SCR®
Risk-Management Fundamentals

GARP®
SCR® | Sustainability and Climate Risk

1 Introduction

All firms face risks stemming from a variety of external and internal factors. Macro factors beyond a firm's control include inflation, interest rates, changes in economic activity, pandemics, and climate change. Firm-specific factors include the market value of the firm's assets and liabilities, demand for its goods and services, operational risks such as internal bad actors (e.g., rogue traders), and cyber threats. Of the many potential sources of risk faced by modern organizations, some are well-known while others are less clear (the "unknown unknowns"), but they all tend to evolve over time. The discipline of risk management has emerged to help organizations identify, measure, manage, and report the risks that impact their operations. This chapter will provide an overview of the major types of risks companies face, with particular attention to the financial context. It will describe the tools and techniques that have been developed to support risk management efforts, including risk measurement, financial hedging, reporting, and governance.

The key learning objectives for this chapter include:

- Define and explore the basic risk types
    - Credit Risk
    - Market Risk
    - Liquidity Risk
    - Operational Risk
- Understand the methodologies behind common risk measurement techniques
- Assess the strengths and weaknesses of those techniques and the methods used to improve upon them
- Examine market and liquidity risk from trading, hedging, and regulatory standpoints
- Evaluate best practices in enterprise-wide risk management
- Focus on risk awareness and analysis of evolving threats such as cybercrime and climate change
- Provide a tool kit to support effective approaches in risk management

2 Basic Risk Types

The major risks faced by firms can be categorized into the following types:

- Credit Risk
- Market Risk
- Liquidity Risk
- Operational Risk

Underlying risk drivers such as weak economic activity, rising interest rates, or climate change manifest themselves through one or more of these risk types and typically can be addressed within the area of risk they are affecting. In addition, enterprise risk management is an approach to managing a firm's risks in a holistic manner and includes frameworks for the principles of risk governance.

3 Credit Risk

Credit risk is the potential loss incurred if a borrower or issuer failed to meet its obligations in accordance with agreed terms. **Default** is the failure to repay or meet existing obligations. Examples of consumer and business credit risk are: 1) a consumer who has a home mortgage and can no longer make payments, hence is defaulting, and 2) a business that issued a bond and cannot make timely interest and principal payments, similarly defaulting on its debt.

Counterparty risk is the potential loss incurred if a party to a contract failed to perform under the terms of the agreement. This could mean failure to provide promised goods, services, loan facilities, or stream of payments in a derivatives contract. Credit risk tends to fall on one side of a transaction, (the lender or bond holder bears the risk), whereas counterparty risk is typically two-sided, such as in an interest rate swap, where either party could renege on the deal.

3.1 Credit and Borrower Types

Firms, including banks and other financial institutions, may extend credit to clients. Retail and wholesale banks differentiate among borrowers based on factors such as size, type, and financing needs. **Retail borrowers** include individuals who borrow money to purchase homes, cars, and other goods and services, or to finance education, vacations, or other activities.

Lenders often group their borrowers into relatively homogeneous risk categories based on standard criteria. One piece of this process is credit scoring, which involves the analysis of the credit histories and characteristics of borrowers. Grouping borrowers and potential borrowers by credit score allows lenders to analyze borrowers and prospective loans collectively and to assess a portfolio's probability of loss (default rate) more accurately. Generally, individuals with high income, low debt, and solid loan-repayment records are considered less-risky borrowers, but a borrower's credit score depends on multiple factors and is tracked over time.

Standardization and credit scoring allow the assessment process to be more efficient, which can make small loans profitable. It has also facilitated securitization, which is the bundling and packaging of loan portfolios, against which debt instruments can be issued. Lenders develop credit decision policies that delineate the types of loans, categorized by size, exposure, and borrower type. Larger loans typically need to the approval of senior management and/or the bank board committee.

Corporate or business borrowers range from small local businesses to global conglomerates. Depending on the ease of access to capital (public markets, banks, private funding), companies may borrow capital or raise equity to finance growth and generate income. Companies with steady profits, low debt, and solid management are less risky and receive better contractual terms for their borrowings.

Public borrowers are primarily state, provincial, and local governments (municipalities) and sub-entities such as water and sewage companies, airport authorities, public hospitals, and school districts. Supranational institutions such as the European Investment Bank, Asian Development Bank, European Bank for Reconstruction and Development, World Bank, African Development Bank, and Inter-American Development Bank are also classified as public borrowers. Amounts borrowed at this level are typically used for public infrastructure investments or general fund spending.

Most local governments can generate cash by taxing their constituencies and are generally viewed as being relatively low risk borrowers. However, local governments have sometimes defaulted on their obligations, particularly when there was mismanagement of funds.

Sovereign borrowers are national governments that raise capital through bonds or direct borrowing, generally from large global banks or funds. Sovereigns often use the capital they raise for infrastructure projects, such as the construction of roads, airports, and railways, or to finance day-to-day government spending. Governments commonly use tax revenues to repay these loans. Despite the substantial taxing and fiscal budget authority that most national governments have, defaults on sovereign debt do occur.

3.2 Credit Assessment and Estimation

Credit assessment is the process of evaluating risk as measured by a borrower's ability and willingness to repay a debt. It also analyzes the creditor's ability to retain or recover asset value should a borrower default. Once the credit assessment is complete, a lender can decide based on its estimation of the risk of default, probability of recovery, the lender's level of exposure to the borrower, and any credit terms that could mitigate the risk to the lender. **Figure 1** shows the steps in the credit process.

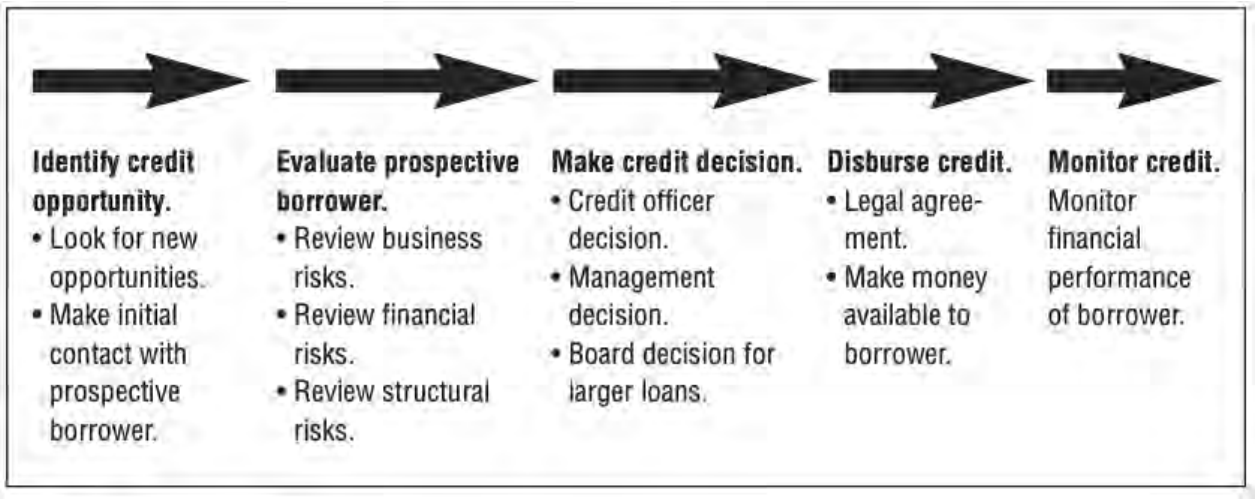

Figure 1: Steps in the Credit Process. Source: Apostolik, R. and Donohue, C. (2019) *Foundations of Financial Risk*, John Wiley & Sons, New Jersey, Figure 4.6.

The finance industry has developed methods to help structure the credit process, including internal scorecards and lending facility and borrower ratings from agencies such as Moody's Investors Service, Fitch Ratings, and S&P Global Ratings. Additional methods include cash flow analysis, sensitivity models, stress testing, and scenario analysis. Used individually or in combination, these methods allow risk managers to weigh the available information to develop a view of the overall risk associated with a particular loan or credit product.

3.2.1 The Credit Analysis Process

The Five Cs of Credit (character, capital, conditions, capacity, collateral,) provide a basic framework for sound lending practices (**Figure 2**). They are particularly relevant to small- and medium-size commercial lending because these sectors typically do not have access to the financial markets through which large and established companies can raise capital by issuing stocks or bonds.

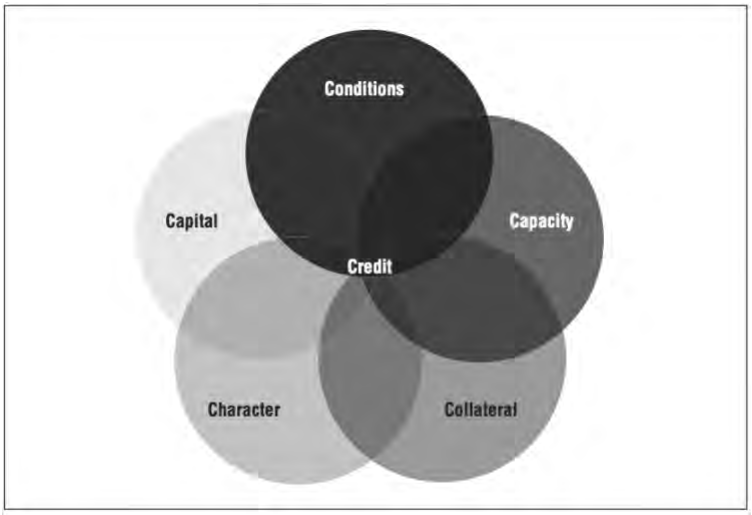

Figure 2: The Five Cs of Credit. Source: Apostolik, R. and Donohue, C. (2019) *Foundations of Financial Risk*, John Wiley & Sons, New Jersey, Figure 4.7.

Character

Lenders prefer to provide capital to borrowers with excellent credentials and references. Credit analysts determine the quality of management's relationship with its employees and its customers and how these relationships are managed as the company fulfills its obligations. Indicators of management capabilities include their level of engagement in day-to-day operations, flexibility in embracing current technologies, understanding of prevailing industry trends, and ability to contain costs and enhance efficiencies.

Capital

The relationship between a corporation's equity and debt is critical. All else equal, the higher the level of equity, the healthier the firm will appear from a credit risk perspective. A high degree of retained capital or equity is also indicative of the financial commitment of the company's owners and reveals the degree to which equity holders have underwritten the corporate risk. In small and medium-sized businesses, the company's financial statements and the owners' personal financial standing, assets, and credit quality should receive scrutiny.

Conditions

In any lending situation, a key question concerns the economic conditions in the region, country, or countries in which a company operates, and the financial and economic dynamics of the relevant industry.

Capacity

Capacity relates to a borrower's ability to meet current and proposed obligations based on the size and stability of its current and expected revenue and cashflow. Financing needs vary between companies and can be affected by timing, economic conditions, and business circumstances. Predictable seasonal fluctuations aside, cash flow tends to follow a stable path for some companies. In general, such companies will find it easier to negotiate a permanent financing facility. However, other businesses may experience significant cash-flow volatility. Such businesses may find it difficult to establish a permanent financing facility with a lender, although a potential lender may recommend combinations of temporary financing to the borrower. A central tenet of banking and lending is that the adequacy and predictability of cash flows weigh heavily in financing decisions.

Collateral

If the borrower cannot honor its obligations, a creditor will seek to claim some collateral to satisfy the debt. A lender is responsible to its own shareholders and/or depositors and must verify secondary or complementary sources of repayment or assets/collateral should a borrower have difficulty meeting its contractual obligations. In the event of a default, the lender should be able to assume control over these assets and organize their orderly sale to satisfy the terms of the original lending agreement.

3.2.2 Credit Rating Agencies

Credit Rating Agencies (CRAs) evaluate the creditworthiness of borrowers and publicly traded debt. These independent ratings provide an assessment of a borrower's general creditworthiness based on a wide array of risk factors. In addition, ratings on individual debt instruments incorporate the creditworthiness of the issuer with relevant instrument-specific risk factors.

The ratings range from the highest credit rating, from AAA or Aaa, indicating very high ability to repay, to the lowest credit rating, typically C or D, which suggests that a borrower is near (or is in) default. An investment grade rating of BBB/Baa or better indicates that the borrower has a very high ability to meet its repayment obligations, leading to a low risk of default. Non–investment, or speculative, grade ratings typically fall in the BB/Ba to C/D range. These letter ratings are effective summary representations of material information, including quantitative, qualitative, and legal data about the borrower. They also communicate the results of the rating process to the public markets.

The three leading rating agencies, Moody's, Fitch, and Standard & Poor's, rerate credit over time for large borrowers. These CRAs examine the borrower's fundamental characteristics, including the borrower's industry, prospects for growth, risks, competitive threats, and other weaknesses. They also issue qualifications called "watches" and "outlooks" to provide forward-looking guidance.

Rating agencies evaluate different criteria for different borrower types. When rating sovereign borrowers, agencies analyze a country's ability and willingness to repay a debt and consider relevant and substantive information on the economic and fiscal strength of the country, the stability and viability of the political and social systems, and the sovereign's susceptibility to event risk. A review of sovereigns also includes their ability to deal with internal as well as global economic, political, interest rate, and commodity price changes. Sovereigns often receive the highest ratings among institutions within a given country (sometimes called the "sovereign ceiling"), but like corporations or financial institutions, their creditworthiness is subject to upgrades and downgrades. For example, during the European sovereign crisis of 2009, Portugal, Ireland, Greece, and Cyprus were downgraded to non-investment grade and, in 2012 and 2013, Greece and Cyprus defaulted. Sovereign debt-related crises have often roiled financial markets and some sovereigns have defaulted more than once.

3.2.3 Credit Scoring Model: Altman's Z-Score

One of the earliest credit scoring models was based on Altman's Z-score, created in the 1960s by Professor Edward Altman. The model analyzed a small sample of manufacturing companies in the US in which half of the sample defaulted, and it correlated each company's financial performance to a credit score. The Z-score is based on the use of financial ratios to predict corporate financial distress. The original model incorporated the following five variables (ratios):

- Working capital to total assets
- Return on total assets
- Sales to total assets
- Equity to debt
- Retained earnings to total assets

The Z-score is a weighted sum of these factors and ranges from 1 to 4. Financially sound companies generally obtain Z-scores above 2.99, while those scoring below 1.81 are highly vulnerable. Scores that fall in the intermediate range indicate a possibility of financial distress. In Altman's original study, 95% of 33 bankrupt companies exhibited Z-scores that predicted distress or imminent default.

Over time, the Z-score formula has been modified by Altman and others, but the approach employing the size and relative relationship of common accounting ratios is believed to be an accurate predictor of financial distress. Competing models expand the use of this methodology to include privately held firms, firms in highly specific sectors, and firms of a certain size, such as small and medium-sized enterprises (SMEs).

3.2.4 Credit Scoring Model: Merton's Distance to Default

Another class of structural models is based on Nobel prize-winning Robert Merton's work on the pricing of corporate debt. In the Merton model, equity is treated as a call option on the firm's assets.[1] Since equity-holders should receive the remaining value of a bankrupt firm once debtholders have been fully paid, in theory, equity ownership is similar to owning a call option on the business with a strike price equal to the value of its liabilities. This call option reflects and tracks the value of the business's equity. When the firm is worth more than its liabilities, the business owner has two choices. It can operate profitably and service the company's creditors, or it can liquidate and realize the owner's equity value. However, if the value of the company's assets is less than the amount of its liabilities, the firm is either nearing or is in default, and the intrinsic value of the option will be zero. In the case of such a default and subsequent liquidation, the firm's creditors will receive repayment first, in order of their seniority, and equity holders will have to divide any remaining value amongst themselves.

Merton and others refined the use of option theory, in combination with default definitions and forward-looking data extracted from security markets, to derive more dynamic and predictive models for default probability. One Merton-type model, called Moody's CreditEdge™, calculates an expected default frequency. The model uses three drivers to arrive at an approximation of default probability within a specific time. These drivers are:

- Market value of assets
- Default point
- Asset volatility

To infer the market value of assets and their volatility, these models use observable price information from tradable financial instruments, particularly equity.

[1] A call is an option contract giving the owner (call buyer) the right, but not the obligation to buy a specified amount of an underlying security at a specified price (the strike) from the call seller within a specified time frame. The buyer of the call will pay the seller a premium for the option and may then choose to exercise (acquire the asset for the specified price) at some point in time, up to the option's expiration.

In practice, this dynamic relationship is captured in a "distance-to-default" measure, which is the estimated number of standard deviations asset values must fall to make cause default. One major advantage of this approach is that it can use market information to assess the creditworthiness of an organization on an on-going basis. A disadvantage of this approach is that if market prices change for reasons unrelated to credit quality, the methodology may cause spurious changes in probability of default (PD) estimates.

3.2.5 Early Warning Signals

Early warning signals alert lenders of increasing credit risk. Such signals may arise from macroeconomic stress, company-specific issues, or industry-wide trends. A robust credit monitoring process should capture early warning signals, such as the reporting of past-due loans, and make them available to managers for assessment.

3.2.6 Credit Monitoring

Effective credit monitoring is an integral part of the credit process and is often prescribed by regulatory agencies and conventions such as Basel III. An effective credit monitoring system should capture aspects of credit risk that may emerge over time. Migration risk, for example, occurs when the credit ratings of a single entity, or an entire portfolio, begin to change in a way that changes the entity's or portfolio's risk profile. A robust monitoring process enables creditors to recognize credit deterioration in the portfolio and take appropriate action.

3.3 Credit Risk Measurement

Organizations use quantitative pricing models to estimate credit risk for each prospective or current borrower. These models incorporate several factors:

- *Probability of Default* (PD) is the likelihood that the obligor or borrower will fail to make full and timely repayment of its financial obligations over a given time horizon. Lenders calculate an obligor's PD using various models. The lender might rely on a combination of causal models, historical frequency models, credit scoring models, and credit rating agency models to assess a borrower's PD.
- *Exposure At Default* (EAD) is the expected exposure at the time of default. In some cases, the lender's exposure at the point of default is obvious. In a loan, it is simply the value of the remaining loan payments. In other cases, the exposure is not apparent and will depend on whether the exposure is fixed or variable, whether the borrower has posted collateral, and whether the lender can "net out" some obligations that it has to the defaulting party.
- *Loss Given Default* (LGD) is the proportion or percentage of the loss if there is a default, expressed as a percentage of the exposure's value. The LGD itself depends on a range of factors, including the debt type and seniority (i.e., where it ranks relative to any other obligations the borrower may have), collateral, the industry, firm-specific capital structure, and the macroeconomic environment.
- *Recovery Rate (RR)* is the amount, expressed as a percentage, recovered from a loan when the borrower is unable to settle the full outstanding amount. By definition: RR = 1-LGD.

In addition to the above credit risk model inputs, two other risk-related measures are important:

- *Expected Loss* (EL) is the average expected financial loss over a given period, calculated from the above inputs.
- *Unexpected Loss* (UL) is a function of losses exceeding the expected loss.

3.3.1 Expected Credit Losses (EL)

For credit instruments, the EL calculation depends on two possible outcomes, default or non-default. The EL is the probability-weighted average of the two outcomes, as summarized in **Figure 3.**

The loss is assumed to be zero if there is no default. If there is default, then the EL is the PD multiplied by the loss given default (LGD) multiplied by the exposure at default (EAD): EL = PD × LGD × EAD, which also equals PD × (1 − RR) × EAD, where RR is the recovery rate. For a portfolio of assets, the EL of the portfolio is the cumulative ELs of the individual assets.

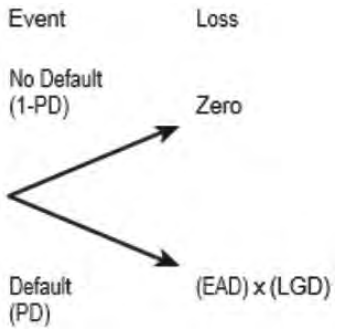

Figure 3: Expected Credit Losses. Source: *Credit Risk Management*, Global Association of Risk Professionals, 2020, Figure 1.1.

3.3.2 Credit VaR and Unexpected Credit Losses (UL)

The VaR (Value-at-Risk) of an instrument is the most a firm would expect to lose on that instrument over a specified time horizon at some level of confidence. For example, the 10-day 95% VaR of a USD 1 million loan is the most you would expect to lose in 10 days 95% of the time and depends on the volatility of the expected losses.

Applying this concept to credit-based assets gives a measure known as Credit VaR. The difference between the Credit VaR measure and EL is called unexpected loss (UL). Unlike the EL for a portfolio of assets, Credit VaR and UL in a portfolio context are not simply the cumulative sum of the Credit VaR or UL of the individual assets. They require a more complex formula because the correlation between assets is important when making the calculation and taking the covariance into account.

While losses related to market risk factors are often modeled with symmetric or near-symmetric return distributions, credit risk models tend to use skewed loss distributions (**Figure 4**). These distributions reflect the higher probability of small losses and the low, but non-zero probability of large losses in the "tail" of the distribution.

The aggregate expected loss of a portfolio is the sum of the expected losses of the individual components of the portfolio, and it cannot be reduced simply through diversification, although reductions in individual asset ELs will reduce portfolio EL. Portfolio UL can be reduced through diversification if it results in lower variance around the portfolio EL.

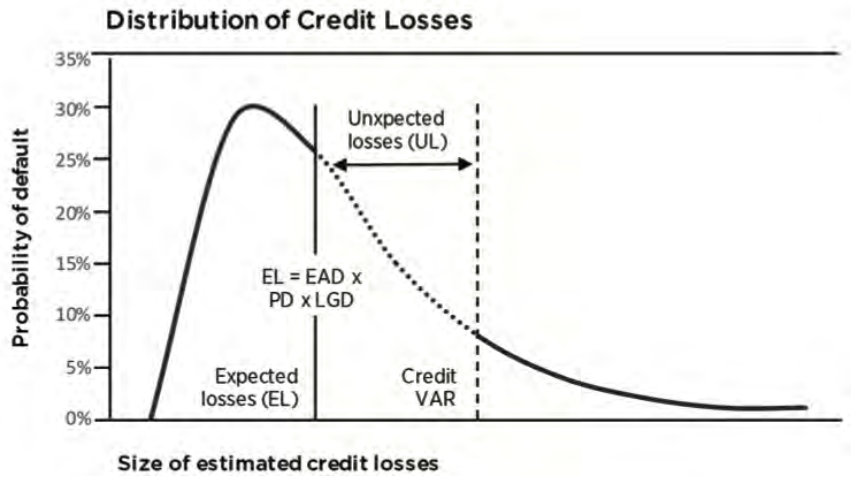

Figure 4: Expected and Unexpected Credit Losses. Source: *Credit Risk Management*, Global Association of Risk Professionals, 2020, Figure 1.2.

Reducing unexpected credit losses is one of the core challenges facing credit risk managers. Although expected credit losses may be covered by loan-loss reserves, creditors must absorb unexpected credit losses through the firm's equity and capital. In this regard, equity shareholders may benefit from unexpected returns (via dividends or share appreciation), but they must also cover unexpected losses, as bondholders have seniority in the event of a bankruptcy and liquidation.

3.3.3 Default Correlation Risk

Default correlation risk refers to the likelihood that the default of one borrower is affected by the default of another borrower. An example of a positive correlation between entities would be two companies that are creditors to each other. Positive correlation may also occur if two creditors are vulnerable to the same external risk, a very large financial client, for example, that was about to default. An example of negative correlation between entities would be two competitors, where the default of one could remove its market share, possibly providing pricing or volume improvements for the remaining company. However, this hypothetical advantage can often be subsumed by sector-wide risks that create positive default correlation risk. Some of the key drivers for default correlation risk are specific industry factors, such as business cycle timing and the macroeconomic environment.

3.3.4 Contagion Risk

Contagion risk refers to the ripple effect of defaults that may occur in a particular industry or between countries, where the default of one borrower or counterparty has a negative effect on other borrowers. One example of contagion risk is the higher likelihood of default of other firms, in the event of the default of a major customer or supplier. Macroeconomic factors often drive contagion risk.

3.4 Credit Risk Management

Risk managers can seek to manage a lender's credit risk through methods that allow a creditor to sacrifice a share of potential future income in exchange for a reduction in risk exposure. These methods include whole loan sales, syndication, securitization, and credit default swaps.

3.4.1 Whole Loan Sales

Whole loan sales allow a creditor to reduce its exposure by selling a specific loan or set of loans to another financial institution. In such transactions, a creditor may prefer to exchange a short duration, adjustable interest rate mortgage that it originated for a longer, fixed duration mortgage originated by a different creditor, for example. There are often gains from loan sales or trades, as the risk preferences of creditors evolve, or other elements of their assets and portfolios change.

3.4.2 Syndication

Loan syndication provides a valuable mechanism to enable a creditor that has a relationship with other similar creditors and significant expertise in a particular market or industry sector to reduce its exposure by sharing, or syndicating, portions of a loan with other financial institutions. Such syndication requires partners to share returns, but also enables them to share and diversify their risks to acceptable levels based on their respective risk tolerances.

3.4.3 Securitization

Securitization is a technique to reduce the effects of credit losses by pooling or bundling assets, such as mortgages or credit card receivable together, and selling them to other financial institutions, or into the capital markets. These sales create a larger pool of more diversified loan assets, that in theory reduces the inherent risk of an individual loan because the loans within the pool would not be expected to default simultaneously (of course, default correlation risk, as described in 2.4.3, therefore becomes an important consideration in a securitization). If the transfer or sale of securities is without recourse (i.e., the issuer is not liable to indemnify the buyer if the loan defaults), this process decreases the original credit risk exposure of the financial institution.

From the originator's perspective, securitizing credit products not only reduces potential risk exposure, including risk arising from sectoral concentration, but also removes these assets from its books. If applicable, it may also reduce the financial institution's reserve capital requirements. As with whole loan sales, the securitization process earns proceeds that enable the financial institution to generate new loans or conduct other business. Many types of loan products can be securitized in this way.

3.4.4 Credit Default Swaps

A credit default swap (CDS) is a form of credit derivative. A CDS contract is similar to insurance and is often referred to as "default protection." It represents the transfer of credit risk between two parties, where the buyer and the seller enter into a swap agreement; however, it would not be correct to say that they are buying or selling the swap itself. Instead, in a CDS, the default protection buyer may already own the underlying credit exposure, and essentially transfers its default risk to the default protection seller. In return, the protection buyer is obligated to make periodic payments to the seller.

If an adverse credit event occurs, such as the default on a specific corporate bond, then the seller must deliver a contracted amount to the buyer. If no such default triggers the CDS terms, the seller earns the periodic fee from the buyer over the life of the bond. From the seller's perspective, a CDS can be used as a means of establishing credit risk exposure to a borrower, whose bond or loan is the underlying ("reference"), instrument in the CDS, or a more general exposure to the sector related to that bond. Credit default swap markets allow portfolio risk managers to reduce losses in the event of default without needing to eliminate the exposure completely by selling the asset, thus it is a form of risk hedging.

4 Market Risk

Market risk is the potential loss resulting from adverse market movements. Some market risk exposures are direct, e.g., when a trader holds a long position in an equity whose price declines. Other market risk exposures are indirect, e.g., when a trader holds a position in a derivative whose value is derived from the price of some other underlying asset. In this case, the value of the derivative may move in the same or opposite direction as that of the underlying asset in what is often a non-linear relationship.

Market risk arises from general market movements — when the prices of the instruments in an entire asset class or group of assets change simultaneously as the result of changes in some underlying risk factor. In this sense, market risk is systematic and undiversifiable within the market itself.

The main types of market risk include:

- *Equity* (*stock*) *price risk* – The potential loss from changes in equity prices. Considering direct effects, the price value of a long position in equities increases/decreases in value as equity market prices increase/decrease. The value of a short position in equities increases/decreases when equity market prices decrease/increase.
- *Interest rate risk* – the potential loss from changes in interest rates. When an investor lends (borrows) money or any other financial instrument, a rate of interest is received (paid). Changes in market interest rates affect the value of the underlying bond, loan, or other financial instruments.
- *Commodity price risk* – the potential loss from changes in commodity prices. The value of a position in a specific commodity market increases/decreases in value as the specific commodity market price changes.
- *Exchange rate (currency) risk* – the potential loss from changes in exchange rates. Every position in a foreign currency implies a long position in one currency and a short position in another currency. Losses occur when the long currency position falls, or the short currency position rises in value.
- *Credit spread risk* – the potential loss from changes in the differences in yields of risky bonds and risk-free bonds (i.e., high quality government Treasury bills).

Other categories of market risk include:

- *Volatility risk* – Many traders and risk managers consider volatility a separate asset/risk class. Most financial instruments, whether cash or derivatives, are not subject to price changes as volatility changes. Options, however, explicitly adjust in value as the volatility of the associated underlying asset changes. A long option position (e.g., a call or put) will increase in value if volatility increases and decrease in value if volatility

decreases. The opposite is true for a short option position: The value increases as volatility decreases and decreases as volatility increases.

- *Correlation risk* – When two separately traded assets display similar characteristics in relation to market price changes, they are positively correlated. The extreme of this phenomenon is a perfect positive correlation, or a correlation of one. Financial assets whose prices seem unconnected to one another are said to have low correlation, the extreme of which is zero correlation. A negative correlation occurs when the price of one financial asset goes up, and another goes down, as a result of the same market influence. The extreme of this phenomenon is a perfect negative correlation, or a correlation of minus one. This is rarely found in financial markets, although highly sought after, as a long position in each of two assets that are highly negatively correlated would reduce the overall market risk of a portfolio dramatically. Correlation risk is, by extension, a portfolio risk that manifests across multiple, interconnected assets. As an example, basket, index, and other portfolio-style products are subject to correlation risk. Being long correlation means gaining value when correlation increases and losing value when it decreases. Being short correlation means gaining value when correlation decreases and losing value when it increases.

4.1 Market Risk Measurement

The range and sophistication of available valuation techniques is substantial, but Value-at-Risk (VaR), which was developed in the 1990s, has been central to market risk measurement, despite its limitations.

VaR provides a qualified answer to the question, "How much could we lose in the next day (or week, month, year) if the market moves sharply against us?" Formally, VaR is defined as the predicted loss at a specific confidence level (e.g., 95% or 99%) over a given period (e.g., one day).

For example, if a firm has a USD 20 million one-day, 99% VaR, this means that the chance of a loss exceeding USD 20 million in one day is 1%. For market risk purposes, VaR is usually calculated based on a presumed holding period such as one day or 10 days (which is the Basel rule regulatory stipulation).

VaR does not provide the worst-case loss, but instead uses a confidence level, generally 95% or higher. With a 99% confidence level, for example, VaR estimates the loss level such that 99% of the time (e.g., in 99 trading days out of 100), the actual loss will be less than that amount. VaR does not predict what the loss could be on the worst day.

VaR calculations make assumptions about likely future movements of market values and as such it is a forward-looking measure of risk. The true VaR cannot be known and, therefore, companies use numerous methods to estimate it. Calculating VaR involves examining current positions closely and estimating the distribution of possible return values during a particular time period. Historical data are often used, and forward-looking data such as option-implied volatilities or independent risk forecasts can also be employed. When using historical data, the time period chosen for collecting price movements is important. If the sample time period is too short, the data may not capture a wide range of possible price movements. Similarly, if data are gathered from a period of stable and benign economic conditions, they may not be useful in predicting how prices will move under more volatile economic conditions. If very long time periods are chosen, then market structure or economic fundamentals may differ widely from the beginning of the window to the end and may fail to shed light on the current market environment.

The graph in **Figure 5** shows an illustrative return distribution for a portfolio. The horizontal axis represents possible gains and losses. Losses are shown to the left of zero and profits to the right. For any return value *x*, the area beneath the curve for all return values less than or equal to *x* represents the probability that the return value is less than or equal to *x*. The area under the entire curve is equal to 1. At any particular return value, the curve's height represents the relative likelihood of that gain or loss. Very low return values (far left points on the curve) and very high return values (far right points on the curve) have likelihoods close to zero because these return values are improbable. The peak of the curve occurs for return values close to zero (middle of the curve) because these values have the highest chance of occurring. The line labeled 95% confidence level is at USD –2 million. The area under the curve to the left of the line is 5%, indicating that there is a 5% chance of losses greater than USD 2 million; the one-day 95% VaR is USD 2 million. Farther to the left, at USD –3 million, there is a line labeled 99% confidence level. The area under the curve to the left of that line is 1% and indicates that there is a 1% chance that losses could exceed USD 3 million. Therefore, the one-day 99% VaR is USD 3 million.

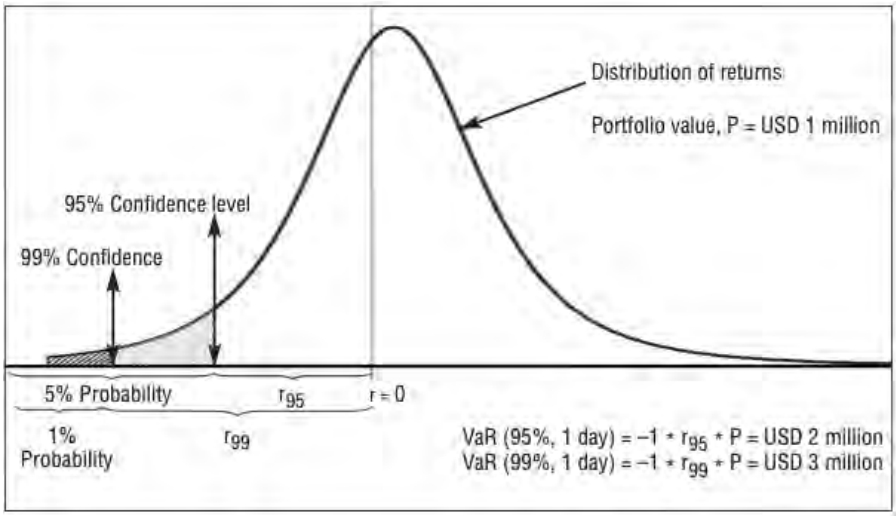

Figure 5: Illustration of VaR

Source: Apostolik, R. and Donohue, C. (2019) *Foundations of Financial Risk*, John Wiley & Sons, New Jersey, Figure 6.11.

4.1.1 Parametric VaR Estimation

A key categorization of the methods for estimating VaR is whether they are parametric or non-parametric. A parametric technique involves assuming a particular distribution for the asset or portfolio returns, where each distribution requires one or more parameters to describe it. Typically, the parameters are the mean and standard deviation.

Unfortunately, assuming returns follow a normal distribution is likely to underestimate realized losses because actual asset return distributions tend to be “leptokurtic” (fat-tailed), as illustrated in **Figure 6.** Here, the solid line indicates the actual return distribution of a typical asset, whereas the dashed line shows a normal distribution with the same mean and variance. It is evident that the actual distribution has fatter tails and more of the distribution in the center, which shows that extreme returns occur much more frequently in reality than the normal distribution would predict.

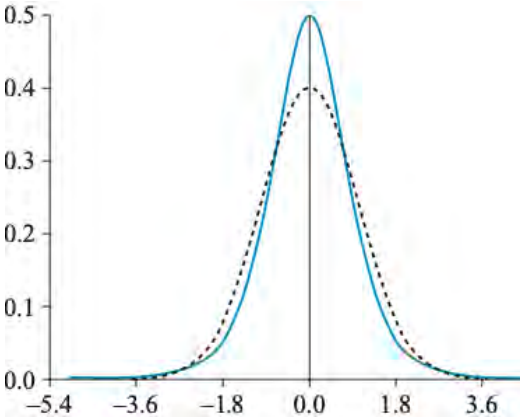

Figure 6: A Leptokurtic Distribution and a Normal Distribution

A common VaR estimation procedure which assumes a normal return distribution and that portfolio returns are a linear combination of normal variables is known as the delta normal method. For some portfolios, however, such as those containing complex options, the delta normal model will lead to highly inaccurate VaR estimates. In such cases, a full valuation that calculates the portfolio value for a wide range of possible prices of underlying assets can be performed via a Monte Carlo (MC) simulation. MC simulation falls under the parametric model umbrella because draws are made from an assumed distribution to simulate future price paths.

Figure 7 illustrates 100 possible simulated paths for the price of a stock with an initial price of USD 98, calculated from a random walk (with drift) model over a 250-trading day horizon. A random walk model is one where the next period data point is equal to the current one plus a random shock term that has a zero mean, but where each individual draw could be positive or negative. Notice that, although, on average, the stock is expected to have a terminal price above its initial price due to the model's modest positive drift term, a meaningful number of the simulated price paths result in a loss.

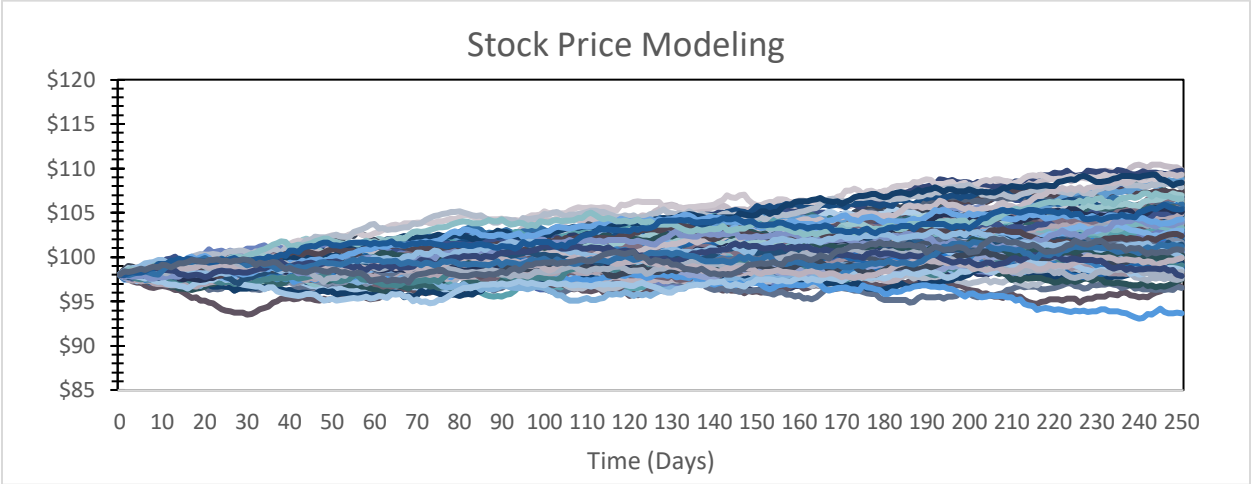

Figure 7: Monte Carlo Simulation over a 250-day trading horizon. Source: Author's calculations.

In practice, such a 100-path simulation is unlikely to be sufficiently precise and would simply serve as a model for a larger run. For real-life applications, 10,000 paths are better and, in certain circumstances, up to 100,000 paths or more could be created. Monte Carlo simulation is a computationally intensive technique. However, with modern computer speeds and computing power, this is much less of an issue than in the past.

4.1.2 Non-parametric VaR Estimation Using Historical Simulation

Non-parametric approaches do not involve specifying a particular distribution pattern for asset or portfolio returns. The simplest non-parametric approach is known as historical simulation. Here, the actual returns on the portfolio are reconstructed, holding the weights on each asset at their current values. For a long position, the portfolio returns are then ordered from worst (most negative) to best, and the α-quantile from this empirical distribution is identified and multiplied by the portfolio value *P* to obtain the α-level VaR.

Historical simulation overcomes the weaknesses of assuming normally distributed returns, but the historical periods sampled may not represent the current market risk situation well. One way to address this issue is to use a longer sample period to capture a broader range of market circumstances, weighting the observations to have less importance when they occurred further in the past. However, even this technique does not provide assurance that the analysis will be representative of future market conditions.

4.1.3 Limitations of VaR

VaR gained popularity because it is intuitive, simple to calculate, can be applied consistently across many contexts, and measures risk in monetary terms. However, it has several important weaknesses:

- VaR indicates the most that it is likely to be lost some percent (e.g., 99%) of the time, but it cannot be used to determine how large losses might be in excess of that (i.e., in the other 1% of the time). This is a serious weakness because extreme tail losses are the most consequential for a firm.
- Because VaR is focused on the likelihood of losses up to a particular confidence level, it can lead to perverse incentives for traders to remain within a VaR limit at the expense of taking risks beyond the limit, which may or may not be the optimal investment decision under a given set of circumstances.
- A lack of market or asset liquidity can affect the transaction costs associated with liquidating a specific asset or portfolio position significantly. Factors that can affect transaction costs, or the time it takes to liquidate a position include bid-ask spreads, brokerage costs, the size of the position relative to the market, and the trade execution strategy. VaR models are often not calibrated to account for asset liquidity constraints, although they can be adjusted by, for example, multiplying the daily VaR amount with the square root of the number of days in an assumed future unwind period.[2]
- The academic Philippe Artzner developed four properties that a risk-measurement framework should possess in order to be termed "coherent." VaR violates one of these axioms because it is not "sub-additive." This means that, in rare circumstances, the calculated VaR of a portfolio can be greater than the sum of the VaRs of the component assets. This can cause several issues, most notably providing an incentive for traders to break up their portfolios into separate accounts, which would have a lower VaR and lower capital requirements when treated separately than they would if the portfolios were combined.

[2] This method is not free from the estimation error associated with the use of the square root of time scaling method described earlier.

4.1.4 Stressed VaR

Stressed Var (SVaR) is an evolution of classic VaR and was intended by bank regulators to address some the weaknesses of VaR in capturing tail risk.[3] SVaR is designed to replicate a VaR calculation that would be estimated if the relevant market factors were experiencing a period of stress. For Basel market risk capital requirement purposes, SVaR is based on the 10-day, 99th percentile, one-tailed confidence interval VaR measure of the current portfolio, with model inputs calibrated to historical data from a continuous 12-month period of significant financial stress relevant to the bank's portfolio.

The biggest differences between stressed and standard VaR are the time periods over which potential losses are calculated and the calibration. Instead of the one-day time period used in classic VaR, SVaR uses 10 days. Standard VaR is calibrated to the most recent past (i.e., current conditions), whereas SVaR calculations are based on stressed market conditions, which might have occurred recently, or sometime further into the past. In general, the SVaR number will be significantly larger than standard VaR.

4.1.5 Expected Shortfall

Expected shortfall (ES) has emerged as an important risk measure that overcomes some of VaRs shortcomings. While VaR is an estimate of the expected loss at a specific confidence level over a given period of time, it does not provide any information about the estimated size of losses beyond the chosen confidence level.[4] ES is an attempt to solve this problem. It is not a direct replacement for VaR, but instead a complement to it. ES attempts to estimate the average loss, not the maximum market risk loss, beyond the 95% or 99% quartile, nor the most likely loss. It asks, "On average, how much will we lose if, despite our best efforts to keep losses within the confidence interval boundary, they turn out to exceed the VaR number?"

ES is an average of losses past the risk threshold; for 99% VaR, ES will represent the average of outcomes in the worst 1% of cases. **Figure 8** provides a pictorial representation for a long position.

[3] In response to the 2008 global financial crisis, when banks' trading books experienced significant losses and a build-up of leverage, the BCBS revised the Basel II market risk framework and published Basel 2.5 in July 2009 (BCBS158). Basel 2.5 aimed to reduce cyclicality inherent in the framework, reduce the incentive for regulatory arbitrage between the banking and trading books, and increase the overall level of capital by introducing several new metrics. One of these metrics was stressed VaR (SVaR).

[4] It could be argued that the maximum loss is the full principal value of the position or portfolio in question (i.e., "the most you could lose is everything"), but that is not particularly helpful and does not apply for leveraged positions, where the loss could exceed the principal amount.

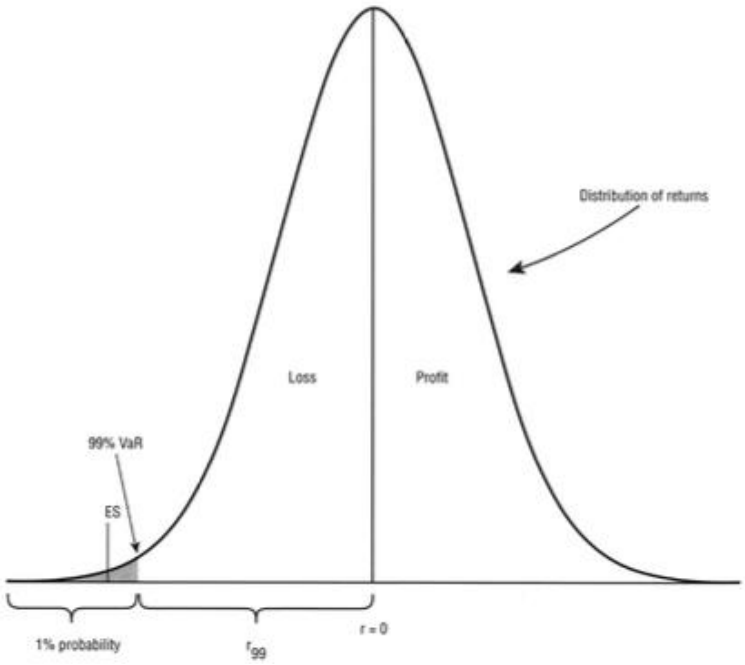

Figure 8: Graphic Showing Expected Shortfall and VaR for a Long Position. Source: *Market Risk Management*, Global Association of Risk Professionals, John Wiley & Sons, New Jersey

For example, a bank has a 99% daily VaR of USD 4 million. If the worst 1% of losses experienced by a bank is equally likely to be USD −5m, USD −6m, and USD −7m, then the expected shortfall is USD 6m (i.e., −(-5m-6m-7m)/3). In reality, the loss distribution is likely to be more complicated, but this illustrates the principle involved.[5]

In this way, ES looks at the distribution of losses beyond the previously determined threshold (which could be the VaR limit) and returns the average of experienced losses.

4.1.6 Stress Testing and Scenario Analysis

Stress testing provides a complement to risk measurement models such as VaR and ES. This technique and scenario analysis are important tools of any risk management system that seeks to understand how a portfolio will perform in extreme cases. Stress testing involves analyzing the potential outcome of a specific change to a risk model parameter (e.g., asset correlations and volatility), or to business and operating environments that are fundamental, material, and adverse. Given the reliance on modeling, risk measures need to be examined closely and tested against extreme events. Stress testing considers instances for specific changes to parameter assumptions, such as a rapid change in interest rates or equity indices, whereas scenario analysis evaluates portfolio performance in severe states of the world, either hypothetical or historical.

[5] ES is also a coherent risk measure because it satisfies all four of the conditions established by Artzner, and it is sub-additive.

Scenarios that a risk manager may consider for an equity portfolio would be the U.S. stock market crash of 1987, the 1997 Asian financial crisis, or the Global Financial Crisis of 2007–2009. Other scenarios might be based on natural disasters, wars, changes in political situations, or other events that would have a dramatic effect on stock prices.

4.2 Market Risk Management

Banks and financial firms face market risk primarily through their proprietary trading operations. There are several approaches firms can take to manage their market risk exposure.

Diversification is a basic and important way that firms seek to protect against having an excessive concentration of risk in highly correlated positions. Concepts from portfolio optimization, which incorporates diversification effects, can be employed to maximize the risk-adjusted expected returns on individual trades, given the positions that the firm already holds.

An additional way to ensure that the overall level of market risk will stay within acceptable bounds is to set market risk limits, including position limits, on trading and portfolio management groups within the firm. For example, a bank's trading desk could have a specified VaR limit that is actively monitored so that it cannot be exceeded without triggering an alert leading to review and possible remediation, which could include the hedging of or closing out of positions.

Hedging is an important tool of market risk management.

4.2.1 Hedging

Firms and individuals hedge to reduce or offset a risk, although it is important to note that hedging alone cannot fully eliminate, or "cancel" risk completely. When a financial firm hedges a position that it currently holds in a financial instrument, the position is matched as closely as possible with an equal and opposite position in another instrument that tracks or mirrors the value changes in the position being hedged. Hedging often involves a position in a derivative instrument that mirrors the value changes of the underlying asset as closely as possible. Many types of derivatives and derivative products have been created to meet a wide range of financial needs. The main categories include:

Options – Financial derivatives that give the buyer the right to buy or sell the underlying asset at a stated price within a specified period of time.

Futures – A contract involving the obligation to sell or buy an asset on a future date at a particular price. Futures contracts are often considered in terms of commodities, such as oil, wheat, or gold.

Forwards – Another type of customized contract to buy or sell an asset at a specified price on a future date.

Swaps – A derivative contract where two parties exchange the cash flows or liabilities from two different financial instruments.

Swaptions – An option to enter into an interest rate swap, or some other type of swap.

Some firms use derivatives to address industry- or investment-specific risks, while others use them for diversification and speculation.

As an example, firms such as airlines that make heavy use of certain commodities face severe exposure to an increase in commodity prices; in the case of airlines, the price of oil is a good example. Such companies will frequently hedge their exposures by using derivatives to mitigate the effect of adverse price moves in the commodity they rely on. If an airline expects the price of oil to increase, it might take out call options on oil, giving the firm the right to buy oil in the future at a price stated today. This way, if the price of oil rises, the airline will be able to exercise the call option, acquiring the oil at a lower price than the now-prevailing rate. Firms can also hedge their exposures to other risks driven by similar fluctuations, such as foreign exchange rates, or interest rates.

- When using a futures contract to hedge a risk exposure, a firm needs to determine how many units of the futures contract to sell (i.e., take a short position in) for each unit of the asset whose value changes the firm is looking to offset. This quantity is known as the hedge ratio, which can be determined mathematically by taking the covariance between the hedged asset returns and those of the futures contract, divided by the variance of the hedged asset returns.
- If a firm wants to hedge a long equity position it could purchase a protective put option (i.e., a long position in a put option) because the value of the put option increases as the value of the stock decreases.[6] Put holders, therefore, are in a position to gain when prices fall.

Measures of the sensitivities of option prices are known as the "Greeks" and they cover a series of factors that can affect option pricing dynamics.

Delta – the price sensitivity of the option relative to the underlying asset.

Gamma – second order price sensitivity; the rate of change of an option's delta due to changes in the underlying asset's price.

Theta – the time sensitivity of an option; the rate of change between the option price and time, sometimes known as "time decay".

Vega – the sensitivity of the option to volatility; the rate of change between an option's value and the underlying asset's volatility.[7]

Rho – interest rate sensitivity; the rate of change between an option's value and changes in interest rates.

Although options are frequently used to hedge exposure to movements in asset prices, financial firms also evaluate the risks inherent in options themselves and may hedge against them by taking out options on options, for example.

5 Liquidity Risk

Liquidity risk can be separated into market liquidity risk and funding liquidity risk. **Market liquidity risk**, also known as asset liquidity risk, can be defined as the risk that a position cannot be unwound at the desired time, in the desired amount, and/or without incurring unreasonably large transactions costs. Illiquidity is typically caused by a lack of market depth, where turnover is low and there are few people currently trading that asset.

[6] A put option gives the holder the right, but not the obligation, to sell an asset at a pre-specified price (known as the strike price) on a specified date in the future.

[7] *While vega is not actually a Greek letter, it is a commonly used term in finance and is considered one of the "Greeks".*

The largest markets in standardized assets tend to be highly liquid, such as the foreign exchange market for major traded currencies (e.g., the US dollar, euro, British pound, and Japanese yen) and large capitalization ("large-cap") equity markets. However, some assets are inherently illiquid due to their unique nature (heterogeneity) and considerable unit value. Examples include a range of over-the-counter instruments and real estate, where it may take time to find a buyer unless the seller is willing to offer a significant discount on the price. In addition, in such cases, sales commissions may be high. Some liquidity problems only manifest at certain times, when normally liquid markets "dry up" due to endogenous market factors, or exogenous macroeconomic conditions. Examples include the dot-com bubble burst in 2001, when the tech sector was hit hard, although the rest of the stock market carried on business more or less as usual, and the great financial crisis, when liquidity shocks were felt throughout a wide range of asset classes and markets.

Note that market or asset liquidity refers to the ability to trade in and out of a position without significant price effects. This type of liquidity is fundamentally different from **funding liquidity risk,** which is the potential loss due to an institution's inability to meet its own business obligations such as depositor withdrawal demands, payroll, and debt obligations. Firms must manage funding liquidity risk on a daily basis.

In order to meet funding liquidity needs, financial firms may establish holdings of highly marketable liquid assets that they could sell on short notice to raise funds if necessary. A bank's liability structure includes both contractual and non-contractual funding from its ordinary sources, such as retail and wholesale depositors, other banks, lenders, and investors. Liquidity from some of these sources can be mobilized within minutes or hours (e.g., interbank and central bank borrowings), while others take much longer to secure. New bond issues, for example, can take weeks or months and retail deposits can take months or even years to accumulate at scale.

The primary daily liquidity obligations specific to banks are the ability to fund deposit withdrawals and the ability to fund loan drawdowns. Apart from these two bank-specific liquidity obligations, banks encounter the standard liquidity obligations of paying their bills and debts in a contractual and timely manner.

Funding issues can become problematic for a bank when its liquidity requirements are not predictable. Some liabilities have scheduled repayment amounts and time frames, so they are clearly known, but one important funding factor—future deposit levels—cannot be predicted with certainty. Other liabilities, such as those created by counterparty failure or market risk in leveraged cash or derivative positions, cannot be forecasted precisely and can have a significant and evolving effect on liquidity requirements over time. The types of events that can stress a bank's liquidity include:

- Obligations to fund assets (e.g., mortgages)
- Maturing debt
- Unusually large depositor withdrawals (if they are part of a series or pattern of withdrawals, they may signal a potential run on the bank)
- Nonperforming assets, which can result in cash shortfalls
- Exercise of customer put provisions requiring a bank to repurchase assets
- Repurchase agreements
- Futures margin requirements
- Counterparty collateral calls, or failure of counterparties to supply collateral when called

Many liquidity problems are caused by unexpected short-term liabilities, but they can also be caused by the funding requirements of long-term liabilities. Liquidity risk, therefore, may arise from the variability in short-term assets and liabilities and the short-term components of long-term assets and liabilities.

Liquidity management is a key component in managing the balance sheet. It ensures that the bank will maintain sufficient cash and liquid assets to meet expected deposit withdrawals or disbursement demands and pay its business expenses. Maintaining a robust level of liquidity can also be profitable as it may reduce a firm's risk profile in the eyes of lenders and make it possible for the firm to borrow at favorable interest rates.

The Treasury function plays an important role in managing a financial firm's assets and liabilities, liquidity, and capital. In both financial and non-financial firms, the Treasury function is crucial in ensuring the continuation of everyday business operations through the payment of outstanding debt obligations, the meeting of payroll, and the timely payment of vendors. Forecasting liquidity needs accurately, managing lines of credit responsibly, adhering to debt covenants, and maintaining a good credit standing with vendors and the capital markets will all support a firm's liquidity management plan.

5.1 Measures of Liquidity Risk

Several indicators of market liquidity can be employed in normally functioning markets. The most straightforward measure is total trading volume since the larger the volume, all else equal, the easier it would be for an order of a given size to be executed quickly without adversely affecting the price.

A second measure is the bid-ask spread, which will be wider in illiquid markets. Market makers are only willing to quote firm two-way prices (i.e., a bid and an ask) if they are compensated by sufficiently wide spreads for the risk that they will end up holding the asset themselves during a period of violent market turbulence and decline.

A third measure is market depth, which is represented by the number of bid and ask quotes placed on the order book by market makers. If the market for a particular asset is deep, it should be possible for a trader to place a large order without impacting the price of the asset.

5.1.1 Financial Ratio Analysis

Whether a firm is evaluating a borrower's ability to service debt obligations, the financial health of a vendor, or its own liquidity position, financial ratios from the balance sheet and income statement provide accounting measures of liquidity. The most frequently quoted ratios are:

- *The quick ratio* – sometimes known as the "acid ratio," is the ratio of cash, saleable securities, and liquid receivables to current liabilities. A quick ratio of less than one indicates that the firm has insufficient liquidity to meet short-term requirements (i.e., current liabilities cannot be covered by liquid assets).
- *The current ratio* – the ratio of the book value of current assets to current liabilities. Again, a value of less than one indicates insufficient liquidity to meet short-term requirements. This measure is less favored than the quick ratio for capturing liquidity since some current assets might be illiquid.
- *The debt-to-equity ratio* – although this is not a direct liquidity measure (unlike the quick ratio and the current ratio), it captures the fact that a higher amount of debt implies a more onerous burden of servicing that debt, as seen from the perspective of the firm's equity. A high debt-to-equity ratio can indicate a potential liquidity risk, because if the firm becomes financially distressed, it may not be able to pay its high

repayment obligations to debtors. However, a very low debt-to-equity ratio can imply a different issue – the firm may be over reliant on funding itself through equity, which can be inefficient and expensive.

- *Interest coverage ratio* – the ratio of a firm's total earnings before interest and taxes to its total interest expenses on debt. As with the debt-to-equity ratio, it is an indirect liquidity risk measure and a low value implies that a firm could struggle to pay the interest costs on its debt if revenues fall in the future.

5.1.2 Bank funding liquidity measures

Measuring a bank's aggregate liquidity entails modelling each of the assets and liabilities that make up the bank's balance sheet. Each asset or liability has a cash flow impact associated with it—origination, purchase, dividends, coupons, interest, default and redemption, or sales. Some assets and liabilities lend themselves to quantitative modeling while others are more difficult to capture this way.

A bank will typically model its liquidity requirements using a liquidity ladder, which is a statement of cash flow sources and uses and is employed in active liquidity management. A typical liquidity ladder would cover a few months, but some firms also evaluate longer-term liquidity ladders to identify weaknesses in their liquidity structure.

A simple liquidity ladder for a bank one day in the future is shown in **Figure 9.**

Day 1		
Sources of Cash	**Uses of Cash**	**Net Cash Requirement**
Maturing assets	Maturing contractual liabilities	
Interest receivable	Interest payable	
Asset sales	Deposit runoffs	
Bank's drawdown on credit lines	Customer drawdown of bank lines	
Total sources	**Total uses**	**Net = Sources minus Uses**

Figure 9: The Liquidity Ladder. Source: *Asset and Liability Management*, Global Association of Risk Professionals, 2020, Figure 3.3.

The liquidity ladder looks at the timing and the direction of cash flows, with the one-day ladder considering contractual payment dates of assets and liabilities, and also incorporating the clearing and settlement features of the bank's assets and liabilities. The sale of an asset today, for example, would typically lead to a cash settlement in the next 2-3 days. If the bank needs the proceeds of the sale to meet an obligation today, it would likely end up defaulting. If the bank discovers its one-day liquidity gap is negative, it can try to shift some of its assets into overnight loans, but this may be difficult if the assets are illiquid, or the settlements are delayed. Therefore, banks manage their liquidity ladders by looking several days into the future. Wherever net liquidity is negative, the bank can work to shift its assets and liabilities to fill the funding gap.

Banks also perform probabilistic analysis on their assets and liabilities to determine the likely and worst-case cash requirements. While they do not necessarily hold enough cash to cover the worst possible liquidity projections, they should have credit lines large enough to cover the contingency of higher-than-expected liquidity demands. Like market and credit risk models, probabilistic models of liquidity must consider the features of the assets and liabilities and understand their actual and potential liquidity interactions to determine overall liquidity requirements.

5.2 Managing Liquidity Risk

Liquidity risk management requires a detailed contingency plan with both contracted and uncontracted liquidity provisions. Contracted liquidity includes changing asset and liability structures to ensure that liquidity is available when needed. It also incorporates credit lines set up by the firm to cover surprise liquidity requirements. Uncontracted provisions include contingency plans developed by the company to address liquidity shortfalls.

Under normal circumstances, liquidity can typically be managed by shifting assets and liabilities, obtaining interbank loans, and drawing down credit lines. The most common methods to increase liquidity in stressed conditions include:

- Issuing securities such as bonds
- Obtaining interbank or government loans
- Obtaining additional credit lines
- Selling or securitizing assets

The cash proceeds from these types of actions will increase liquidity unless the cash is invested in illiquid assets, or assets that then decline in value or fail, perhaps as part of a market-wide downturn.

If a firm has pre-agreed access to a line of credit, this can be used to cover some unexpected short-term liquidity needs. Such external financing facilities reduce liquidity risk more when the firm:

- Relies less on the facilities during standard times
- Has a maturity profile of debts such that sources of financing do not require rollover at the same time
- Has multiple lenders to whom it can turn
- Has a solid and stable relationship with its lenders
- Has confidence that funding will remain available even in crisis conditions

5.2.1 Cash Flow Forecasting

Even when a firm is highly profitable, it will encounter severe difficulties if it cannot meet its obligations to service debts and pay employees, suppliers, and taxes. Consequently, producing timely and accurate cash flow forecasts is essential. To that end, there are several measures of operating cash flow:

- The total value of net retained cash, defined as cash after dividends and owner withdrawals
- The total value of uncommitted funds, defined as retained cash balances after allowing for working capital requirements and capital expenditures
- The ratio of debts to gross cash flows, which measures how many years of current cash flows would be needed to cover all outstanding debts

Cash flow forecasts form an integral part of a firm's yearly operating budget and are communicated to the firm's senior management. If cash flow forecasts are generated frequently, they can be compared with actual cash holdings subsequently, as a "backtest" of the accuracy of those predictions. If there are inaccuracies, then remedial action can be taken so that the forecast precision will improve over time. Crisis plans can also be developed to handle unanticipated cash shortages in the firm.

5.2.2 Basel III Liquidity Measures

In 2008, the Basel Committee on Banking Supervision (BCBS) published a document entitled "Principles for Sound Liquidity Risk Management and Supervision" as the foundation for its bank liquidity management framework. In that document, the BCBS identifies six operational elements that require management on an intraday basis:

- Capacity to measure in- and outflows and anticipate their timing
- Capability to monitor liquidity positions against expectations
- Acquisition of intraday funds
- Ability to manage and mobilize collateral
- Capacity to manage the timings of inflows and outflows
- Preparedness to deal with disruptions to liquidity flows

The BCBS produced a white paper at the end of 2009 explaining best practices for liquidity management in banks and in the Basel III proposal of 2010, it confirmed two measures for liquidity risk management: the **Liquidity Coverage Ratio (LCR**), a short-term liquidity measure, and the **Net Stable Funding Ratio (NSFR)**, a longer-term measure. The LCR is defined as the stock of high-quality assets divided by the bank's total net cash outflows over the next 30 days. High-quality assets are those that are deemed to be sufficiently liquid even during times of stress. The NSFR is the ratio of the available amount of stable funding divided by the required amount of stable funding. The objective is to maximize the amount of available funding while minimizing the amount of required financing. The objective of both measures is to support insights on liquidity that will help ensure a bank's survival, should it come under funding pressure, in the short term or the long term.

6 Operational Risk

Operational risk is the potential loss resulting from inadequate or failed processes or systems related to the everyday operations of the firm. Five categories of operational risk encompass most events that may occur: internal process risk, people risk, systems risk, external risk, and legal risk.

Internal process risk is the potential loss due to the failure of a firm's prescribed procedures and policies, which the staff employ in the company's day-to-day operations. These include the checks and controls required to ensure that customers receive appropriate levels of service and that the organization operates within the laws and regulations governing its activities. Examples of internal process risk include:

- *Lack of controls* – failure to audit recorded transactions in and among the firm's accounts and customers' accounts
- *Marketing errors* – the firm represents that a good or service includes specific features that, in reality, are not offered
- *Money laundering* – engaging in transactions that conceal where money is coming from, where the money is going, or whose money it is
- *Documentation or reporting failures* – inaccurate or incorrect reports submitted to regulators or other governmental agencies
- *Transaction error* – mistakes in data entry or transaction process related to financial amounts, transaction dates, parties to the transaction, or other clerical errors

- *Internal fraud* – intentional behavior on the part of employees to enrich themselves at the expense of the customers, clients, or the firm itself

Errors may occur when a process is unnecessarily complicated, disorganized, or easily circumvented, all of which are signs of inefficient business practices. Reviewing and improving a firm's internal processes to improve operational risk management can enhance operating efficiency and overall profitability. Similarly, reviewing and enhancing auditing procedures can reduce internal process risk.

People risk, the potential loss due to employees of an organization, is a common source of operational risk and may occur due to any of the following scenarios: high staff turnover, poor management practice, inadequate staff training, or overreliance on key staff, for example. People risk can lead to other sources of risk, such as internal process risk and systems risk, particularly around cybersecurity.

Systems risk is associated with the use of computer hardware and software and computer systems, where technology-related risk events include:

- *Data corruption* – an electrical surge or other physical problem alters data
- *Inadequate project control* – a failure to plan properly could affect the quality of information produced by a computer system
- *Programming errors* – computer models can be programmed with flaws that will cause the program to fail, or to generate inaccurate results
- *System unsuitability* –system hardware might not be sufficient to handle high traffic volumes, and crashes or provides inaccurate results
- *Overreliance on "black box" technology* – users may believe that the computer system's internal mathematical models are correct, without back-testing and stress-testing the system adequately
- *Service interruptions* – a computer failure resulting from a technical malfunction or cyberattack
- *System security problems* – systems are compromised by computer viruses or other types of hacking; an increasingly problematic and costly issue in risk management
- *Cybercrime* – an adjunct to system security, cybercrime can take many forms, from denial-of-service attacks and malware to identity or information theft, industrial espionage, money laundering, and financial fraud

In theory, the failure of a firm's technology could lead to a catastrophic event, even its collapse, particularly in the case of banks. Many firms, therefore, have invested heavily to ensure that their operations can continue after technology failure events. This process is called continuity planning or business resumption planning.

External (event) risk is associated with events occurring beyond a firm's direct control and include natural disasters, climate change, wars, terrorist attacks, pandemics, riots, and civil protests. External risk events are generally rare, but when they occur, they can affect a company's operations significantly, which may result in difficulties and intense media coverage.

Legal risk is associated with the uncertainty of legal actions or the application or interpretation of contracts, laws, or regulations. Legal risk varies greatly from country to country. In some cases, legal risk results from unclearly stated laws, leading to a murky legal interpretation. From a global viewpoint, legal risk has evolved in complex ways with the passage of anti-money-laundering, antiterrorism, and customer data protection regulations worldwide.

In addition to the main five categories of operational risk, others are also worth mentioning:

- *Business risk* – the potential loss due to weakening of a firm's competitive position
- *Strategic risk* – the potential loss due to flawed business decisions, or poor execution of business decisions
- *Reputational or headline risk* – the potential loss due to a decrease in a company's standing in public opinion

It is unusual for a major event to occur due to a single control failure. To understand its operational risk profile, a firm should identify risks that may occur due to multiple control failures in the form of:

- *Cascading events* – the failure of a control leads directly to the failure of another control;
- *Escalating failures* – the failure of a second control exacerbates the impact of the control failure of the first.

6.1 Operational Risk Measurement

Firms adopt many different techniques to identify the risks within their businesses. These include the use of:

- Process mapping and building flow charts
- Existing business experience
- Analysis of existing records and data (e.g., loss data)
- Brainstorming
- Scenario analysis
- Systems engineering techniques
- Risk and Control Self Assessments (RCSA)

The techniques used will depend on the nature of the activities under review, types of risk, the organizational context, and the objectives of the risk-management function.

6.1.1 Operational Risk Assessments

Once operational risks and their associated controls are identified, it is important to assess the current level of controls, identify any weaknesses, and understand the likelihood of an event occurring. This assessment involves rating the risk and the control using a scoring system. An objective-based scoring process should identify:

- *Likelihood* – the frequency of occurrence with existing controls
- *Impact* – the potential financial losses, regulatory sanctions, impact on shareholder value, and impact on the firm's reputation
- *Risk Score* – the product of likelihood and impact
- *Current Exposure Level* – the quality of the existing controls and mitigation

Establishing the risk score helps the organization prioritize its operational risk-management efforts. Operational loss events are commonly classified by the frequency with which they occur, as well as the severity of the potential loss. As illustrated in **Figure 10**, operational risk management practices focus on two general loss types: loss events that

occur often, but with low impact or severity (high- frequency/low-impact events); and loss events that occur infrequently, but with high impact (low-frequency/high-impact events). **Figure 10** suggests that operational risk management should strive to ensure that high-frequency operational risk events are very low-severity events and that high-severity events are very low-frequency events. The worst outcomes would arise from events with both high frequency and high impact, so risk managers should strive to shift the curve inward following the arrows.

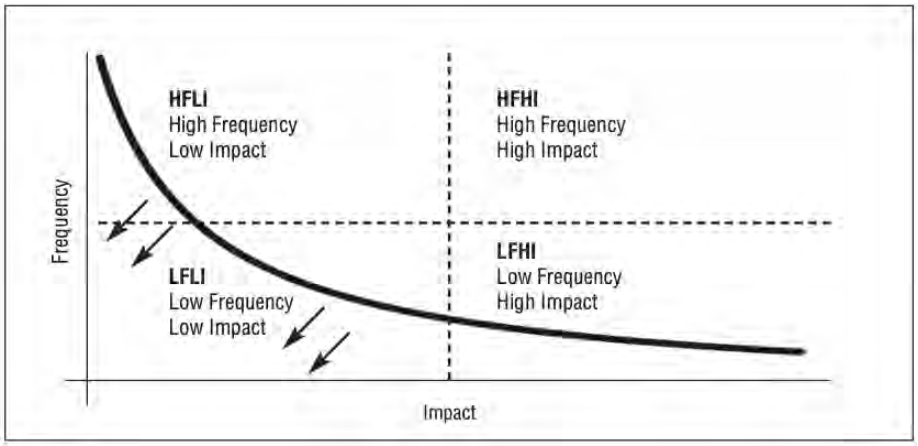

Figure 10: Loss Impact and Frequency Chart of Operational Risk Events. Source: Apostolik, R. and Donohue, C. (2019) *Foundations of Financial Risk*, John Wiley & Sons, New Jersey, Figure 7.2.

6.1.2 Risk Registers

When identifying operational risks, there are three "classes" of risk that a firm should consider:

- *Inherent risks* – risks that exist in a business in the absence of any action to control or mitigate the circumstances
- *Residual risk* – the risk that remains once a control has been implemented
- *Secondary risk* – risk that is a direct result of the control implemented to mitigate the risk

Once these three sets of risks have been identified, they need to be recorded to enable assessment, measurement, mitigation, and reporting. A firm uses a risk register, which is a repository of all risks identified within the company and is used throughout the risk-management process. The risk register is a dynamic management tool and should be updated on an ongoing basis.

6.1.3 Expected and Unexpected Losses

When an operational risk event occurs, losses may be either direct or indirect. Direct losses result from the risk event itself, whereas indirect losses result from other events triggered by the original event's occurrence. Indirect losses are far more difficult to quantify than direct losses. It is important to remember that not all events result in a loss, as although controls have failed, the firm may experience no loss or even make a profit. The possibility of near misses and gain events should be considered in the assessment process.

Unexpected losses are significantly above the level accepted as expected losses. These are the losses resulting from unforeseen or extreme events that, although unlikely, a firm believes could occur. Rather than losses experienced as part of everyday business, they are losses from events with a very low probability of occurring (i.e., low-frequency/high-impact events as described in 5.1.1 and illustrated in **Figure 10**).

A firm may rely on internal loss data, as is typical for expected loss estimation, when modeling unexpected losses. Unexpected losses, however, may result from events that have never been experienced by the firm and, hence, would not be reflected in its internal data. To estimate unexpected losses, therefore, a firm may use a combination of internal data, external data from similar firms, and data from operational risk scenarios.

Operational Risk Loss Data

Many firms have found that collecting and analyzing operational risk events or loss data provides valuable insight into the current operational risk exposure of the firm. In addition to the events that have occurred within a firm, the operational risk group will look at events that have happened outside the company, including those taking place at other firms in the same industry. These events can offer valuable insight into the operational risks faced by the firm and may also provide input into operational risk capital calculations.

External events are useful in many areas of the firm's operational risk framework. They can help inform the risk and control self-assessment activities, they can provide sample input for scenario analysis, and they might be used to develop key risk indicators that monitor the changing business environment. It is unlikely that a firm will have internal historical loss data for every possible operational risk event, particularly when considering low-frequency/high-impact events. When estimating unexpected losses, it is probable that the company will have little or no data on extreme events on which to base its predictions. To calculate unexpected losses that include potential events, and not just those the firm has already experienced, risk managers can supplement the internal data with relevant external data.

External events are a valuable source of operational risk information on an individual event basis, and as a benchmarking tool. Comparing internal loss patterns to external loss patterns can provide insight into whether the losses in the firm reflect the usual losses within its industry. External events are usually of real interest to senior management, who might not immediately associate events that are in the news with operational risk that applies either directly or indirectly to the firm. Therefore, external data are critical in developing an operational risk culture and awareness, as they underscore the importance of effective operational risk management and mitigation practices.

Scenario Analysis

Scenario analysis is used to derive reasoned assessments of plausible severe losses. The appraisals are then used to explore "what-if" cases that may be beyond the current experience of the firm. External data play a crucial role in scenario analysis, as they provide insight into what has already occurred in other firms. Scenario analysis also considers events that might not have happened at any firm yet.

Different methods will produce different outputs, but scenario analysis aims to create reasoned assessments of plausible severe losses, so outputs need to support that goal. Scenario analysis methods can produce an average loss estimate, a worst-case loss estimate, range of loss estimates, and frequency estimates for each type of loss. While designed to produce fat-tail estimates, scenario analysis can also be used to identify key mitigation activities that can be undertaken to reduce the risks identified in the process.

6.2 Managing Operational Risk: Governance, Risk, and Compliance

Integrating all operational risk-related activities is often referred to as Governance, Risk, and Compliance (GRC) or convergence. This integration relates to activities that are part of the operational risk framework and activities that

exist outside that framework, but are also related to operational risk, such as business continuity planning, information security, compliance desk reviews, legal event tracking, audit reports, and regulatory compliance.

The typical operational risk management process can be split into five fundamental steps, as illustrated in **Figure 11:**

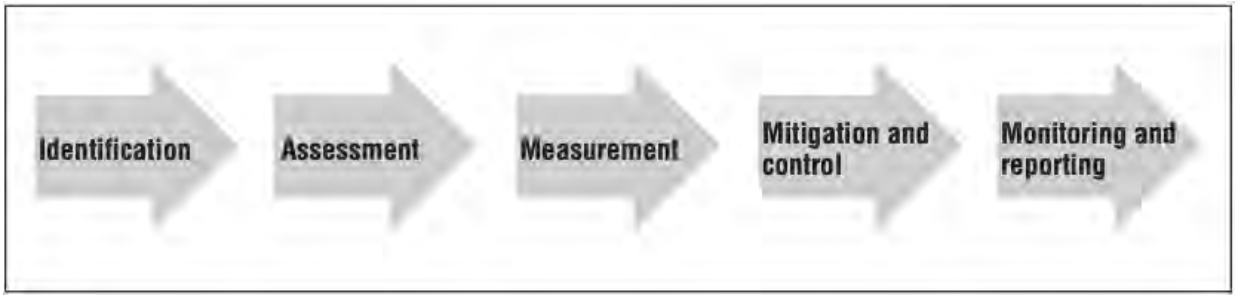

Figure 11: Steps in the Operational Risk Management Process. Source: Apostolik, R. and Donohue, C. (2019) Foundations of Financial Risk, John Wiley & Sons, New Jersey, Figure 7.3.

The objective of risk mitigation and control is to minimize the frequency and impact of a risk event. There are many techniques that a firm can use to mitigate and control risks, although making a system or process wholly secure and free from operational risk is, in business terms, virtually impossible. Mitigation techniques can be aimed at preventing an event from occurring (proactive) or reducing the impact of an event (reactive).

One mitigation technique is to take out operational risk insurance, which can cover a specific individual, or job function. Most large corporations, including banks, commonly take out director's and officer's liability insurance. These policies are designed to protect directors and board members from shareholder or class action lawsuits. They can be structured to indemnify the director, or the corporation, or both. It should be noted that there is a residual risk when buying insurance, namely the credit risk of the insurance company itself.

7 Enterprise-wide Risk Management

Companies have come to recognize the importance of conducting risk management at the firm level, known as enterprise-wide risk management (ERM), where an organization manages all risks on a firm-wide basis across types of risk, locations, and business lines. This will improve coordination, enhance the quality of decision-making, and ensure that resources are directed to the units where they will have the most significant impact on the firm's performance. Conducting ERM effectively requires senior management to take a holistic view of risk, and explicitly consider how the various categories of risk are interrelated. The relationship among these risks is illustrated in **Figure 12.**

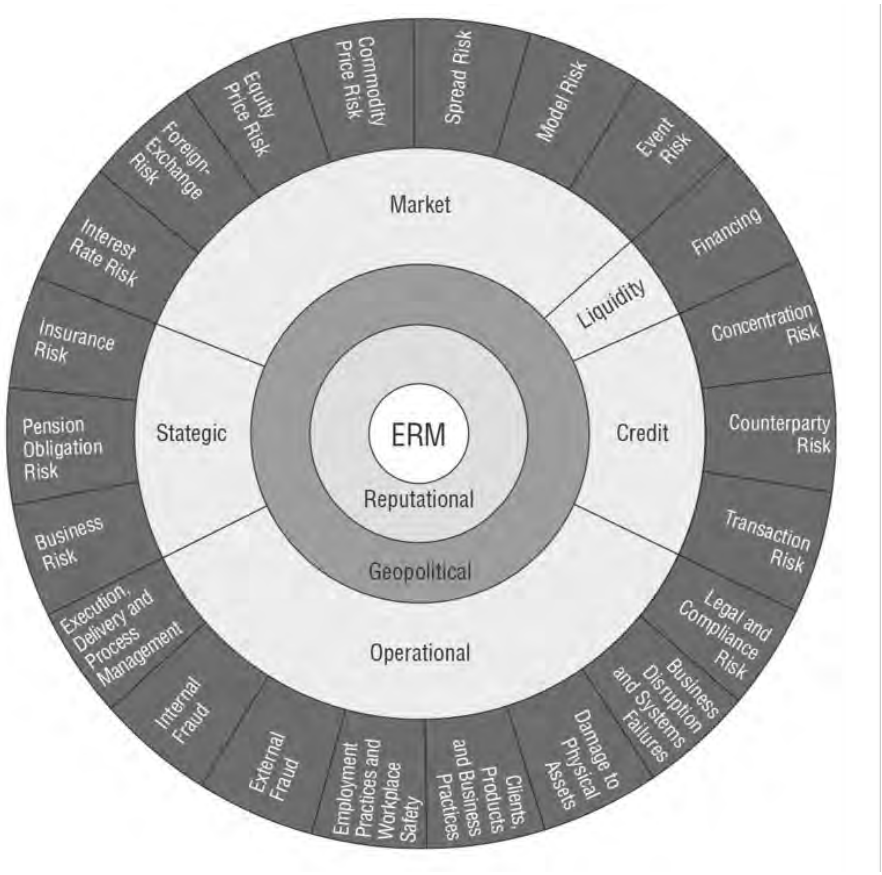

Figure 12: The ERM Wheel. Source: *Operational Risk Management* Financial Risk and Regulation Series, Global Association of Risk Professionals (2020), John Wiley & Sons, New Jersey, Figure 1.1.

This ERM wheel provides a way to show the interrelatedness of different types of risk and demonstrate that certain core risks can affect all of a firm's activities. Reputational risk can arise from any individual type of risk event and is located at the center of the circle. Similarly, geopolitical risks, such as major international conflicts, could cause increases in all major classes of financial risk.

A firm faces a significant challenge in attempting to identify these inherent risks because operational risk:

- Is prevalent throughout the whole of the business;
- Crosses many different business disciplines and technical areas;
- Is made up of many diverse categories of risk, each with its own characteristics.

Consequently, any framework for managing operational risk must account for this business-wide challenge. There are two main approaches to building an enterprise-wide risk profile:

- Establish a general enterprise-level risk assessment and then refine it by appraising the key processes identified during the first stage (top-down)
- Assess all processes within each business unit and combine the information produced, usually through a risk management committee, to generate an enterprise-wide risk profile (bottom-up)

Whichever approach is adopted, it must be consistent and appropriate to the risk profile of the firm and the size, sophistication, nature, and complexity of its activities.

A key component of ERM is for the organization to establish a centralized data warehouse that stores quantitative and qualitative information relating to all the major risks that the firm faces. The risks inherent in each line of business or unit need to be measured consistently and then aggregated across the entire company. A major benefit of ERM is that it involves sharing timely information across divisions within the firm, so that each can operate while being cognizant of what others are doing and aware of the effect their decisions could have on the organization. This coordination also facilitates the observation of interactions between different kinds of risks.

7.1 Risk Appetite Statements

Risk appetite statements (RASs) are documents that describe the organization's attitude to risk and how much it is willing to take, being mindful of the regulatory environment in which it operates, its strategic objectives, and the extent to which taking risks will support or detract from these objectives. The RAS will be established by the board of directors and tailored to the firm, providing a means through which it can facilitate ERM and communicate the desired risk culture throughout the organization. The RAS will take a long-term perspective, including a high-level description of the firm's activities and an explicit declaration of how much risk the firm is willing to take, as well as articulating the primary sources of risk, how it will avoid any intolerable risks and manage tolerable risks. Some firms elect to make their RAS publicly available, whereas others are more concerned with the confidential nature of the information it contains. The RAS should be stable but updated frequently as the organization and its external environment evolve.[8]

7.2 Climate Risks

The weight of scientific evidence strongly supports the assertion that climate change is occurring and profoundly affecting ecosystems and quality of life, causing extreme weather events to occur more frequently than in the past. Firms are being pushed to reduce their own climate effects and protect their balance sheets and profitability from climate risk. Climate-related risks are separated into two major categories:

Physical risks – the impacts on people and economies of the physical manifestations of climate risk, including intense heatwaves, forest fires, floods, droughts, and rising sea levels

Transition risks – the impacts that could result from the transition to lower carbon emissions, including policy changes, reputational impacts, technological innovations or limitations, and shifts in market preferences and social norms.

Transition risk involves substantial changes in public policy and regulation, as well as modifications in patterns of demand for products and services away from those that governments or consumers perceive as causing environmental damage. This can lead to considerable changes in the values of certain types of assets and liabilities.

Scenario analysis can consider the potential effects of both physical and transition risk, although quantifying the economic and financial impacts of ecological changes and modeling future policy paths, as well as societal and individual behaviors, is not straightforward. There may be direct effects, such as the closure of coal-fired power stations, or indirect effects, such as increased energy prices for consumers or supply constraints due to coal-fired power plants shutting down, for example.

[8] Recent examples of publicly available risk appetite statements include: The Office of the Comptroller of the Treasury (OCC – United States), https://www.occ.gov/publications-and-resources/publications/banker-education/files/pub-risk-appetite-statement.pdf and The Nordic Investment Bank, https://www.nib.int/files/93baa38195f247179b5c242bdec55c157b4288d5/risk-appetite-statement-june-2022.pdf.

Measuring the likelihood and severity of climate related risks is particularly challenging. Climate change and the potential failure to deal with it adequately in the eyes of stakeholders and the media is a potential reputational risk. Climate change may also manifest itself as a direct financial risk that can affect conventional risk classes (known as “transverse risk"), including:

- *Regulatory risk* – where regulators may impose increasingly onerous informational or operating requirements on firms, or may enforce penalties when firms failed to disclose climate-related risks
- *Market risk* – where the values of assets held are affected by climate events, or shifts in demand due to perceptions of products' harmful effects on the environment. Examples include oil companies and food producers
- *Credit risk* – where firms that might be borrowers could experience financial distress due to significant increases in their cost bases from having to comply with environmental legislation or deep declines in demand for their products as a result of their perceived contribution to climate change
- *Operational risk* – where firms experience an increased likelihood of a flood or power outage in their offices due to climate events
- *Legal risk* – where firms accused of causing environmental damage are sued by parties who allege that they have been affected

Firms seeking to manage their exposure to climate change risk should:

- Ensure that the financial and non-financial risks from climate change are assessed and discussed at the board level and are incorporated in the firm’s risk management processes;
- Incorporate climate risks into the RAS;
- Specify the individuals within each function or unit who are responsible for identifying, measuring, and monitoring climate risks;
- Review the range of products and financing offered to determine appropriateness;
- Explain how significant risks will be managed;
- Develop metrics to evaluate how successful climate-risk controls or mitigations have been.

7.3 Risk Governance

Corporate governance refers to the structures and processes that a firm puts in place to ensure that it operates effectively and complies with its legal and regulatory requirements to the benefit of both the firm and its wider stakeholders. Prudent management is a function of the firm's corporate governance and reflects the risk-management culture promoted by the firm's board of directors and its operational structure.

Although the structure of a company’s corporate governance will vary depending on its host country’s legal system, business customs, and the historical development of the organization, there are generally accepted governance concepts and ideas that have been shown to support an adequately functioning governance system:

- Setting the firm's overall strategic direction, including establishing its risk-tolerance levels
- Advising on recruitment and human resources (HR); overseeing, guiding, and reviewing the performance of senior management; and setting the level of senior management compensation
- Monitoring the firm’s performance and reviewing regular financial and risk reports
- Being qualified, both personally and professionally, to act as directors with integrity and in the interest of shareholders

- Meeting regularly with senior management and internal auditors to establish and approve policies
- Reviewing the reporting lines, authority, and responsibilities of the firm's senior management

Figure 13 lists the techniques typically adopted by a bank to implement good corporate governance.

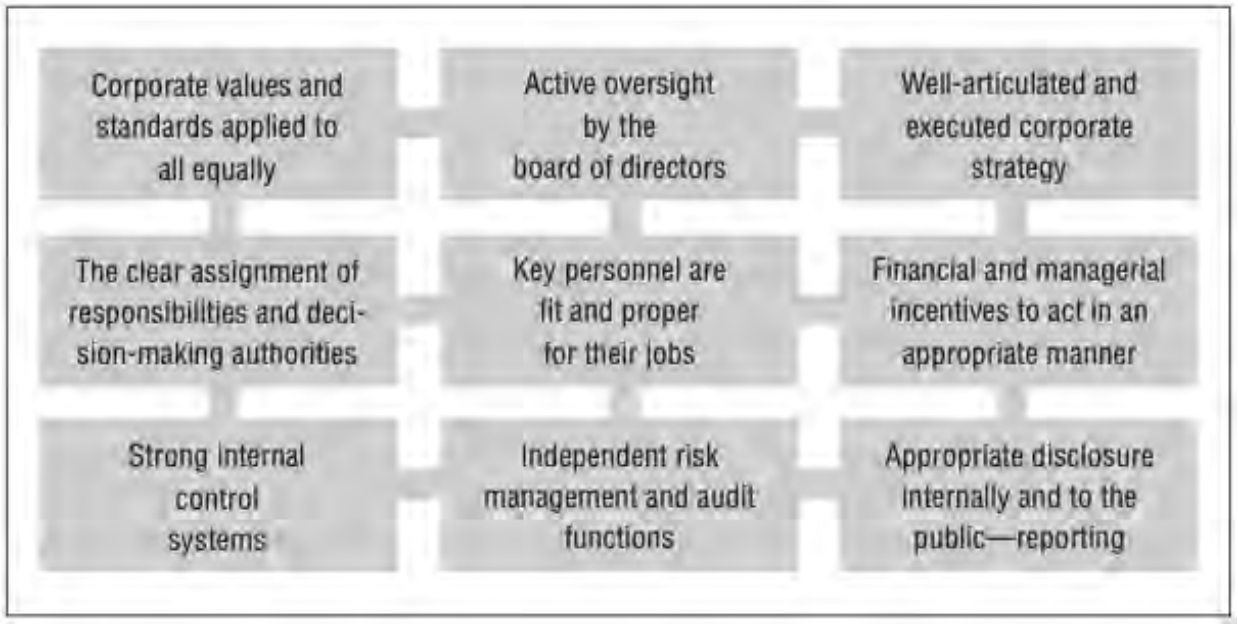

Figure 13: Corporate Governance Techniques (Source: Apostolik, R. and Donohue, C. (2019) *Foundations of Financial Risk*, John Wiley & Sons, New Jersey, Figure 2.19).

A commonly adopted model for risk-management governance is the "three lines of defense" model, which includes business-line management (first line), an independent risk-management function (second line), and an independent audit function to review and challenge (third line). All staff within a firm have a share in managing risk effectively, and this model helps clarify responsibilities, which enables all involved in managing risk to understand how they fit into the overall risk and control structure. Irrespective of a firm's size, complexity, and risk profile, the three lines of defense model provides a simple and effective way to communicate risk-management responsibilities and clarify essential roles and duties.

It is also vital for a firm to have a robust corporate culture. By establishing a corporate culture, the organization will be able to conduct its business according to clearly defined values. The company should also apply its values to all areas, including the board of directors. The board of directors must develop a compensation policy that reflects the firm's culture, objectives, strategy, and control environment and set the compensation for senior management and other key personnel. Any such compensation scheme should not create undesired incentives through an imbalance between risks and rewards, as it is important to align pay and bonus structures with long-term risk management. Internal and external auditors validate the information senior management provides to the board of directors, regulators, and the public, and both sets of auditors play a central role in corporate governance.

The board of directors will delegate much of the day-to-day responsibility for managing a firm's various sources of risk to a risk-management function. This team will be responsible for establishing and maintaining a robust set of policies and processes that safeguard the firm against credit, market, operational, liquidity, and other financial risks. This will, in turn, protect the firm's customers, creditors, investors, and other stakeholders.

8 Conclusion

Risk management is a critical component of everyday operations and long-term strategy for all types of firms. The main risk types—credit risk, market risk, liquidity risk, and operational risk—are ever-present, but also evolving within firms, markets, and the macro environment. To navigate the risk landscape effectively, corporate managers and executives must build risk awareness and capacity within their companies, promoting principles of strong governance and evaluating existing and emerging risks holistically. For those who are interested in a potential career in this field, GARP's Financial Risk Manager (FRM) certification program offers a deeper look at the essential areas of risk management theory and practice: https://www.garp.org/frm .

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