk type for the bank's classifications purposes. Such a simplistic distinction may result in inaccurate measurements of the risk types and this may bias the aggregation process.
  Most banks begin by aggregating risk into silos by risk-type across the entire bank. Other banks prefer using business unit silos, while others combine both approaches. There is no one unanimously accepted method, as each approach has its specific advantages.

Risk Aggregation

- Before risk types can be aggregated into a single measure, they must be expressed in comparable units. There are three items to consider: risk metric, confidence level, and time horizon.
  1. **Risk metric:** Relies on the metrics used in the quantification of different risk types. Must consider whether the metric satisfies the subadditivity condition.
  2. **Confidence level:** Loss distributions for different types of risk are assumed to have different shapes, which implies differences in confidence intervals. The lack of consistency in choosing confidence levels creates additional complexity in the aggregation process.
  3. **Time horizon:** Choosing the risk measurement time horizon is one of the most challenging tasks in risk measurement. For example, combining risk measures that have been determined using different time horizons creates problems irrespective of actual measurement methods used. Specifically, there will be inaccurate comparisons between risk types.

Risk Aggregation

- A common belief is that combining two portfolios will result in lower risk per investment unit in the combined portfolio versus the weighted average of the two separate portfolios.
  However, when we consider risk aggregations across different portfolios or business units, such a belief does not hold up with VaR because it does not necessarily satisfy the subadditivity condition. Also, there may be a false assumption that covariance always fully takes into account the dependencies between risks. Specifically, there could be times where the risk interactions are such that the resulting combinations represent higher, not lower, risk. These points highlight an additional challenge in the computation of risk.

Risk Aggregation

- Firms that use value at risk (VaR) to assess potential loss amounts will ultimately have three different VaR measures to manage. Market risk, credit risk, and operational risk will each produce their own VaR measures. The trick to accurately measuring and managing firm-wide risk, and in turn **firm-wide VaR**, is to understand how these VaR measures interact.
- Market risks will typically follow a normal distribution; however, the distributions for credit risks and operational risks are usually asymmetric in shape, due to the fat-tail nature of these risks. Due to diversification effects of aggregating market, credit, and operational risk, firm-wide VaR will be less than the sum of the VaRs from each risk category. This suggests that the correlation among risks is some value less than one. It can be difficult to determine this correlation amount, so firms typically use average correlation values within their respective industry. However, firms should recognize that correlations can be influenced by firmspecific actions as well as external events such as a financial crisis.

Risk Aggregation

- the properties of a **coherent risk measure** are as follows:

  1. **Monotonicity**: A portfolio with greater future returns will likely have less risk.
  2. **Subadditivity**: The risk of a portfolio is at most equal to the risk of the assets within the portfolio.
  3. **Positive homogeneity**: The size of a portfolio will impact the size of its risk.
  4. **Translation invariance**: The risk of a portfolio is dependent on the assets within the portfolio.

- There are five commonly used aggregation methodologies.

1. **Simple summation**
   Adding together individual capital components.
   Does not differentiate between risk types and therefore assumes equal weighting.
   Also, does not take into account the underlying interactions between risk types or for differences in the way the risk types may create diversification benefits. In addition, complications arising from using different confidence levels are ignored.
2. **Constant diversification**
   Same process as simple summation except that it subtracts a fixed diversification percentage from the overall amount.
   Similar challenges as simple summation.

3.Variance-covariance matrix

Summarizes the interdependencies across risk types and provides a flexible framework for recognizing diversification benefits.
Estimates of inter-risk correlations (a bank-specific characteristic) are difficult and costly to obtain, and the matrix does not adequately capture non-linearities and skewed distributions.

4. **Copulas**

Combines marginal probability distributions into a joint probability distribution through copula functions.
More demanding input requirements and parameterization is very difficult to validate. In addition, building a joint distribution is very difficult.

5. **Full modeling/simulation**

Simulate the impact of common risk drivers on all risk types and construct the joint distribution of losses.
The most demanding method in terms of required inputs. Also, there are high information technology demands, the process is time consuming, and it may provide a false sense of security.

Validation of Models

- Validation is the “proof” that a model works as intended. As an example, while it is a useful tool to test a model’s risk sensitivity, it is less useful for testing the accuracy of high quantiles in a loss distribution.
- The validation of economic capital models differs from the valuation of an IRB (internal-ratings based) model because the output of economic capital models is a distribution rather than a single predicted forecast against which actual outcomes may be compared. Also, economic capital models are quite similar to VaR models despite the longer time horizons, higher confidence levels, and greater lack of data.

Validation of Models

- According to the Basel Committee, a rating system (or a rating model) "comprises all of the methods, processes, controls, and data collection and IT systems that support the assessment of credit risk, the assignment of internal risk ratings, and the quantification of default and loss estimates." To validate a rating model, a financial institution must confirm the reliability of the results produced by the model and that the model still meets the financial institution's operating needs and any regulatory requirements. The tools and approaches to validation are regularly reassessed and revised to stay current with the changing market and operating environment.

Validation of Models

- The breadth and depth of validation should be consistent with the type of credit portfolios analyzed, the complexity of the financial institution, and the level of market volatility.

  The rating model validation process includes a series of formal activities and tools to determine the accuracy of the estimates for the key risk components as well as the model's predictive power. The overall validation process can be divided between quantitative and qualitative validation.

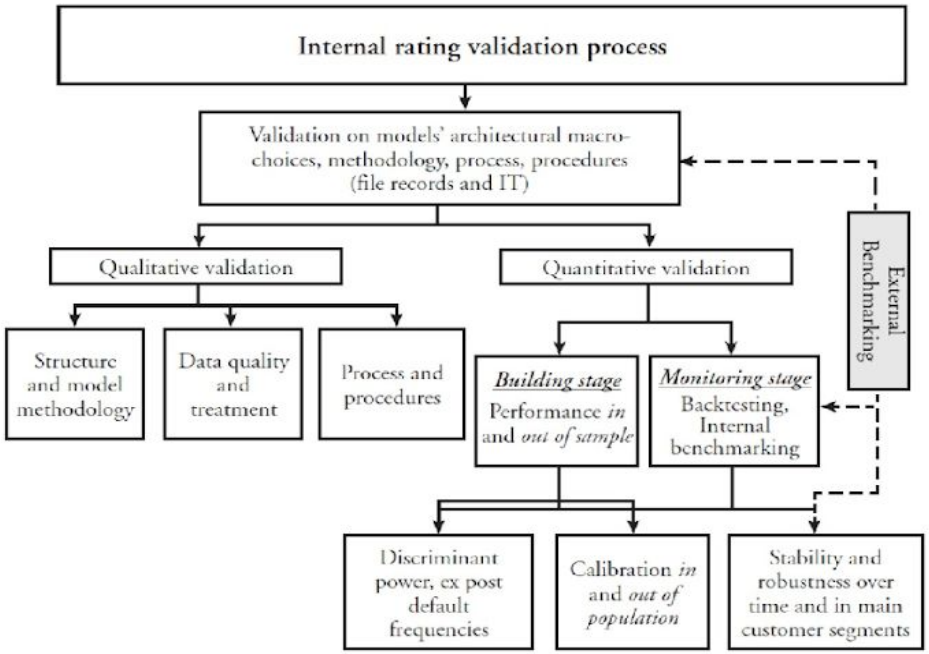
- **Quantitative validation** includes comparing ex post results of risk measures to ex ante estimates, parameter calibrations, benchmarking, and stress tests.

  Qualitative validation focuses on non-numerical issues pertaining to model development such as logic, methodology, controls, documentation, and information technology.

Validation of Models

- The goal of qualitative validation is to correctly apply quantitative procedures and to correctly use ratings. Qualitative and quantitative validation are complements although a greater emphasis is placed on qualitative validation given its holistic nature.
- Rating systems design involves the selection of the correct model structure in context of the market segments where the model will be used. There are five key areas regarding rating systems that are analyzed during the qualitative validation process: (1) obtaining probabilities of default, (2) completeness, (3) objectivity, (4) acceptance, and (5) consistency

Figure 45.1: Model Validation Process



Source: Figure 5.1. *Fundamental steps in rating systems validation process*. Reprinted from "Developing, Validating and Using Internal Ratings," by Giacomo De Laurentis, Renato Maino, Luca Molteni, (Hoboken, New

- Quantitative validation comprises the following areas: (1) sample representativeness, (2) discriminatory power, (3) dynamic properties, and (4) calibration
- Dynamic properties include rating systems stability and attributes of migration matrices. Calibration looks at the relative ability to estimate probability of default (PD).
  Discriminatory power is the relative ability of a rating model to accurately differentiate between defaulting and non-defaulting entities for a given forecast period. Sample representativeness is demonstrated when a sample from a population is taken and its characteristics match those of the total population

- Heuristic models are *more easily accepted* since they mirror past experience and the credit assessments tend to be consistent with cultural norms. In contrast, statistical models are *less easily accepted* given the high technical knowledge demands to understand them and the high complexity that creates challenges when interpreting the output.

  Completeness refers to the sufficiency in number of factors used for credit granting purposes since many default-based models use very few borrower characteristics. In contrast, statistical-based models allow for many borrower characteristics to be used.

  Consistency refers to models making sense and being appropriate for their intended use. For example, statistical models may produce relationships between variables that are nonsensical, so the process of eliminating such variables increases consistency.

  Objectivity is achieved when the rating system can clearly define creditworthiness factors with the least amount of interpretation required, choosing between judgment based versus statistical-based models

- There are six *qualitative* validation processes to consider. The following is a brief description
  of them, as well as the challenges associated with using them (where applicable).
  1. Use test
  If a bank uses its measurement systems for internal purposes, then regulators could place more reliance on the outputs for regulatory capital.
  The challenge is for regulators to obtain a detailed understanding of which model's properties are being used and which are not.
  2. Qualitative review
  Must examine documentation and development work, have discussions with the model's developers, test and derive algorithms, and compare with other practices
  and known information.
  The challenge is to ensure that the model works in theory and takes into account the correct risk drivers. Also, confirmation of the accuracy of the mathematics behind the model is necessary.
  3. Systems implementation
  For example, user acceptance testing and checking of code should be done prior to implementation to ensure implementation of the model is done properly.

- 4. Management oversight

  It is necessary to have involvement of senior management in examining the output data from the model and knowing how to use the data to make business decisions.

  The challenge is ensuring that senior management is aware of how the model is used and how the model outputs are interpreted.

  5. Data quality checks

  Processes to ensure completeness, accuracy, and relevance of data used in the model. Examples include: qualitative review, identifying errors, and verification of transaction data.

  6. Examination of assumptions—sensitivity testing

  Assumptions include: correlations, recovery rates, and shape of tail distributions. The process involves reviewing the assumptions and examining the impact on model outputs.

- There are also six *quantitative* validation processes to consider. The following is a brief description of them, as well as the challenges associated with using them (where applicable).

  1. Validation of inputs and parameters

  Validating input parameters for economic capital models requires validation of those parameters not included in the IRB approach, such as correlations.

  The challenge is that checking model inputs is not likely to be fully effective because every model is based on underlying assumptions. Therefore, the more complex the model, the more likely there will be model error. Simply examining input parameters will not prevent the problem.

  2. Model replication

  Attempts to replicate the model results obtained by the bank.

  The challenge is that the process is rarely enough to validate models and in practice, there is little evidence of it being used by banks. Specifically, replication simply by re-running a set of algorithms to produce the same set of results is not considered enough model validation.

- 3. Benchmarking and hypothetical portfolio testing The process is commonly used and involves determining whether the model produces results comparable to a standard model or comparing models on a set of reference portfolios. The challenge is that the process can only compare one model against another and may provide little comfort that the model reflects "reality." All that the process is able to do is provide broad comparisons confirming that input
parameters or model outputs are broadly comparable.
4. Backtesting
Considers how well the model forecasts the distribution of outcomes—comparison of outcomes to forecasts. The challenge is that the process can really only be used for models whose outputs can be characterized by a quantifiable metric with which to compare an outcome. Obviously, there will be risk measurement systems whose outputs cannot be interpreted this way. Also, back-testing is not yet a major part of banks' validation practices for economic purposes.

- 5. Profit and loss attribution

  Involves regular analysis of profit and loss—comparison between causes of actual profit and loss versus the model's risk drivers. The challenge is that the process is not widely used except for market risk pricing models.

  6. Stress testing

  Involves stressing the model and comparing model outputs to stress losses

- ***Challenges to Data Quality***

  Strong data quality is crucial when performing quantitative validation. General challenges involved with data quality include (1) completeness, (2) availability, (3) sample representativeness, (4) consistency and integrity, and (5) data cleansing procedures

RISK CAPITAL ATTRIBUTION AND RISK-ADJUSTED PERFORMANCE MEASUREMENT

- 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

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
- Economic capital = risk capital + strategic capital

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).

Risk Capital

- **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.

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.

Risk Capital

- *Capital is used extensively to cushion risk*. Compared to most other non-financial 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.

Risk Capital

- *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

- 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.

- 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

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

$$\text{RAROC} = \frac{\begin{pmatrix}\text{expected revenues} - \text{costs} - \text{expected losses} \\ - \text{taxes} + \text{return on economic capital} \pm \text{transfers}\end{pmatrix}}{\text{economic capital}}$$

- 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

- 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: (expected return - risk-free rate) / 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.