THE FUNDAMENTALS OF RISK MEASUREMENT

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PREFACE

Over the last decade, the understanding of risk measurement has become increasingly important as most international banks have adopted Value-at-Risk, economic capital, and risk-adjusted return on capital (RAROC) to control and price their risks. They use these tools to find the loans, trades, and deals that are most profitable, leaving the unprofitable ones for their less sophisticated competitors. The understanding of risk measurement is therefore vital to those who want to manage a bank safely and profitably.

The importance of these risk measurement tools has been greatly magnified by regulators, such as the Federal Reserve and the Bank of England, who plan to start using these concepts to calculate the minimum amount of capital that banks must hold. For competitive and regulatory reasons, it is now necessary for all banks to have a sound risk-measurement framework.

This book was written to address the growing need for easy-to-understand information about how banks can apply effective risk measurement techniques. The goals of this book are the following:

- Provide quick access to the whys and hows of risk measurement.
- Provide easy-to-understand information, including equations and examples, that can be quickly applied to most risk measurement problems.
- Provide information about how risk measurement is used in the management of risk and profitability.

This is a textbook to teach you how to measure risk. The book assumes that you have a general background in science, economics, or finance, and now have a need to quickly understand the field of financial risk analysis. Alternatively you may already have a good understanding of one area of risk but now seek to have an integrated understanding across all types.

The book is deliberately compact so it can be read and understood quickly. It includes background chapters for those unfamiliar with finance and statistics, and includes descriptions of the many techniques that are commonly used in risk measurement. It applies these techniques to the four major risks faced by banks: market risk, credit risk, asset liability mismatch, and operating risk.

The book begins with chapters describing how banks make, and often lose, money. It then describes the two fundamental building blocks of integrated risk measurement: economic capital and RAROC. Chapter 3 reviews the statistical relationships that are commonly used in risk measurement and provides reference material for the rest of the book. It is useful for those readers who do not have a recent working knowledge of statistics.

Market risks arise when the perceived value of an investment falls and is most closely associated with trading operations. The measurement of market risks is covered in Chapters 4 to 11. Chapter 4 gives an overview of the main traded instruments and how they can be valued. This chapter is useful for those readers who are new to the finance industry.

Chapter 5 describes the most common ways to measure market risks: sensitivity analysis (including duration and the Greeks), stress testing, scenario testing, the Sharpe ratio and Value at Risk (VaR). It gives detailed examples using each of the metrics. Of these metrics, VaR has become the standard approach for measuring market risk. Chapter 6 is devoted to explaining the details of the three common approaches to calculating VaR: parametric VaR, historical VaR, and Monte Carlo VaR. We work through increasingly complex examples and compare the strengths of each approach. In

Chapter 7 the VaR contribution methodology is used to pinpoint the source of a portfolio's risk.

Regulators allow banks to use their VaR caculators to set the amount of capital that they hold against market risks. Chapter 8 discusses the procedures required by regulators to test VaR calculators, and Chapter 9 shows how VaR can be used to calculate the economic capital for market risks. Chapter 9 also extends VaR to measure the risk of asset management operations.

Although VaR is the best single metric for market risks, it has several limitations. These limitations, and typical solutions, are discussed in Chapter 10. In Chapter 11 the market risk section concludes by describing how the results of risk measurement are used in risk management, including the procedure for setting VaR limits.

Chapter 12 introduces asset liability management (ALM). ALM is primarily concerned with the interest rate and liquidity risks that are created when commercial banks take in short-term deposits from customers and give out long-term loans. Chapter 12 describes how those risks arise and the risk characteristics of different types of deposits and loans.

The measurement of interest rate risk and liquidity risk for ALM is discussed in Chapters 13 and 14, including gap reports, rate shift scenarios, simulations, and models of customer behaviour.

Chapter 15 uses the ALM concepts to explain funds transfer pricing. This is one of the keys to integrated risk measurement and is a crucial component in measuring risk-adjusted profitability and setting prices to customers. A typical balance sheet is used to illustrate in detail how transfer pricing works.

Credit risk is the possibility of losses due to a counterparty or customer failing to make promised payments. It is covered in Chapters 16 to 23. Chapter 16 discusses the sources of credit risk and how measurement can be used to manage the risks. For readers who are unfamiliar with lending operation Chapter 17 discusses the ways that credit exposures are structured in commercial and retail lending. I also describes the calculation of credit exposure for derivatives trading operations and gives an introduction to credit derivatives. Chapter 18 shows how the expected loss and unexpected loss for a single loan can be calculated from the probability of default, loss in the event of default, exposure at default and the grade migration matrix. These are the basic building blocks for both economic capital and the New Capital Accords from the Basel Committee.

Chapter 19 discusses the techniques that are used to estimate values for probability of default, loss given default, and exposure at default, including discriminant analysis and the Merton model. It also gives parameter values that can be used as the basis for the reader's own models. The parameter values are used in examples to demonstrate how the credit risk calculations are used.

Chapters 20 and 21 describe the common methods used to estimate the overall risk for a portfolio, including the covariance approach, the actuarial model, the Merton-based simulation model, the macro economic default model, and the macro economic cash-flow model are used for structured and project finance. The chapters also discuss the different approaches available for estimating default correlations and how the correlations can be used to estimate the unexpected loss contribution and the economic capital for a single facility within a portfolio. The chapters conclude with a section describing how the different models can be combined in a unified framework to create an integrated simulation of all the bank's risks.

The results for the credit portfolio models are used in Chapter 22 to give risk adjusted performanc and pricing for loans. This chapter shows how to calculate the minimum price that should be charged to a loan customer. The analysis also shows how to include multiyear effects such as grade migration Chapter 23 explains the New Capital Accords being introduced by the Basel Committee on Banking

Supervision. This chapter summarizes the history of the Capital Accords, explains Tier I and Tier II capital, and details the three alternative capital calculations that will be allowed under the new accords. The chapter discusses the advantages and disadvantages of adopting each approach and the steps that a bank must take to comply with the new requirements.

Chapter 24 gives an introduction to the different types of operating risk and the approaches being developed to manage and measure these risks. The approaches are categorized as either qualitative, structural, or actuarial. Each approach is described, including key risk indicators and the approaches suggested in the Basel Accords.

The final chapter returns to the bank level and describes how all the models can be linked together to calculate economic capital and risk-adjusted profitability for the bank as a whole, including alternative methods for calculating inter-risk diversification. It concludes with the steps normally required to implement the bankwide measurement of economic capital and RAROC.

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THE FUNDAMENTALS OF RISK MEASUREMENT

CHAPTER 1
The Basics of Risk Management

INTRODUCTION

Banks make money in one of two ways: providing services to customers and taking risks. For example, retail banks take in customers' deposits and provide them with the services of check clearance and safe storage. Retail banks also take risks by giving out personal loans and taking the ri that some of the loans may not be repaid. The bank is willing to take that risk if it is able to charge th customers a high rate of interest.

In this book we address the business of making money by taking risk. In general, if a bank takes more risk it can expect to make more money, but greater risk also increases the danger that the bank could lose badly and be forced out of business. Banks must run their operations with two goals in mind: to generate profit and to stay in business. Banks therefore try to ensure that their risk taking is informed and prudent. The control of that gambling is the business of risk management. The primary function of risk management is to ensure that the total risk being taken is matched to the bank's capacity for absorbing losses in case things go wrong. A second reason for understanding risk is to help the CEO direct the scarce resource of capital to the opportunities that are expected to create the maximum return with the minimum risk.

Proper risk management is essential for bank survival, and it enables management to allocate resources to various risk units based on a trade-off between risk and revenue potential. These risk-management decisions should be supported by quantitative risk measurement. Risk measurement attempts to answer the following four questions:

- How much could we lose?
- Can we absorb a significant loss without going bankrupt?
- Is the return high enough for us to take that risk?
- How can we reduce the risk without significantly reducing the return?

The goal of this book is to provide a detailed guide to the modern techniques for quantifying risk within a bank.

Before going into the mathematics of risk, it is very useful to have an idea of how banks are organized, how they make money, and especially how they can lose money. This chapter therefore describes bank operations and the way that risks are managed at the highest levels of the bank.

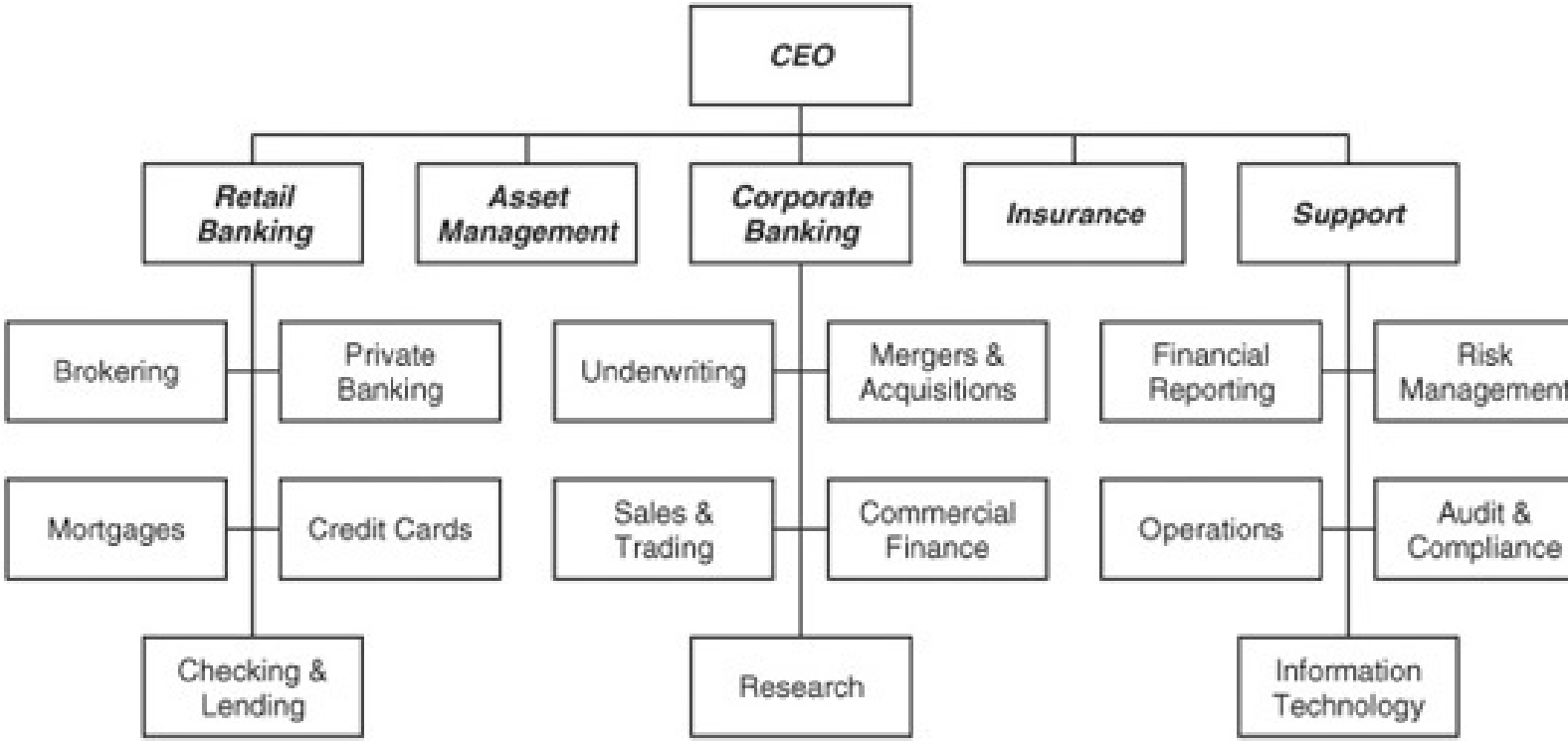
THE ORGANIZATIONAL STRUCTURE OF A TYPICAL BANK AND HOW EACH UNIT GENERATES REVENUE

Large, international banks are typically organized into five divisions: corporate banking, retail banking, asset management, insurance, and support. Figure 1-1 shows the typical organization of a universal bank.

The corporate banking division deals with other financial institutions and corporate clients such as large, industrial corporations. There are typically five primary groups: underwriting, mergers and acquisitions, sales and trading, commercial lending, and research.

The underwriting group creates new securities, such as stocks and bonds. For example, if a corporation wanted to raise money, it could go to a bank and ask it to underwrite an issuance of bond The bank would structure the bond contract then give the corporation cash. The bank would then sell the bonds to investors, and the corporation would be responsible for making the required payments o the bonds. The bank can make money as a fee from the corporation for structuring the contracts and can also make money by selling the bonds for a higher price than the amount given to the corporation There is also a risk that the bank could lose money if the value of the bonds falls significantly before the bank can sell them.

FIGURE 1-1 Typical Organization of a Universal Bank



The above graphic details the organizational structure of a universal bank. Note that the majority of the book will focus on risk-management techniques for the corporate and retail banking divisions of the bank.

The mergers and acquisitions (M&A) group advises corporations on how they can structure the finances of merged companies so as to minimize the funding cost and maximize the tax credits. The M&A group typically receives a fee from the client and uses some of the services of the underwriting group.

The sales and trading group sells securities to investors, trades securities with other banks, and manages the bank's asset and liability mismatch. As we will see, most of the bank's market risk resides in the sales and trading group. Within the trading group there is also the funding desk, which borrows and lends funds with other financial institutions whenever the bank has an overall deficit or surplus of funds.

The commercial finance group provides structured products to corporations, including loans. It als advises companies on their financial structures. For example, if a company wanted to fund a new venture, the commercial finance group would advise it on whether to use debt or equity to raise money. The group makes money largely by lending money to corporations at a moderately high interest rate. Due to the risk of default, a large portion of the credit risk in a bank arises from loans given by the commercial finance group.

The research group produces economic and company-specific reports that are used by the sales an trading group, used by the brokerage group, and sold to clients of the bank.

The retail division deals with the mass of personal customers. The main function is to take deposi from customers in the form of checking accounts, savings, and fixed deposits, then lend funds to othe customers in the form of mortgages, credit cards, and personal loans. The division makes a profit by giving low interest rates to depositors and charging high interest rates to borrowers. This profit pays for the cost of processing all the accounts and should cover losses from defaults on loans.

Private banking and brokerage services may also be in the retail division, or they may be in the corporate division. Private banking provides tailored loans and investment to high-net-worth individuals. The brokerage group allows individuals access to the sales and trading group so that for fee they can trade their securities.

The asset management division administers funds such as mutual funds or unit trusts in which individuals can invest. The asset management division is managing money that belongs not to the bank, but rather to the individuals or institutions. Therefore, if the value of the assets falls, the bank does not lose money directly, but may lose money in the form of reduced fee income.

Some banks also have an insurance division. The insurance division takes fees (or premiums) fron its clients and promises to pay the clients if a specific incident happens. To be sure of having enough money to make the required payments, the insurance group holds a large amount of capital in the for of investments in securities such as stocks and bonds. The lines of business include property and casualty insurance, life insurance, and carefully tailored commercial insurance.

The support division has the crucial task of making sure everything works for the other divisions. The operations group ensures that all payments are processed, received, and recorded correctly. Audi and compliance ensures that all the policies and procedures are being followed, and also ensures that the bank complies with all government regulations. The financial reporting group produces information on the profit, loss, and the current amount of assets and liabilities. The risk management group also resides within the support division, where it can be independent from the groups that are taking the risks.

HOW BANKS CAN LOSE MONEY

In the section above we noted that banks often hope to make money by taking risks. However, banks can, and often do, lose money when they take these risks. Banking risks can be put in three categories market risk, credit risk, and operating risk. Examples of losses occur daily and even hourly. To give a intuitive understanding of how money is lost, consider the following sample of case studies.

Market Risk

Market risk arises from the possibility of losses resulting from unfavorable market movements. It is the risk of losing money because the perceived value of an instrument has changed: for example, whe investors are no longer willing to pay such a high price for a stock.

The classic market-risk example comes from losses in the stock market:

- The Nasdaq stock index lost 65% between March 2000 and March 2001.
- The Dow Jones index lost 31% in one week in 1987, 23% on Black Monday, October 19.
- The Dow Jones index lost 89% between 1929–1932, and it did not recover until 1954.

In each of these crises, banks made losses, and some went bankrupt. The ones who made the least

losses were those who realized that they were vulnerable and reduced their positions before the crisis. For example, when Chase realized that it was overexposed to Russia at the beginning of 1998, it started to shed its Russian holdings; it was then able to carry on business as usual during the ensuing crisis as Russia defaulted.

On the other hand, Long Term Capital Management (LTCM) was a hedge fund that had bet heavily that any Russian default would have a correlated currency devaluation, which LTCM could use as a hedge. The default happened but the devaluation did not. The result was that LTCM lost $3 billion and was taken over.

Losses can also occur due to long-term market trends.

- In the 1980s many U.S. savings and loans (S&L) institutions went bankrupt because they had been lending out long-term fixed-rate mortgages and borrowing short-term deposits. This strategy was safe while interest rates were stable, but rates suddenly rose in the 1980s. The S&Ls were then left receiving low interest-payments from long-term mortgages but paying high interest rates to get deposits. After a few years of paying more than they received, many of these institutions went bankrupt. The management of these long-term interest-rate risks is typically called asset liability management (ALM).

Credit Risk

Credit risk arises from defaults, when an individual, company, or government fails to honor a promise to make a payment. There is a gray area between market risk and credit risk. The price of corporate bonds fluctuates relative to treasury bonds due to the market's perception of the probability of a corporate default. The aspect of risk before the default happens, is generally considered to be market risk. The actual default is considered credit risk.

Credit risk arises in many forms. The most obvious form is default on a loan, i.e., failure to repay an amount that has been lent. The same risk occurs when the issuer of a bond fails to make the payments promised by the bond. More subtle forms of credit risk arise in trading operations. *Counterparty risk* refers to the possibility that a trading counterparty will fail to pay if it loses money on a deal. *Settlement risk* occurs if a bank fails to settle its side of a trade; this is also known as *Herstatt risk*, after the famous default described below.

Loan Credit Risk

- In January of 1999, Guangdong International Trust and Investment Corporation defaulted on the repayment of $4.5 billion, half of which was owed to overseas banks.
- In August of 1999, Iridium, the satellite telecommunications company, defaulted on two syndicated loans of $1.5 billion that it had borrowed to launch the satellites but could not repay due to unexpectedly low earnings.

Issuer Credit Risk

- On August 17, 1998, Russia unilaterally rescheduled repayments on $43 billion of bonds that had been sold to western banks and investors. The investors eventually recovered only a fraction of the $43 billion.
- In February of 2001, PG&E, a Californian electric utility, defaulted on $726 million of short-term bonds that it had issued. However, its default was selective, and it continued to pay interest on $8 billion of other debt.

Counterparty Credit Risk

- In 1998, the Moscow Interbank Currency Exchange and several Russian banks defaulted on currency derivatives with Credit Suisse First Boston (CSFB). The exchange rate had moved such that the banks owed $600 million to CSFB.

Settlement Credit Risk

- In 1974, a small German bank, Bankhaus Herstatt, had a string of losses in foreign exchange dealings. It went bankrupt at the end of a trading day in Germany. Because it was the end of the trading day in Germany, it had already received $620 million worth of FX payments from its U.S trading counterparties, but because the U.S. markets were still open, Herstatt had not yet been required to deliver $620 million for its side of the trades. At the time that it went bankrupt, it stopped all payments, and the U.S. banks lost virtually all of the $620 million.

Operating Risk

Operating risk encompasses all the other ways in which banks can lose money. The Basel Committee on Banking defines *operational risk* as "the risk of direct or indirect losses resulting from inadequate or failed internal processes, people and systems or from external events." Operating risk includes fraud and the possibility of a mistake being made.

- A U.S. government bond trader at the New York branch of a Japanese bank was able to switch securities out of customers' accounts to cover trading losses, which mounted to over $1 billion over 10 years.
- In 1997, NatWest lost $127 million and had to greatly reduce its trading operations because its options traders had been using the wrong data for implied volatility in their pricing models, and were therefore taking risks that they did not see.

Blends of Risks

Often banks will lose money from an incident that involves several forms of risk. This is well-illustrated in the collapse of Barings bank.

- Nick Leeson was a trader in the Singapore branch of Barings bank. He had seemingly generated 20% of Barings' profits in 1994. In fact, he had been making losses and hiding them in a fictitiou account. To recover the losses he tried a large, risky gamble with derivatives on the Nikkei 225. I 1995, he lost $1 billion and wiped out Barings' capital. He was able to hide the original losses because he was in charge of both trading and accounting in the Singapore office. He was able to take the final gamble because senior management had no effective measurement of the risks bein taken.

Banks try to minimize their losses by managing risk at three levels: at the transaction level, the business-unit level, and the corporate level. Most of this book will concern risk management and measurement at the transaction and business-unit levels. We will first look at the management and measurement of trading risks, followed by sections on asset/liability management, credit risk, and operating risk. Finally, we will show how each of the bank's risks can be brought together to estimate the total risk for the bank.

We will often refer to the contribution that the transaction or unit is making to the bank's overall risk. The next section will therefore describe the management of risk at the highest corporate levels and discuss the macro objectives of risk management.

MANAGING RISK AT THE MACRO LEVEL

Ultimately, risk, and all other bank functions, are overseen by the bank's board of directors. The boa is urged to take risk by the shareholders who want high returns. Balancing the shareholders, the boar is limited in its risk taking by debt holders, rating agencies, regulators, and the bank's own desire to stay in business. The result can be seen as a constrained maximization in which the institution is allowed to take a limited amount of risk and tries to maximize the returns on that risk.

The board oversees three key risk-management functions: deciding the target debt rating, determining the amount of available capital, and allocating risk limits to each business unit within th bank.

Determining the Target Debt Rating

The debt rating is a measure of the bank's creditworthiness and corresponds to the bank's probability of default. A high debt rating corresponds to a low probability of default. The bank's creditworthines is determined by the amount of risks it takes compared to the amount of capital held. *Capital* is the difference in value between the bank's assets and liabilities. It can be viewed as the current net worth of the bank.

If the bank has a small amount of capital and takes a large amount of risk, there is a high probability that the losses will be greater than the capital, and the bank will go bankrupt. If the bank wants a high rating, it must hold a large amount of capital in relation to its risks.

Although the board sets the credit-rating goal, the actual ratings are granted by independent agencies that use quantitative and qualitative tools to assess a bank's strengths. These agencies include Standard & Poor's (S&P), Moody's, and Fitch.

A low target debt rating has the advantage that the bank can take on many risks and expect to earn high rate of return for the shareholders. However, a low debt rating means that debt holders will charge higher interest rates to lend to the more risky bank.

The debt rating is also important to the bank's customers. For example, retail customers do not want to give their savings to a bank that is likely to go bankrupt. Similarly, corporations who are considering buying derivatives want to modify their market-risk positions and do not want to be exposed to the credit risk of a lowly rated counterparty. Therefore, corporations buying derivatives would not deal with lowly rated banks.

The highest S&P rating is "AAA," most international banks are rated "AA," and national and regional banks tend to be rated "A" or "BBB."

Once the board has decided the target debt rating, it must align the risks that it allows the bank to take with the amount of capital available.

Determining the Amount of Available Capital

In this discussion we will refer to liabilities, debt, assets, and shares. Readers unfamiliar with these concepts should refer to the appendix to this chapter. The *available capital* is the current value of the assets minus the current value of the liabilities. If all the assets and liabilities are traded, their values are simply the prices at which they trade. However, many assets such as personal loans are not frequently traded. Management must then determine a reasonable value for the assets. This is done b taking the nominal value of the assets and subtracting specific and general provisions. The *nominal value* is the total amount owed to the bank. The *specific provisions* is the amount that is expected to b

unpaid by customers who are already in financial trouble. The *general provisions* is the amount that i expected to be unpaid by other customers who get in trouble over the next year. The *capital* is then th nominal amount, minus the provisions, minus the expected value of the liabilities:

Capital = Nominal Asset Value – Provisions – Liabilities

If the board wishes to increase the capital quickly, it can do so by issuing more bank shares. This giv the bank more cash without increasing the liabilities that must be paid to avoid default. Alternatively the capital can be increased over several years by retaining earnings and not paying dividends to shareholders.

Allocating Risk Limits

Once the target debt rating is set and the amount of available capital has been calculated, the bank's total risk capacity is fixed. Conceptually, the relationship can be simplified to the following equation

Risk Capacity = Probability of Default x Available Capital

The board then decides how to allocate the total risk capacity to the different business units, e.g., trading, credit cards, and corporate lending. In doing this it must consider the expected return from each unit and the diversification of the risk between units. We will deal extensively with diversification later. In general, the board will allocate most of the risk capacity to the units that are expected to make the highest returns. The risk capacity is allocated by giving each business unit a limit on the amount of risk it can take. This limit may be in terms of risk capital or in more familiar terms, such as the total amount of loans it can give.

Having allocated a block of capital to a business unit, the board will expect the unit to make a profit on the risks it takes. The target rate of profit is called the *hurdle rate*.

These policy decisions are typically made by the board on an annual or quarterly basis. The day-to day management of risk is delegated to the CEO, the chief risk officer, and the risk management group, who create risk reports and advise the board and the business units as to how they can maximize the bank's return with a limited amount of risk.

Importantly, for the risk-management function to be credible to shareholders, regulators, and seni management, it must be independent of line management interference. For example, risk managers should not report to the heads of the business units who are taking the risks, because in some circumstances, they may be tempted to "massage" the numbers to make the profitability of their own business units look good. Instead, risk managers should report to senior executives, such as CEOs and CFOs, who will recognize and reward accurate reporting.

SUMMARY

This chapter has given a qualitative overview of how banks make money and how they manage the risk of losing money. In the next chapter, we will start to build the quantitative framework of risk measurement.

APPENDIX: DEFINITION OF ASSETS, LIABILITIES, AND SHARES

Liabilities

In general, the term *liabilites* refers to all transactions for which the bank owes money to another

party, however in common usage, the term liabilities may not include the equity owed to the shareholders, and would therefore only include the debt.

The debt may be in the form of bonds that the bank issues for itself, it may be in the form of loans given to the bank by other banks, or it may be in the form of deposits taken from corporations and retail customers. Debt holders expect to be paid a relatively small interest rate, but they also expect t get back the full amount of the principle that they lent to the bank.

Assets

Banks use the money that they have raised from debt and shares to buy assets. Generally, *assets* are any securities or transactions for which the bank is owed money by another party. The assets may, fo example, be loans that they grant or equities they buy. In granting a loan, the bank gives cash to an individual or corporation. In return, the individual or corporation commits to making a series of futu payments to the bank. This commitment of future payments is an asset to the bank, and a liability to the individual or corporation.

Shares and Equity

The *shareholders* are the owners of the bank and expect to get a share in the profits after the debt is paid. Most of the bank's profit and loss is reflected in the return that the shareholders receive. If the bank is profitable, it will pay dividends to the shareholders; if it is unprofitable, the shareholders wil lose the money that they invested when they bought shares in the bank. Shares are also called *equitie* The value of the equity is close to the net value of the bank, i.e., the assets minus the liabilities. The net value of the bank is also called *capital*. There are several definitions for different types of capital depending on how the value of the assets and liabilities are measured; therefore, it is not always true that the equity equals the capital, but often the terms are used interchangeably.

CHAPTER 2

Risk Measurement at the Corporate Level: Economic Capital and RAROC

INTRODUCTION

This chapter discusses two concepts that will be used throughout this book and that are critical to the integrated measurement of risk: economic capital and risk-adjusted return on capital (RAROC). Economic capital gives us a common framework for quantifying the risk arising from many diverse sources. It also allows us to calculate the amount of equity capital that the bank should hold. RAROC has become the industry's standard way of measuring risk-adjusted profitability. It allows us to compare the profitability of different transactions. A variation on RAROC is shareholder value added (SVA), which we will describe at the end of the chapter. As an introduction to economic capital, let u first look more closely at the relationship between capital, risk, and the probability of default.

CAPITAL, RISK, AND THE PROBABILITY OF DEFAULT

The difference between the value of assets minus the value of liabilities is called capital. While the concept of assets and liabilities is fairly straightforward, the real-life interplay between the two is somewhat complex, as the value of each can change daily. This affects available capital, which impacts the bank's ability to pay its debts. There is therefore a tight relationship between the amount of capital a bank holds, the amount of risk it takes, and the probability of the bank's defaulting. Let u illustrate this with an example.

Illustration of the Relationship between Capital, Risk, and Default

Consider setting up a new bank. You get $5 million of capital from investors who want a share of the profits (shareholders). You borrow $95 million of debt from people who want a relatively safe return on their money (e.g., savings accounts, banks, or corporations with spare cash). You promise to pay back the $95 million in one year, plus 5% interest. You then buy $100 million of corporate bonds fro companies like IBM or British Airways. These companies promise to pay you back $106 million in one year's time. These bonds are the assets of the bank. If none of the companies default, then in one year you will receive $106 million. You will then pay $99.8 million to the debt holders and pay $6.2 million to the shareholders. This gives a 25% return on equity (ROE) to the shareholders, which is a reasonable profit.

However, what happens if some of the bond issuers default on their promises? If at the end of the year 4% of the bonds default (with no recoveries) then the bond portfolio will pay only $102 million. The debt holders still get $99.8 million, but the shareholders absorb the loss, getting only $2.2 millio If at the end of the year the losses are even worse, and 8% of the bonds have defaulted, the bonds wil be worth $98 million. This forces the bank to default on its obligation to the debt holders and only give them $98 million instead of the $99.8 million that they were promised. In this case, the bank go out of business and the shareholders get nothing. These three possible outcomes are given in Table 2-1. The columns give the initial amount of assets, debt, and equity at the beginning of the year, and th amount at the end of the year, under the three different scenarios. The bottom row shows the return o equity, which is calculated by the following formula:

$$\text{ROE} = \frac{\text{Final Equity} - \text{Initial Equity}}{\text{Initial Equity}}$$

Now let us consider the same situation with the same assets but assuming that the bank had been set up with 10% equity at the start of the year and only 90% debt. Now there is a much better chance that the remaining assets will be sufficient to pay back the debt. The results in Table 2-2 show that under the three scenarios the percentage return on equity is lower because the profits are diluted amongst $10 of shareholders rather than $5. But with $10 of initial capital, even in the worst case, at the end of the year the asset value is greater than the debt, and the bank does not fail.

TABLE 2-1 Capital Example: Basecase Results

Basecase	Initial	End of the year		
Default Rate		0%	4%	8%
Assets	$100.0	$106.0	$101.8	$97.5
Debt	$95.0	$99.8	$99.8	$97.5
Equity	$5.0	$6.3	$2.0	$ –
ROE		25%	–60%	–100%

This table shows the interplay between capital, risk, and the probability of default, demonstrating the close relationship between each variable.

TABLE 2-2 Capital Example: Results with Extra Capital

High Capital	Initial	End of the year		
Default Rate		0%	4%	8%
Assets	$100.0	$106.0	$101.8	$97.5
Debt	$90.0	$94.5	$94.5	$94.5
Equity	$10.0	$11.5	$7.3	$3.0
ROE		15%	−27%	−70%

This table shows that holding more equity increases the chances that the remaining assets will be sufficient to pay back the remaining debt.

Finally, consider the original case with 5% of equity, but with assets whose values could drop muc further.[1] In this case let us say that up to 16% of the assets could default. Table 2-3 shows that for the same amount of capital, higher uncertainty in the asset value increases the probability of defaulting o the debt. In this case, the bank fails in two out of the three cases.

In the example above there were three scenarios for asset value. As a step closer to reality, let us now assume that there are ten possible scenarios and that each one could

TABLE 2-3 Capital Example: Results with Extra Risk

High Capital	Initial	End of the year		
Default Rate		0%	8%	16%
Assets	$100.0	$106.0	$97.5	$89.0
Debt	$95.0	$99.8	$97.5	$89.0
Equity	$5.0	$6.3	$ –	$ –
ROE		25%	–100%	–100%

This table demonstrates that with the same amount of capital, an increase in the uncertain
in the asset value increases the default probability.

TABLE 2-4 Results of 10 Possible Credit-Loss Scenarios

Scenario	Asset Value
1	96.5
2	98.4
3	100.6
4	101.7
5	102.3
6	103.2
7	103.9
8	104.4
9	104.7
10	105.2

occur with equal probability. The results are shown in Table 2-4 and plotted in the histogram of Figu
2-1. The histogram gives us a crude indication of the probability distribution for the asset value. For
example, it shows us that there is a 20% chance that the asset value will be less than $100.

FIGURE 2-1 Histogram of 10 Credit-Loss Scenarios