



CORPORATE METRICS

The Benchmark for
Corporate Risk Management

Technical Document

CorporateMetrics™ Technical Document

The development of CorporateMetrics™

The CorporateMetrics™ framework, LongRun data sets, and CorporateManager™ software were created by the RiskMetrics Group in conjunction with a variety of different groups within J.P. Morgan, including risk management services, corporate finance, advisory, foreign exchange, and capital markets.

All historical market and macroeconomic data used in the production of long-term market forecasts and scenarios according to the RiskMetrics Group's LongRun methodology are provided by Reuters.

CorporateMetrics™

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Introduction

Market risk management: The corporate perspective

Many companies have expressed an interest in understanding how the principles of Value-at-Risk, which were initially developed for managing market risk in a financial environment, can be applied in the corporate environment. In our discussions with corporate clients, they have raised a number of issues about implementing a strategic risk management program within their companies. This document outlines a framework we have entitled *CorporateMetrics*[™] that addresses the unique market risk management needs of corporations as follows:

- **Market risk versus business risk:** Risk management in the corporate environment is inherently more complex than in a pure financial environment (i.e., trading and investment functions) in that companies have both non-hedgeable business risks (relating to the nature of their specific products and services) and hedgeable market risks (e.g., commodity, currency, interest rate, equity exposures). The level of market risks is furthermore a function of business risks, which can make the implementation of a risk management system a complex process. This document proposes an analytical framework for identifying the market risks inherent in the business activities of corporates by integrating risk measurement into the budgeting and planning process.
- **Financial results and firm value:** Whereas financial managers (e.g., trader, portfolio manager, treasurer) tend to manage the value of their assets and liabilities, corporate managers tend to focus more on the level, growth, and, increasingly, the volatility of corporate financial results such as earnings and cash flow as benchmarks for good performance. In this document, we propose a re-characterization of Value-at-Risk concepts from a financial environment to an earnings and cashflow environment. We also discuss the implications of managing earnings volatility for the valuation of the company.
- **Short-term versus long-term management cycle:** Compared to financial institutions, which may actively take short-term risk positions to generate trading profits, corporates are generally less sensitive to daily fluctuations in the market and focus more on monthly and quarterly earnings volatility when measuring performance. We discuss the issues relating to a shift from managing daily market volatility to a longer management cycle.
- **Capital:** In a number of industries, there is growing interest in assessing the level of capital to sustain risk-generating activities and relating the cost of capital to the riskiness of business activities and projects. The risk measures proposed in this document can provide insights into capital-related decisions.
- **Derivative disclosure requirements:** Not only are shareholders and investors more interested in understanding the dynamics of earnings risk and the company's risk management philosophy, but the Securities and Exchange Commission (SEC) and the Financial Accounting Standards Board (FASB) have issued a set of requirements to regulate how companies are to disclose both the level and the effectiveness of their risk management programs. In this document, we propose a methodology that can be used to help address some of these requirements.

What is CorporateMetrics?

CorporateMetrics is a conceptual framework for measuring market risk in the corporate environment. CorporateMetrics has five basic components:

- A set of corporate-oriented definitions for risk measures, which are outlined in this document.
- A set of market risk measurement methodologies, outlined in this document.
- Data sets and methodologies for forecasting market rates and prices over long horizons. The data and methodologies are outlined in a companion publication, the *LongRun Technical Document (LongRun)*.
- A Web site containing historical data, stress scenarios, long-horizon forecasts, and methodology discussion that can be accessed at <http://www.riskmetrics.com>.
- *CorporateManager* risk calculation and reporting software designed, developed, and supported by the RiskMetrics Group. The Windows[®]-based software applies the risk measurement methodologies set forth in this publication and the data methodologies outlined in *LongRun*.

With the help of this publication and the associated line of products, companies should be in a position to estimate the impact of market risk on corporate earnings and cash flows.

How are CorporateMetrics and RiskMetrics related?

Both RiskMetrics and CorporateMetrics are methodologies for measuring the potential impact of market rate changes on financial results. In the case of RiskMetrics, the focus is on potential changes in the market values of portfolios of financial instruments over time horizons of one day and one month. In the case of CorporateMetrics, the focus is on the potential impact of market rate changes on a company's financial results relative to the results targeted for a particular period (e.g., uncertainty in meeting next quarter's targeted earnings). The time horizon over which financial results can be affected tend to be longer, ranging from 2 months to 24 months or beyond, necessitating techniques for characterizing potential market rate volatility over long horizons.

An overview of the CorporateMetrics approach

In the corporate environment, uncertainty in future earnings and cash flow is caused not only by uncertainty in a company's underlying business (e.g., sales volumes), but also by a number of other risks, including market risk. Market risk can arise from a number of factors, including foreign exchange exposures, interest rate exposures, commodity price-sensitive revenues or expenses, pension liabilities, and stock option plans. CorporateMetrics, which focuses on market risk, provides a framework centered on the key financial results that corporations monitor. While many companies already perform specific sensitivity analyses to forecast the impact on financial results of specific market moves, CorporateMetrics outlines a methodology for a more complete analysis of market risk, taking into account a full range of probability-weighted market outcomes as well as the integration of market risks across different markets—commodities, foreign exchange, interest rates, and equities.

- CorporateMetrics provides *definitions* for risk measures that quantify the impact of market risk on earnings and cash flow to promote a common language for communicating about market risk.

- CorporateMetrics reviews the key considerations in mapping the relationship between changes in market rates and their effect on financial results, a process we refer to as *exposure mapping*.
- CorporateMetrics and *LongRun* provide explanations for the different techniques for forecasting market rates and prices over long horizons to generate the scenarios needed for measuring risk. We refer to the procedure as *scenario generation*.
- This document explains how exposure maps and scenarios can be used to generate distributions of financial results using a procedure we refer to as *valuation*.
- From the resulting distributions of earnings or cash flow components, the final step of *risk computation* yields summary market risk measures.

Benefits

We believe corporations can benefit in the following ways by applying CorporateMetrics risk management concepts at the business, senior management, and board of directors levels:

- **Increased transparency of risks:** The formalized quantification of the impact of market rate volatility on a company's financial results should significantly improve the clarity of risk awareness within the organization.
- **Communication:** The risk measures and reporting formats proposed in this document should improve communication not only between Senior Management and the business units that assume risk, but also between senior management, the board of directors, shareholders, ratings agencies, and regulatory bodies.
- **Hedging decisions:** By integrating the analysis of risks for underlying exposures and financial instruments, we believe CorporateMetrics should facilitate the analysis of how risks and expected returns vary for different hedging strategies.
- **Capital allocation and performance evaluation:** By heightening risk awareness, CorporateMetrics provides the basis for evaluating the potential impact of adverse market movements on a firm's capital and the ability to apply variable rate-of-return targets to business or project evaluation based upon risk considerations.
- **Control:** Many companies would like to improve the control procedures for ensuring that their exposures to financial markets remain within prudent limits. The Earnings-at-Risk framework described could be the basis for implementing effective policies, developing information to help control and reduce earnings volatility, and establishing a limit structure.

The conceptual framework provided in this document is intended as a basis for discussion of corporate-wide risk management issues. This is a rapidly evolving area of research, and we view this publication as a document that will also evolve over time. We welcome all suggestions and comments, and invite companies to visit our Web site at <http://www.riskmetrics.com> for the latest updates to our research and data.

What CorporateMetrics is not

Currently, the CorporateMetrics framework specifically addresses firmwide market risk. CorporateMetrics does not address other risk types such as credit and operating risks. In the future, as we further develop measures for risk management, we will update the CorporateMetrics approach.

As described above, we have focused upon providing clearly defined risk measures and methodology guidelines for market risk measurement. Since the way in which financial results are projected depends on **firm-specific** accounting standards and exposure mapping assumptions, CorporateMetrics does **not** advocate any specific set of accounting standards or approaches to modeling corporate exposures. Our aim is to discuss the implications of various approaches and their potential impact on financial results to provide greater clarity to the risk management process.

How is this document organized?

The *CorporateMetrics Technical Document* has three parts.

Part I, “Risk Measurement Framework,” is for executives, corporate managers, and general practitioners. It introduces the conceptual framework for measuring market risk within the corporation and addresses the issues mentioned above. We illustrate the approach with examples and discuss how the results of the risk measurement process can be practically applied.

Part II, “Framework Components,” will be useful for readers who will be involved with the implementation of a market risk measurement framework. It covers the technical aspects of identifying and modeling exposures, the alternative approaches for scenario generation, and calculating risk measures.

Part III, “Examples and Backtesting,” is intended for the general practitioner. It provides analytical examples of how risk measures can be calculated, using typical corporate exposures as the basis for illustration. In addition, it discusses how the risk measurement process can be evaluated to ensure that the risk measures are adequately quantifying market risk.

For whom is this book intended?

We developed CorporateMetrics to provide a broadly applicable framework for the corporate community. We hope the concepts outlined will be useful to companies as they further develop their risk management practices. Within an organization, the following individuals should find this document useful:

- **Senior management**—This would include chief executive officers, chief financial officers, heads of planning, and treasurers. For those responsible for deciding upon an appropriate risk management framework for a company, the discussion in Part I of this document highlights a number of important issues that may help the decision process.
- **Planning and budgeting staff**—In many organizations, the planning department develops projections for a variety of different business outcomes and market conditions. This document provides an approach for measuring market risk across markets and for a full spectrum of scenarios, rather than just for a few specific downside scenarios. A balanced approach should enable companies to incorporate within their plans a more complete assessment of the market risks being taken in the course of their business.
- **Treasury and purchasing staff**—In any given company, the treasury and purchasing departments are usually the units that deal directly with the foreign exchange, interest rate, and commodity risks that the company incurs as part of its business. The CorporateMetrics approach should provide a way for these departments to enhance communication about risk as they work with senior management and the business units to agree upon hedging programs and risk taking/mitigation policies.

Part I
Risk Measurement Framework

Chapter 1.

How can market risk measurement help corporates?

Since the advent of Value-at-Risk (VaR) methodologies for risk measurement, many corporations have shown interest in the general approach. While VaR was first applied in the 1990s by financial institutions to measure the potential effect of market risk on the market value of portfolios of financial instruments, a number of companies have been interested in applying VaR concepts in the corporate environment.

By *corporate environment*, we are referring to a setting that focuses on a company's shareholder value and on key corporate financial results such as earnings and cash flow. This can be contrasted with a *financial environment* wherein the focus is on the market value of portfolios of financial instruments. While the market values of portfolios are of interest to corporations (e.g., the value of cash portfolios and hedge transactions portfolios), they are just a subset of the types of financial results that corporations care about. To corporate managers, financial results such as earnings and cash flow are generally more important since they directly drive shareholder value. While corporate-level analysis naturally applies to non-financial institutions, it can also apply in financial institutions. These enterprises often have fee-based as well as trading business, for which earnings and cashflow-based risk measures can be useful additions to VaR for corporate-level risk management purposes.

The driving force behind corporate interest to better understand and measure market risk originates from several sources:

- The corporate community is becoming increasingly aware of the fact that earnings volatility can affect stock price valuation and shareholder value. Given that market risk is one of the factors contributing to earnings volatility, many companies want to better quantify it.
- The trends toward globalization and increased international trade have led many companies to face greater and more types of market risks.
- Companies need simpler, more transparent risk management methods to handle external factors that can influence their performance.
- Companies need improved exposure and risk-related information to make better hedging decisions.
- Risk management practices are increasingly scrutinized by analysts, investors, and rating agencies.
- Regulatory agencies are requiring certain types of disclosures and computational standards, such as the reporting of VaR-type measures for earnings, cash flow, and fair values.

In summary, as the market becomes more focused on quantifying risk, corporations are moving toward VaR-based methodologies that enable them to measure the potential impact of market risk on the financial results that matter most to them.

1.1 Improved risk measurement facilitates improved risk management

Risk management, broadly speaking, is about identifying, measuring, and managing risks. It is a process that allows companies to increase the clarity of their communication about risks and to more proactively decide on their most appropriate type of risk profile. With a robust approach to market risk measurement, companies are better positioned to address the following risk management issues:

- **Integrating market risks:** In many companies, the management of different market risks may be spread across different departments, such as treasury, purchasing, and business units. Also, the way in which risks are measured may vary by risk type. An integrated approach to risk measurement enables companies to compare different types of risk on a consistent basis.
- **The ability to compare market risks with business risks:** Although market risk measurement is important, we emphasize that business risk remains the key concern for most corporations. For different companies, the relative magnitude of business risk to market risk varies. Risk measurement can help companies assess the relative magnitude of market risks to business risks and to manage the risks accordingly.
- **Managing earnings volatility:** Market risk measures can be used to assess whether market risk represents a factor that could cause a company to miss (i.e., fall short of) its earnings targets. The relative riskiness of hedging to not hedging market exposures can be measured, which enables companies to make informed decisions on a risk/return basis.
- **Preserving margins:** To protect operating margins in an environment of increasingly liberalized international trade, managers require a firm grasp of their cross-border risks. However, the management and preservation of operating margins (e.g., with the use of derivatives and other hedging instruments) has often been hindered by the lack of complete information concerning the aggregate risks to which the company is exposed. A firmwide risk measurement approach can make risks better understood and can be used to quantify how different risks augment or diversify each other.
- **Minimizing the likelihood of market-induced financial distress:** Through effective risk management, companies can hedge against market risks that might otherwise unexpectedly impair cash flow or drain capital. Companies in distress may face downgrades in credit ratings, increased borrowing costs, and other barriers to raising capital. By implementing a program that aims to minimize the risk of insufficient cash flow and financial distress, companies can ensure access to capital and potentially optimize their capital structure by increasing their debt capacity.¹
- **Managing the market risk of anticipated transactions:** With the release of FAS 133, many companies subject to U.S. accounting standards are reviewing the potential effects of hedging anticipated transactions.² An approach for estimating earnings- and cashflow-related risks over long horizons can help companies assess the accounting and economic implications of hedging versus not hedging such exposures.
- **Corporate governance of risk management adequacy:** Due to a number of well-publicized, market-related losses in recent years, the boards of directors of many companies have asked senior management to review their companies' risk management policies and practices, and improve them where necessary. A risk measurement framework provides important information that the boards of directors and senior management can use to assess the appropriateness of a company's risk profile.
- **Improving internal and external communication:** By promoting greater transparency of market risks, corporate managers can improve communication both internally and externally: within the company, with the board of directors, and with analysts, rating agencies, and shareholders. Risk management disclosure can help analysts and investors gain comfort

¹ For a detailed discussion on the elimination of downside risk as a goal for corporate risk management and its implications on capital decisions, see Stulz (1996) and *Corporate Risk Management* (1997, Chapter 2).

² FAS 133 is the Statement of Financial Accounting Standards No. 133, released by the FASB in June 1998.

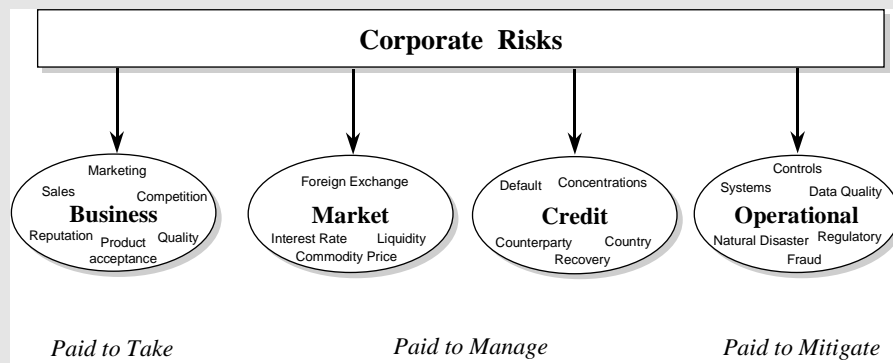
with a company's risk management approach and make more informed assessments about future earnings, earnings volatility, and other market-related risks.

Differentiating between market risk and business risk

A company's financial results can fluctuate because of many different factors, as shown in Chart 1.1.

Chart 1.1

Types of risks in the corporate environment



Business risk and market risk are two key sources of risk that can affect a company's ability to achieve earnings or cashflow targets. While the relative magnitude of business risk to market risk varies across different companies, articulating the approach and policy for managing both types of risks helps set the tone for a company's risk management culture and awareness.

By business risk, we are referring to the uncertainty of future financial results related to the business decisions that companies make and to the business environment in which companies operate. For example, business risk can arise from investment decisions and strategy, product development choices, marketing strategies, competitive pricing issues, and sales volume uncertainty. Largely speaking, these are decisions with inherent long-term, structural risks that companies are "paid to take" in order to generate profits. Companies take business risks in areas within their expertise and, with varying degrees, exert significant influence over potential returns.

In contrast, market risk refers to the uncertainty of future financial results that arises from market rate changes. Market risk can affect a company's business in a variety of ways. For example, operating margins can be eroded because of rising prices of raw materials or depreciating currencies for countries in which a company has foreign sales (*direct market risk impact*). Also, changes in market rates can eventually force companies to adjust the prices of their products or services, which can alter sales volumes or competitiveness depending on the positioning and market exposures of the company's competitors (*indirect impact of market risk on business results*).

Individual companies typically have little if any influence over market rates, though some may have informational insights as a result of the nature of their businesses (e.g., commodity and energy companies) that provide them with a comparative advantage to bear certain market risks. Thus, while some corporates may be "paid to take" market risks, most seek to *manage* the impact of market risk on financial results.

1.2 The trend toward risk-based disclosures

In addition to deriving strategic benefits from risk measurement and management, companies can use their risk measurement systems to generate the kinds of risk reports that regulators are seeking. Disclosure guidelines released by the Securities and Exchange Commission of the U.S. (SEC) in 1997 allow companies to use VaR-type measures to communicate information about market risk. While many companies may be interested in measuring the aggregate market risk of their underlying exposures and hedge instruments for internal purposes, current regulations require only the reporting of market risk sensitive instruments (e.g., derivative contracts). Reporting of underlying exposures and other positions is encouraged, but not required. Whether companies decide to report only the required disclosures or to also include the encouraged disclosures, the systems being used for internal risk measurement can be leveraged to meet regulatory disclosure requirements.

Below, we briefly summarize the SEC guidelines and note our observations about the different alternatives companies have for reporting.

1.2.1 Disclosure requirements

SEC market risk disclosure requirements affect all companies reporting their financial results in the U.S.³ These requirements apply to derivative commodity instruments, derivative financial instruments, and other financial instruments that are sensitive to market risk, all of which are collectively called *market risk sensitive instruments*.⁴

The SEC requires that companies provide both quantitative and qualitative information about the market risk sensitive instruments they are using.⁵ Currently, the allowed alternatives for the reporting of quantitative information include tabular summaries of contract *fair values*, measures of sensitivity to market rate changes, and VaR measures expressing potential loss of earnings, cash flows, or fair values.

1.2.2 Encouraged disclosures

Apart from setting requirements on the market-risk sensitive instruments, the SEC encourages, but does not require, risk disclosures on instruments, positions, and transactions not covered by items 305 and 9A. Such instruments can include physically settled commodity derivatives, commodity positions, cash flows from anticipated transactions, and other financial instruments such as insurance contracts.

1.2.3 Observations

In general, the reporting of the combined market risk of underlying business exposures and market risk sensitive instruments should provide a more accurate portrayal of a firm's total risk profile than reporting for market risk sensitive instruments alone. For example, if a manufacturer uses natural gas and chooses to hedge its estimated energy needs with a forward contract, it can elect to report the combined market risk for both the expected physical purchase of gas and the offsetting forward contract. Since the forward contract in this case represents a hedge of the underlying exposure, the risk of the combined position may be relatively low. The risk of the forward contract on a stand-alone basis would be higher and does not present a complete picture of the company's risks.

³ See Securities and Exchange Commission Item 305 of Regulation S-K and Item 9A of Form 20-F.

⁴ "Other financial instruments" also include investments, loans, structured notes, mortgage-backed securities, indexed debt instruments, interest only and principal only obligations, deposits, and other debt obligations.

⁵ For a description of the required qualitative market risk disclosures, see items 305(b) and 9A(b).

1.3 What types of companies can benefit most from a risk measurement framework?

As we have discussed, the magnitude of market risk to business risk varies across different companies. At one extreme, some companies seek to hedge nearly all of their market risks. For example, a project-oriented company with large capital expenditures may be taking such large business risks that it seeks to shield itself from as many other forms of risk as possible. At the other extreme, some companies actively take market risks. For example, energy and commodity companies may take risk positions by trading commodities. Also, in some companies, the treasury department is a profit center that is authorized to take foreign exchange, interest rate, or other market risks.

In our view, a market risk measurement framework can benefit any company that is exposed to market risk by enhancing communication about risks. In companies where market risk can have a significant impact on financial results, whether through a direct or indirect (e.g., competitive) impact, the benefits of increased clarity and the improved ability to manage risks are probably greatest.

1.4 Summary

In this chapter, we outlined the major factors that have motivated companies to better understand their market risks. By improving the way risk is measured, companies can also improve the way risk is managed, especially by communicating an “official” understanding of risk throughout the organization and implementing strategies that are consistent with their risk preferences and tolerance for earnings volatility. With this in mind, we outline in the following chapters the CorporateMetrics approach to market risk measurement.

Chapter 2. Overview of CorporateMetrics

2.1 What is CorporateMetrics?

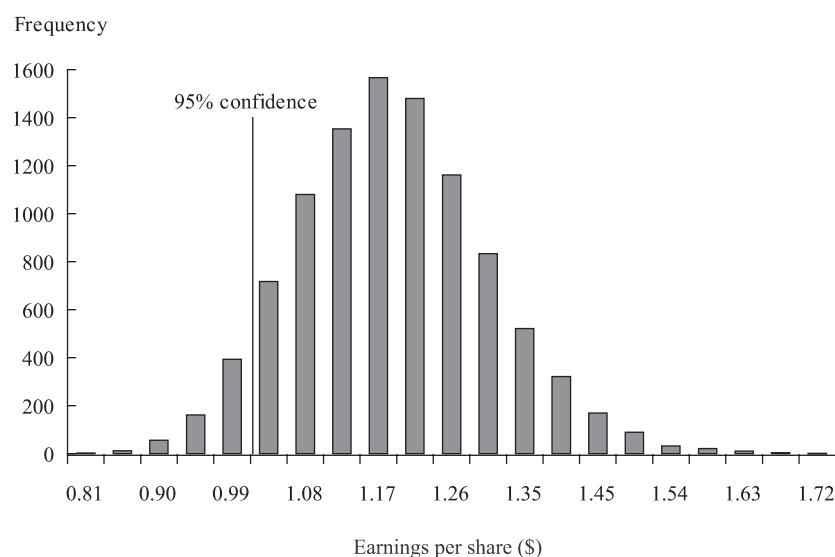
CorporateMetrics is a comprehensive package of definitions, methodologies, data sets, and software for measuring market risk in the corporate environment. In broad terms, CorporateMetrics concentrates on two corporate financial results that affect, and that are commonly used to gauge a company's value — earnings and cash flow. Specifically, CorporateMetrics enables companies to forecast earnings and cash flow for a range of different projected market rates — foreign exchange rates, interest rates, commodity prices, and equity prices.¹ From the resulting range of forecasts, market risk measures can be obtained.

The package is designed to accommodate long-horizon forecasting to coincide with the long-term management cycle that is typical to corporate planning and business management. Furthermore, CorporateMetrics offers a VaR-type of methodology, the principles of which have long been widely used in portfolio risk analysis, where the exposure of financial instruments to market risk is routinely measured. Since VaR measures the uncertainty, or volatility of value regardless of how “value” is defined, it can be easily applied to corporate risk measurement.

A typical result of the CorporateMetrics risk measurement process is shown in Chart 2.1.

Chart 2.1

Distribution of 12-month earnings due to JPY/USD foreign exchange risk
10,000 trials



The distribution shows earnings per share outcomes for the upcoming 12-month period for a Japanese subsidiary of a U.S. company. The subsidiary's earnings are translated to U.S. dollars and each outcome corresponds to a different possible path of JPY/USD over the 12-month period. At 95% confidence, the result is \$0.99 of earnings per share. From the earnings distribution, risk measures such as standard deviation or maximum shortfall relative to target can be calculated.

¹ In this document, we will refer to foreign exchange rates, interest rates, commodity prices, and equity prices generically as *market rates*.

Adapting VaR techniques from a portfolio setting, CorporateMetrics provides a solid base of methods from which to quantify market risk in the corporate environment.

The key features of CorporateMetrics include:

- Definitions of risk measures: Earnings-at-Risk (EaR), Earnings-per-Share-at-Risk (EPSaR), and Cash-Flow-at-Risk (CFaR).
- Methodology guidelines, which explain how to identify and map market-sensitive exposures, and describe the methods available for calculating market risk.
- Data sets and methodologies for long-horizon forecasting (2 to 24 months). The data and methodologies are described in a companion publication, the *LongRun Technical Document* (*LongRun*).
- A Web site containing historical data, stress scenarios, long-horizon forecasts, and methodology discussion that can be accessed at <http://www.riskmetrics.com>.
- *CorporateManager* risk calculation and reporting software designed, developed, and supported by the RiskMetrics Group. The Windows-based software applies the risk measurement methodologies set forth in this publication and the data methodologies outlined in *LongRun*.

2.2 How does CorporateMetrics compare to other market risk management tools?

CorporateMetrics borrows key principles from well-known risk management techniques, such as RiskMetrics and other VaR approaches for portfolios of financial instruments, and adapts them to the corporate environment. It also extends typical corporate practices such as sensitivity analysis by considering risk across a full range of market rate scenarios rather than just in a few selected scenarios.

2.2.1 How is CorporateMetrics related to RiskMetrics?

Both CorporateMetrics and RiskMetrics provide an analytical framework for market risk measurement. However, RiskMetrics is designed for portfolio analysis, while CorporateMetrics handles corporate financial results.

RiskMetrics is used to forecast the potential change in value due to market risk of portfolios of financial instruments such as fixed income securities, foreign exchange, commodities, equities, and their derivatives. The analysis horizon is usually relatively short, ranging from one day to one month. Given its focus on potential changes in portfolio value, VaR is an appropriate measure of risk for portfolio managers who need to estimate potential losses in the portfolio's market value, usually with respect to a market index.

CorporateMetrics, on the other hand, is more appropriate for the corporate environment, given its focus on corporate financial results. It uses performance benchmarks that are based on company-specific internal or equity analyst forecasts and targets rather than directly observable market indices. For corporates, the "neutral" underlying business position is generally exposed to market risk, so that it makes sense to compare the risks across different risk taking/hedging strategies relative to the "neutral" case. Unlike financial instruments, the underlying business exposures that companies have are usually "illiquid" in that they cannot be easily bought and sold. Also, the methodology focuses on financial results, which can be accounted for on a number of different bases, e.g., accrual, fair value or mark-to-market, and hedge accounting.

Although RiskMetrics and CorporateMetrics focus on different measures of value, both frameworks require assumptions for market rate distributions in order to calculate values at a chosen horizon. Given companies' typical forecasting horizons of up to 24 months for budgets and plans, CorporateMetrics requires market rate data for longer horizons than those addressed by RiskMetrics, which provides 1-day and 1-month volatility forecasts.

Table 2.1 compares the risk management approaches used in the financial environment and the corporate environment. As shown, both RiskMetrics and CorporateMetrics address areas such as value measurement, accounting and valuation issues, horizons, and performance benchmarks; however, RiskMetrics is tailored to the financial environment, while CorporateMetrics is tailored to the corporate environment. The table highlights the complexities of corporate oriented analysis, in which there are numerous options and different considerations for value measures, horizons, accounting treatment, and benchmarks.

Table 2.1

Comparison of risk management parameters in financial and corporate environments

Parameter	Financial	Corporate
Framework	RiskMetrics	CorporateMetrics
Measure of value	Portfolio value	Earnings, cash flow
Accounting treatment	Fair value (mark to market)	Accrual, fair value (mark to market), hedge accounting
Horizon	Daily, monthly	Monthly, quarterly, annual
Benchmark	Market index	Specified targets (e.g., budgeted plan, spot, forward, expected, and analyst forecast)

2.2.2 Beyond traditional corporate sensitivity analysis

Sensitivity analysis is a common approach to risk analysis in corporate planning departments. It involves applying specific market rate scenarios to budgeted plans to forecast so-called “worst case” or “downside case” scenarios for future financial results. For example, a company may wish to forecast earnings for foreign subsidiaries in case of potential currency devaluations, or it may decide to forecast expenses in case of potential commodity price shocks. While such scenarios provide insights into the potential results associated with a specific market condition, the probability of the scenarios occurring is usually difficult to assess. Also, the scenarios may or may not reflect a full range of different potential outcomes.

In contrast, the CorporateMetrics methodology offers a broader approach to market risk measurement. By using market rate probability distributions for multiple asset classes as a foundation, a company can generate many different market rate scenarios that, collectively, reflect a full range of probability-weighted market outcomes. Also, the scenarios can be generated to reflect specific assumptions about the correlation between different market rates. Scenarios can be developed from long-horizon forecasting techniques based on current market information (e.g., forward rates, option prices), econometric models, or user-defined parameters. The CorporateMetrics approach can extend traditional corporate risk analysis to provide a more comprehensive view of risk.

2.3 How does CorporateMetrics work?

The procedure for measuring market risk can be summarized in five basic steps:

STEP 1: Metric specification. Specify the financial result for which risk will be measured: earnings or cash flow. Specify the time horizon(s) and the confidence level for the risk measurement.

STEP 2: Exposure mapping. Using the metric specified in Step 1, identify all earnings or cashflow components, as appropriate, whose values can change as market rates fluctuate. Relate the exposures to market rates by defining how the value of each exposure is affected by each market rate.

STEP 3: Scenario generation. Generate a large number of scenarios that chart the different possible values for a given set of market rates over time.

- a. For each horizon defined in Step 1, specify a probability distribution of the market rates identified in Step 2.
- b. Generate each scenario by sampling a value from each distribution, and plot the values as a function of time.

An individual scenario thus defines a unique path that the market rates can take over the specified horizons. A set of scenarios defines a range of different paths that market rates can take over the specified horizons.

STEP 4: Valuation. Calculate the future financial results under each market rate scenario.

STEP 5: Risk measure computation. From the resulting distribution of financial results, calculate the risk statistics.

This five-step process is known as a **simulation-based approach**, which forms the basis of CorporateMetrics. In a simulation-based approach, a large set of market rate scenarios is used to generate a distribution of future financial results. The advantage of this approach is the ability to describe in detail a distribution of future financial results, from which a variety of risk measures may be obtained. This is especially useful for companies whose financial results vary nonlinearly with changes in market rates (e.g., when contracts with embedded optionality are used, or business volumes react non-linearly to market rate changes), in which case analytical techniques may not provide the flexibility needed to describe a detailed distribution of results. One drawback of simulation-based approaches compared to analytical approaches is their greater computational intensity. For cases where financial results are linear functions of market rates, analytical approaches may be adequate. Appendix A provides a description of such approaches.

Below, we provide an overview of how Steps 1 through 5 are implemented.

2.3.1 Metric specification

In this step, the company decides which financial result to analyze, and therefore which of the following risk measures to calculate:

- EaR, Earnings-at-Risk
- EPSaR, Earnings-per-Share-at-Risk
- CFaR, Cash-Flow-at-Risk

The company also specifies the time horizon(s) and the confidence level to be used for risk measurement.

The risk measures defined in CorporateMetrics focus on measuring the maximum potential short-fall of financial results relative to target (for a specified confidence level) due to market risk. In Chapter 5, we define each measure and explain our rationale for including it in this framework.

2.3.2 Exposure mapping

In order to forecast financial results under different market rate scenarios, we must first specify, by equations or pro forma statements, how the financial results and the market rates are related. The equations and pro forma statements are referred to as *exposure maps*.

Two key considerations that companies must decide upon are the scope of analysis (which exposures to analyze) and the types of functions that will be used to relate financial results to business and market variables.

CorporateMetrics provides a flexible framework that explains how risk can be calculated for any set of exposures, whether a subset of a company's exposures (such as specific positions or the combined exposures of a particular business unit), consolidated exposures for a subsidiary, or, at the highest level, the consolidated exposures for an entire company.

2.3.2.1 Scope of analysis

A selected set of exposures or positions can be analyzed by using equations that express a financial result as a function of market rates and business variables. For example, the earnings for a foreign subsidiary will be a function of both the level of exchange rates during the analysis period and the quantity of goods sold (which could itself be a function of the level of exchange rates). Selective analysis may be appropriate for measuring the risk of particular exposures or line items in the company's pro forma financial statements.

If a higher level of analysis is required (e.g., modeling risk for a business unit, subsidiary, entire company), the entity's pro forma financial statements can be used as the basis for exposure mapping. The statements' entries can be expressed as functions of business variables and market rates. Since the financial results for a subsidiary or entire company tend to be very complicated functions of multiple business and market variables, using a model of pro forma financial statements provides an intuitive way to organize the information and relationships. This type of high-level analysis can provide useful information to facilitate discussion at the senior management and board of directors levels, as well as with investors and analysts.

2.3.2.2 Mapping functions

Many different kinds of functions can be used to relate financial results to business and market variables depending on the type of analysis required. For example, if a company wants to model the relationship between foreign exchange rates and earnings, assuming that business volumes are fixed regardless of the level of exchange rates, then its exposure maps can be simple linear functions of exchange rate changes. Alternatively, if what is desired is an analysis that identifies how business volumes can vary for different levels of exchange rates, then the exposure maps may contain econometric relationships that reflect earnings as a more complex function of business and market variables. It should be emphasized that the degree of complexity modeled is entirely the decision of the company, which involves an internal assessment of the trade-off between factors such as ease of implementation, availability of data for econometric and competitive analysis, and levels of accuracy required.

For a more detailed discussion of exposure mapping, see Chapter 6.

2.3.3 Scenario generation

A major challenge for corporates is forecasting market rates over the long horizons typically associated with planning cycles. Business planning commonly focuses on horizons of up to one or two years within the context of a strategic plan that may span five years. Measuring the market risk inherent in targeted financial results over these typical planning horizons (e.g., 2 to 24 months into the future or for particular periods within that range) requires market rate scenarios that span these horizons. In order to develop the necessary scenarios, companies first need forecasting models to specify the probability distributions of the market variables, which can be a complex task for horizons beyond one month.

There are many techniques for long-horizon forecasting, which is the subject of a large body of existing academic research. Three general approaches include the use of current market information (e.g., forward rates and option implied volatilities), econometric models, and user-specified scenarios. Chapter 7 discusses the issues relating to long-horizon forecasting and the generation of market rate scenarios. *LongRun* is provided as a companion document with this publication and contains the technical details for the forecasting and simulation techniques surveyed in this document. Data sets, long-term forecasts, and volatility estimates that can be used for generating scenarios based on the approaches detailed in *LongRun* can be accessed at <http://www.riskmetrics.com>.

2.3.4 Valuation

By inputting the market rates for a particular scenario into the exposure map, we obtain a particular value for a future financial result. By repeating this process for each scenario, we obtain a distribution of financial results.

2.3.5 Risk computation

Using the resulting distribution of financial results, we can calculate sample statistics that describe the distribution and characterize the riskiness of the results. Examples of sample statistics include:

- **Standard deviation:** A symmetric measure of dispersion from the expected (or *mean*) value of the financial result being forecasted.
- **Confidence level:** Threshold that reflects the likelihood of a financial result not falling below a specified level.
- **Maximum shortfall relative to target:** A value that measures the maximum amount by which a financial result can fall short of a target level, for a specified confidence level.
- **Average shortfall:** The expected level by which financial results can fall short of a specified level.

In this document, we will illustrate how to calculate *maximum shortfall relative to target*, since the risk measures described in Chapter 5 are defined in this fashion. However, it is important to note that from a distribution of financial results generated by using the CorporateMetrics approach, companies have the choice of calculating any type of sample statistic that provides useful information about risk. Chapter 8 provides a detailed description of valuation and risk computation.

Corporate analysis beyond market risk

The discussions in this document focus on calculating only the risk due to market price fluctuations. However, as noted in Chapter 1, companies also face numerous non-market risks such as

- business risk,
- credit risk,
- patent risk,
- strikes and employment risks,
- operating risks, and
- catastrophic risks.

The CorporateMetrics methodology could be extended to handle the listed risk types and many others. This requires developing more comprehensive scenarios that, when combined with exposure maps, simulate market *and* non-market related changes and events.

2.4 Implementing CorporateMetrics: An example

We illustrate how the CorporateMetrics approach can be implemented by working through a simple example, using the five steps on page 12. Our example focuses on just one component of a company's earnings: foreign revenues. For in-depth examples that illustrate risk measurement for a variety of exposures, and for sets of exposures, see Chapter 9.

Example: Earnings-per-Share-at-Risk (EPSaR) due to foreign exchange risk

ABC Corporation (ABC) is a U.S. multinational that sells some of its products in Japan. For reporting purposes, assume that ABC translates its sales revenues in yen to dollars using end-of-quarter JPY/USD exchange rates. ABC's assumed budget rates for planning purposes are as follows:

Budget rate	31-Dec-98	31-Mar-99	30-Jun-99	30-Sep-99
JPY per USD	140	142	145	150

Step 1: Metric specification

For its yen-denominated sales, ABC would like to calculate EPSaR due to fluctuations in the JPY/USD exchange rate. ABC calculates risk for a 12-month time horizon and 95% confidence level. Assume that the date of the analysis is 30 September 1998.

Step 2: Exposure mapping

ABC's projected sales revenue in yen per quarter are as follows:

Sales revenue	4Q98	1Q99	2Q99	3Q99
JPY 000s	200,000	199,800	199,800	200,200

For this analysis, ABC assumes that it is not exposed to any business risk (i.e., its sales projections will occur with certainty). Its only risk is therefore due to potential fluctuations in JPY/USD exchange rates affecting the translated value of the company's revenues. The U.S. dollar value (in USD 000s) of the translated revenue can be summarized by the following simple equation:

$$[2.1] \quad \text{Revenues} = \frac{200,000}{X_1} + \frac{199,800}{X_2} + \frac{199,800}{X_3} + \frac{200,200}{X_4},$$

where X_i is the JPY/USD exchange rate, expressed in JPY per USD, at the end of the i -th quarter from the analysis date.

Since translated revenues are a component of earnings, Eq. [2.1] can be used as an exposure map in the EPSaR calculation process.

Step 3: Scenario generation

To project the translated revenue for the upcoming four quarters, we need scenarios that forecast the JPY/USD exchange rate over the four quarters. First, we need to specify JPY/USD exchange rate distributions at each end-of-quarter horizon. Procedures for constructing market rate distributions are provided in *LongRun*. In this example, we apply one of the econometric models described in *LongRun* for constructing distributions, which is known as the **Vector Error Correction Model (VECM)**.

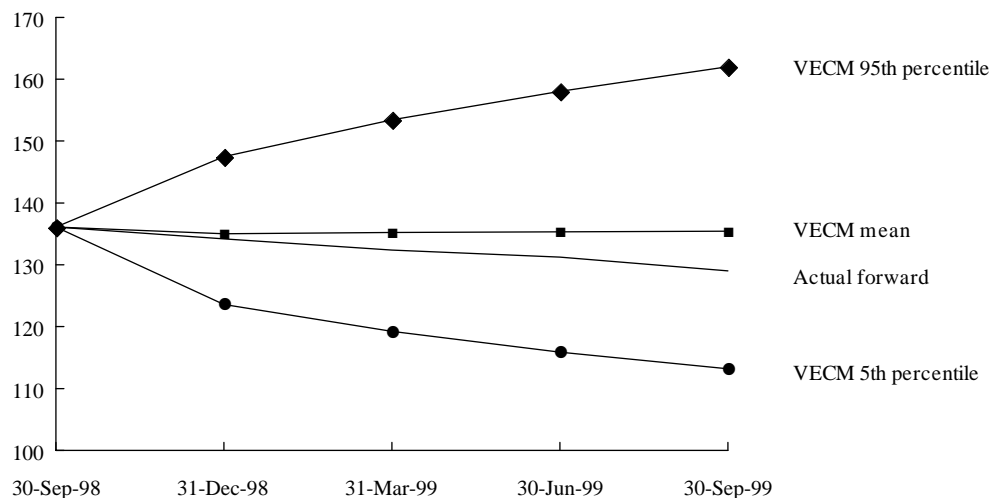
Chart 2.2 shows several parameters of the distributions we have assumed for this example, including the mean and the 5th and 95th percentile levels.

Chart 2.2

JPY/USD exchange rate distribution parameters and forward rates

Forecast date: 30 September 1998

JPY/USD



Using the JPY/USD distributions (from which selected parameters are shown in Chart 2.2) and the scenario generation algorithms from *LongRun*, we simulated 10,000 possible paths for the JPY/USD end-of-quarter exchange rates during the period covering 31 December 1998 to 30 September 1999.

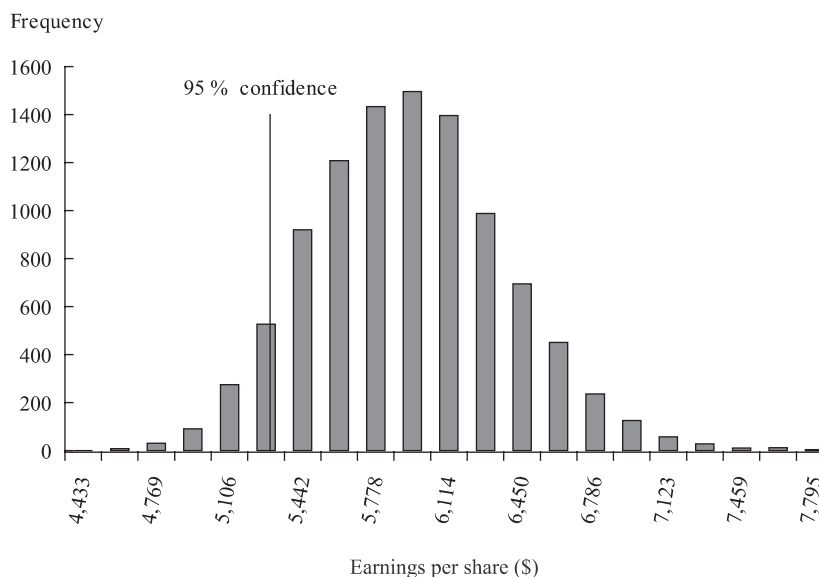
Step 4: Valuation

By using Eq. [2.1] to calculate the translated yen revenues under each of the 10,000 JPY/USD scenarios, we obtained a distribution of the revenues for the upcoming four quarters. As shown in Chart 2.3, the result at 95% confidence is \$5.2mm.

Chart 2.3

Distribution of translated yen revenues

10,000 trials

**Step 5: Risk computation**

Using the budgeted rates by quarter for JPY/USD exchange rates assumed in ABC's annual planning process, ABC's target revenue (in \$000s) from yen-denominated sales is the following:

Target revenue	31-Dec-98	31-Mar-99	30-Jun-99	30-Sep-99	Total
Yen sales revenue (¥000s)	200,000	199,800	199,800	200,200	799,800
Budget rate	140	142	145	150	
Translated revenue (\$000s)	1,429	1,407	1,378	1,335	5,548

Given budgeted revenues of \$5.55mm and a result of \$5.2mm at 95% confidence, the maximum potential revenue shortfall relative to target is $\$5.55\text{mm} - \$5.2\text{mm} = \$319,000$, with 95% confidence.

Using the maximum revenue shortfall measure, we need to infer its potential impact on earnings. Since revenues from yen-denominated sales affect earnings directly (i.e., every \$1 equivalent of incremental sales results in \$1 of incremental earnings), the maximum revenue shortfall of \$319,000 can result in a pre-tax earnings shortfall of \$319,000. Assuming ABC has 5,000,000 common shares outstanding, ABC's EPSaR is \$0.06.

This number means that with 95% confidence, fluctuations in the JPY/USD exchange rate over the next 12 months will cause an earnings shortfall of not more than \$0.06 per share. Using this EPSaR result, ABC's management can assess whether this level of earnings risk due to foreign exchange is acceptable. This information can be used when deciding whether or not to hedge the foreign exchange exposures. For a detailed discussion on the managerial applications of corporate risk measures, see Chapter 3.

2.5 Summary

In this chapter, we provided an overview of the CorporateMetrics framework and the key steps in implementing CorporateMetrics to calculate corporate risk measures. We illustrated with a simple

example how the approach can be implemented to calculate risk measures such as EPSaR. More complex examples will be shown in Chapter 9. In the next chapter, we will explore various practical applications of the CorporateMetrics approach.

Chapter 3. Managerial applications

The CorporateMetrics framework can have a variety of applications. We highlight a few:

- Deciding which hedging strategy to use
- Setting market risk limits
- Regulatory reporting of market risk

The analysis of expected returns for different risk levels and the use of risk limits can help companies make efficient use of their risk taking capacity.

3.1 Which hedging strategy to use?

Using the CorporateMetrics risk measures, companies can assess the levels of market risk associated with different hedging strategies. For example, companies can compare both the levels of market risks (as well as expected returns) associated with hedging versus not hedging, and the risks associated with using different hedge instruments.

Furthermore, companies can compare the riskiness of new businesses or different risk profiles. For example, if an energy company is considering setting up a natural gas trading desk, the company can estimate the incremental earnings and earning volatility that might be generated. Or, a company considering the use of more floating rate debt versus fixed rate debt can estimate the expected interest expense savings and cashflow volatility of different financing alternatives. With these measures, companies can make more informed decisions based on their risk preferences.

We illustrate with an example of how EaR can be used in making decisions concerning potential hedging activities.

Chart 3.1 depicts a 12-month earnings distribution for a company that is exposed to commodity prices. As shown, the company's earnings target over the 12-month period is \$105mm. The Earnings-at-Risk (EaR) due to commodity price risk is \$25mm at the 95% confidence level.

Chart 3.2 also depicts a 12-month earnings distribution for the same company, but assumes that the company has entered into a contract that hedges part of its commodity exposure. As shown, the company in this case has an earnings target of \$100mm over the 12-month period, with an EaR of \$10mm at the 95% confidence level.

The different risk (EaR) and return (target earnings) characteristics of the two cases shown are summarized in Chart 3.3.

Chart 3.1

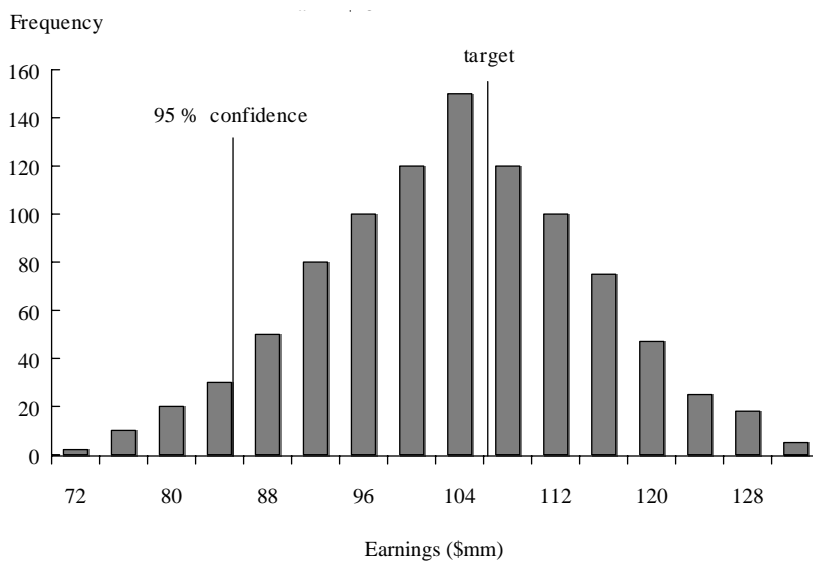
Distribution of earnings—unhedged underlying exposures

Chart 3.2

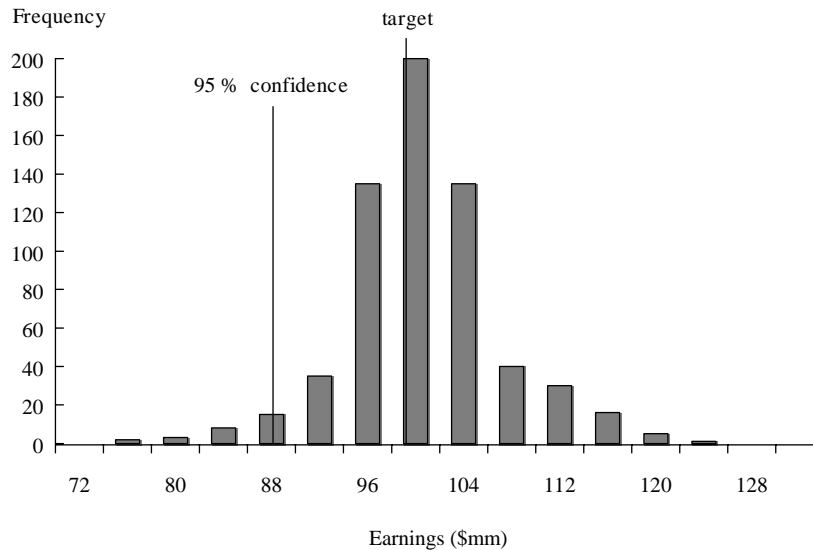
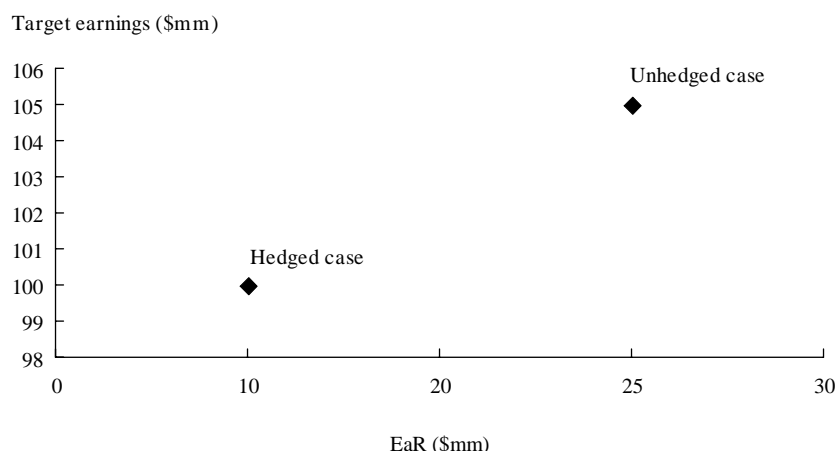
Distribution of earnings—underlying exposures plus commodity hedge

Chart 3.3

Risk-return summary for unhedged versus hedged exposures

By using EaR to measure the risk associated with hedging or not hedging, the company can consider whether, by hedging, the \$15mm reduction in earnings volatility (from an EaR of \$25mm down to \$10mm) is an adequate benefit, given a \$5mm reduction in expected earnings. In other words, the company expects to earn either \$105mm by remaining unhedged (with a worst case earnings outcome of \$80mm with 95% confidence), or \$100mm by hedging (with a worst case earnings outcome of \$90mm with 95% confidence). One of the benefits of corporate risk management is that it can add value by identifying the risk associated with alternate business decisions and thus helping a firm attain what it believes to be its appropriate risk profile, regardless of whether its resulting action takes the form of decreasing or of increasing the firm's risk.¹

Note that the difference between the company's targeted earnings in the unhedged and hedged cases can arise from a number of factors, such as:

- **Budget rates**

Budget rates are used to project revenues and expenses in order to determine targeted earnings. In many companies, the methodology for setting the budget rates can result in rates that are different from the forward rates quoted in the market place. However, the rates that govern the price of hedging transactions are of course fully determined by the market. If forwards are being used to hedge, the difference between hedged and unhedged earnings is due to the company's budget rates not being based on market forwards. Hence, the difference is not necessarily a cost, but rather a reflection of difference in the company's view of future market rates and the market's assessment of future market rates.

- **The use of options**

If options are being used to hedge, then the cost of option premiums must be taken into account.

3.2 Market risk limits

Many corporate policies contain guidelines on hedging and other risk management issues. One policy commonly used in market risk management is to specify target hedge ratios for the company's "natural" exposures. For example, a company with foreign sales has a natural, underlying exposure

¹ For more discussion on the benefits of corporate risk management, see *Corporate Risk Management* (1997, Chapter 2).

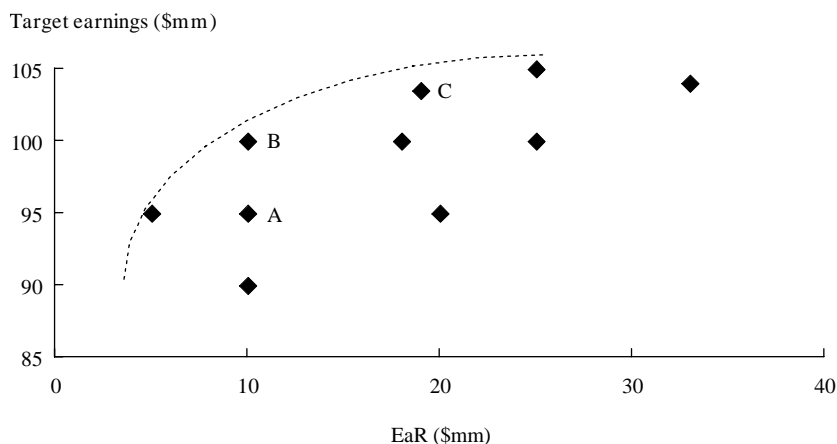
to foreign exchange rates. The company might use a set of target hedge ratios that specify hedging 50% of the current year's foreign earnings and 25% of next year's foreign earnings. Also, some companies have notional limits by hedge instrument type. For example, there may be limits on the volume of futures contracts that can be used, or on the maximum notional value of exotic option contracts.

While the specification of target hedge ratios can lead to reduced market risk relative to the market risk of unhedged exposures, the policy may not be the most efficient from a risk/return perspective for the company as a whole. In other words, for a given set of target hedge ratios for a company's exposures to various markets, there may be a different set of ratios that has a higher earnings expectation for a given level of EaR. Simple hedge ratio limits do not usually explicitly account for either the relationship between risk and return or the relationship between different risk types (e.g., correlation across markets) and their potential combined effect on corporate performance.

Chart 3.4 shows various target earnings and EaR associated with several different hedging strategies across a company's exposures. We consider three strategies A, B, and C, represented by points A, B, and C on the chart. Suppose hedging strategy A has the target earnings and EaR (shown at point A on the chart) that would result if a company were to follow target hedge ratios that have been arbitrarily chosen, but are intuitively appealing (e.g., hedge 50% of current year's commodity, foreign exchange, and interest rate exposure). There may, however, be a different strategy, B, which has a mix of hedge ratios that could lead to the target earnings and EaR shown at point B on the chart. Since B has a higher target earnings level than A for the same level of EaR, it is a more efficient strategy. A third strategy, C, may have higher target earnings than B, but higher EaR. Strategy C is therefore not necessarily more efficient than B, but represents a strategy with a different risk-return trade-off.

Chart 3.4

Risk and return for alternative hedging strategies

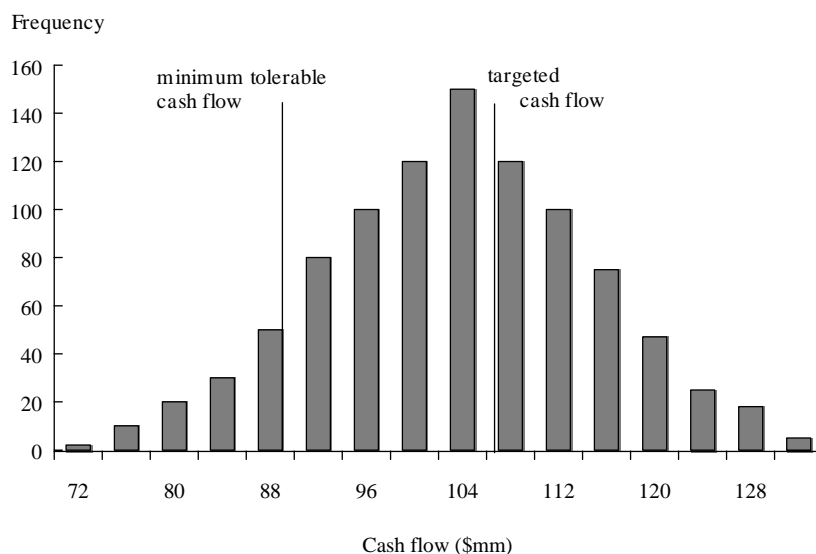


As illustrated above, arbitrarily chosen target hedge ratios may not lead to the most efficient hedging strategies. An alternative approach to setting risk management policy could be to set limits on risk measures such as EaR or CFaR. This approach is consistent with the true objective of risk management policies, which is to limit the likelihood of large variances from budgeted financial results. Traditional limit-setting techniques such as targets on hedge ratios are an indirect way to achieve this objective, with the disadvantage of being potentially inefficient from a risk/return perspective. An additional benefit of risk-based limits is the potential for putting in place a more flexible policy regarding the use of different hedging instruments. Rather than relying solely upon strict limits on the size and amount of each derivative contract that can be used for hedging, companies can focus more on overall risk. This can help companies relax instrument-specific notional limits where appropriate, which can sometimes lead to the construction of more efficient hedging strategies.

Setting risk limits makes indirect and qualitative risk management policies more quantitative. Chart 3.5 shows a company's distribution of cash flows, highlighting the targeted level and a minimum tolerable level, below which, for example, the company may need to cut its dividend or forego planned investment using internally generated funds.² The difference between the company's targeted cash flow and minimum tolerable cash flow defines the maximum level of CFaR the firm could take, although a smaller CFaR limit may be desirable if the company wants to meet its budgeted plans with greater likelihood.

Chart 3.5

Distribution of future cash flows due to market risk



The approach discussed above draws upon the experiences of many financial institutions as they have developed their risk management policies. Financial institutions focus on and manage risk given their limited capital as a risk-bearing resource. Traditionally, to manage market risk, the treasury groups within banks set limits on the maximum size of trading positions and other positions such as interest rate gaps. Similarly, notional limits on credit exposure to specified counterparties were implemented. While such methods are used to indirectly manage risk, they do not explicitly account for the inherent volatility and correlations of underlying market and credit factors to provide a portfolio view of risk. Today, with measures such as VaR for market and credit portfolios, companies can directly manage the parameter they care about, which is the level of risk to which the firm is exposed. CorporateMetrics provides the same type of objective risk measures to managers in a corporate environment.

3.3 Applying CorporateMetrics to SEC reporting

To comply with SEC guidelines for reporting activity in market risk sensitive instruments, companies can select from a number of different reporting options, including the reporting of VaR measures expressing the potential loss in future earnings, fair values, or cash flows of market risk sensitive instruments due to market movements. Since the CorporateMetrics framework specifically addresses risk measures such as EaR and CFaR for financial results such as earnings and cash

² This motivation is discussed in Hayt, G. and Song, S. (1995).

flow, the framework is well suited for corporate managers seeking a clearly defined and structured approach for meeting the SEC quantitative reporting requirements.³

While the SEC currently requires quantitative reporting for only market risk sensitive instruments, the CorporateMetrics provides an approach for addressing the risk of both market risk sensitive instruments as well as underlying business exposures and other exposures that companies only need to report externally on a voluntary basis. Hence, should companies choose to do so, they can apply CorporateMetrics to a broader range of exposures than is required, which would help the companies meet the SEC's *encouraged disclosures* policy (see Section 1.2.2).

While the SEC does not require specific time horizons or confidence levels for VaR-type disclosures, it does provide the following guidelines for reporting VaR: companies should select confidence intervals that reflect reasonably possible near-term changes in market rates and prices;⁴ lacking economic justification for selecting different confidence intervals, registrants should use intervals that are 95% or higher.

Companies therefore have some freedom in establishing their exact disclosure methodology, as long as it complies with the guidelines and intent established by the SEC. As per the guidelines, companies should generally calculate the measures using a confidence interval of 95% or higher and for near term-time horizons (i.e., up to one year). For details on how to calculate risk measures for a particular level of confidence, see Chapter 8.

³ Companies still need to prepare qualitative information discussing the assumptions of the chosen approach and any limitations that may be inherent in the measures. For example, any omission of exposures that are encouraged but not required that cause reported market risk not to fully reflect the net market risk of the entity should be discussed.

⁴ *Reasonably possible*, as defined by FASB's Statement of Financial Accounting Standards No. 5, "Accounting for Contingencies," means the chance of a future transaction or event occurring is more than remote but less than likely. *Near-term* means a period of time going forward up to **one year** from the date of the financial statements.

Part II

Framework Components

Chapter 4. CorporateMetrics road map

The remainder of this document details the CorporateMetrics methodology, starting with the road map and quick reference in this chapter.

Risk measurement in the corporate environment is a complex process that involves three major components: (1) specifying the risk measures to be computed, (2) providing corporate inputs on exposures and forecasting methodology, and (3) calculating the risk measures from earnings and cashflow distributions.

These components make up the CorporateMetrics framework, which offers a number of methods, guidelines, and references to assist with exposure mapping, scenario generation, and market risk calculation. Chart 4.1 summarizes the CorporateMetrics framework, and breaks down the component tasks into the steps that were introduced in Section 2.3. It also provides a “roadmap” to this document. Table 4.1 provides a quick reference to using CorporateMetrics. It summarizes each step in the risk measurement process, the purpose of each step, and the result of each step.

Chart 4.1

CorporateMetrics road map

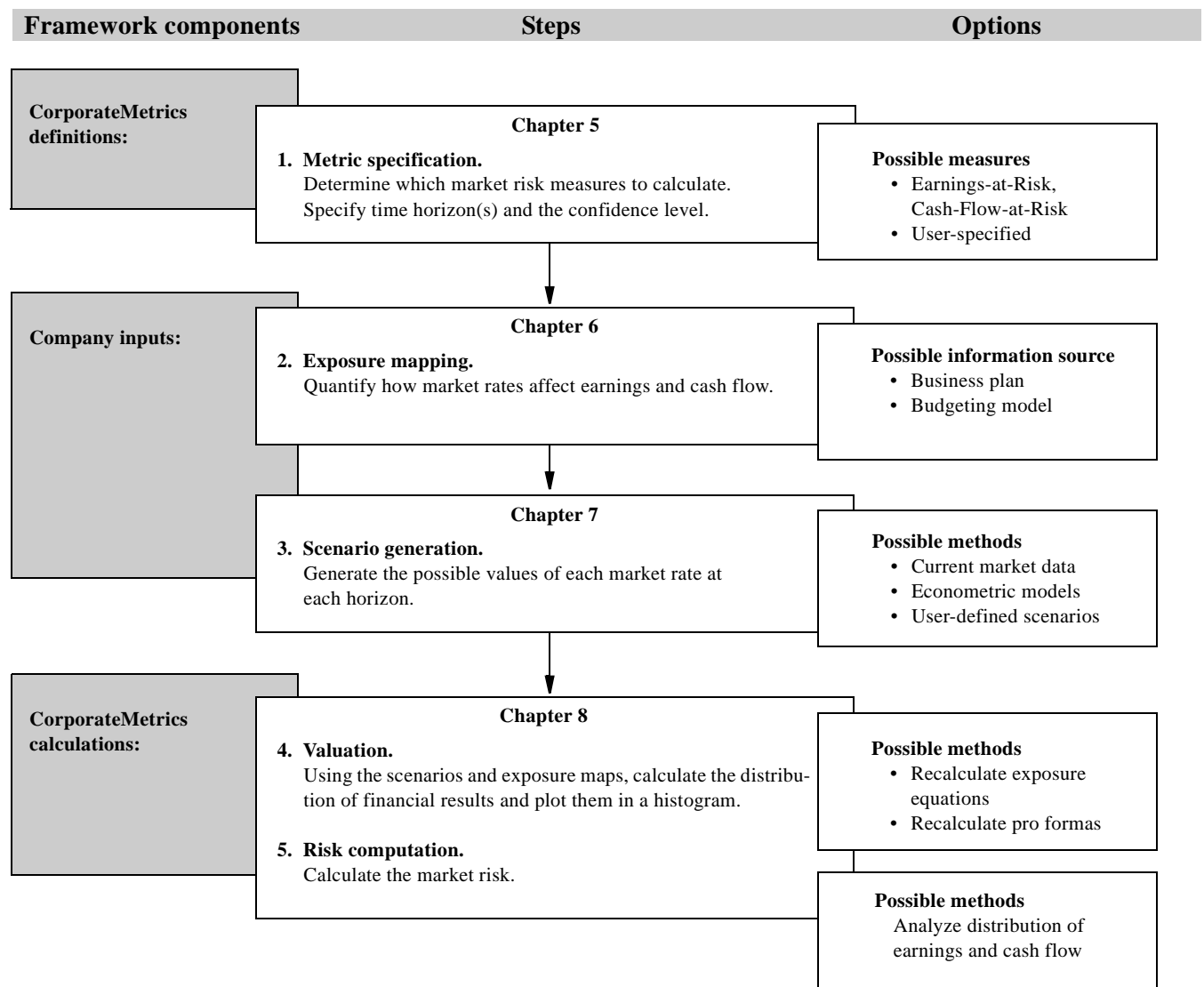


Table 4.1

CorporateMetrics quick reference

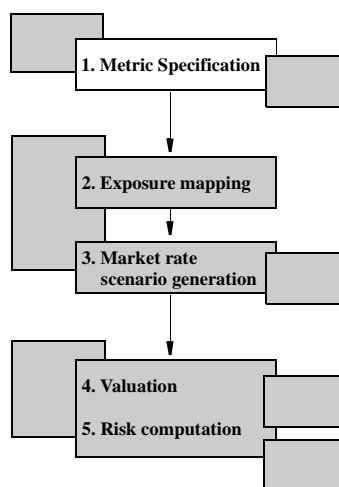
Framework	Step	Purpose	Procedure	Methodology
CorporateMetrics definitions	1. Metric specification	Determine which market risk measures to calculate.	Select risk measures, time horizon(s), and confidence level.	User-selected
Company inputs	2. Exposure mapping	Express how market rates (the random variables) operate on the financial result (i.e., earnings or cash flow) for which risk is to be calculated.	a. Characterize isolated exposures by using equations, or b. develop pro forma statement.	In-house (e.g., obtain from business plan or budgeting model)
	3. Scenario generation	Generate a range of possible values for the market rate(s) at each horizon.	a. Apply long-horizon forecasting methodologies to specify market rate distributions for each horizon selected in Step 1 (<i>forecasting</i>).	<ul style="list-style-type: none"> Current market information Econometric models User-defined scenarios
			b. Sampling from the distributions in Step 3a, generate N scenarios such that each scenario specifies a path of market rate values over the horizons selected in Step 1 (<i>simulation</i>).	
CorporateMetrics calculations	4. Valuation	Calculate the distribution of financial results.	Iteratively substitute values from each of the N scenarios from Step 3b into the exposure map from Step 2, calculate the N future financial results, and plot them in a histogram.	<ul style="list-style-type: none"> Recalculate exposure equation for each scenario Recalculate pro forma statement for each scenario
	5. Risk computation	Calculate the market risk.	Using the distribution of financial results from Step 4, find the financial result corresponding to the desired confidence level. Compare to target.	<ul style="list-style-type: none"> Analyze distribution of earnings or cash flow Calculate target value for financial result using company's budget rates

Table 4.1 (continued)

CorporateMetrics quick reference

Result		Reference
Risk measures: one or more of the following — EaR, EPSaR, CFaR, or user-defined Horizons: one or more, typically ranging up to 24 months Confidence level: for example, 95%		Chapter 5
Equations (e.g., Foreign earnings = number of items sold \times price per item \times foreign exchange rate) <i>and/or</i> pro forma statements (e.g., sets of equations, as summarized in pro forma financial statements)		Chapter 6
Distribution of market rate values (e.g., DEM/USD exchange rate)		Chapter 7
N market rate scenarios		Chapter 7
Distribution of N forecasted financial results		Chapter 8
Market risk measure:	<div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> Absolute <p>Calculated risk \rightarrow Financial results</p> </div> <div style="text-align: center;"> Relative to target <p>Calculated risk = B - A</p> </div> </div>	Chapter 8

Chapter 5. Metric specification



5.1 Measures of financial results and market risk

There are numerous financial results whose values can be affected by market rate changes: market capitalization, portfolio values, return on equity, earnings growth, debt-to-equity ratio, and interest coverage, to name but a few. In this first release of CorporateMetrics, we have chosen earnings and cash flow as the two financial performance measures on which to base risk measures. We made our choice according to our perception of the corporate and investor communities' key interests.

- **Earnings**—This measure attracts tremendous attention given the widespread use of earnings-based methodologies to value companies.
- **Cash flow**—Companies project cash flows from operating, investing, and financing activities to ensure the availability of sufficient liquidity to run day-to-day activities smoothly. Furthermore, a number of cashflow based methodologies are used to value companies.

In this chapter, we examine the importance to corporate managers of each of the above financial performance measures and define risk measures based on them. We plan to expand the CorporateMetrics framework to cover a wider range of risk measures according to users' needs.

5.2 Earnings

5.2.1 Managing shareholder value by focusing on earnings

Earnings directly affect the market values of companies since they are frequently used by investors and analysts to determine the value of those companies.¹ For example, a number of widely used equity valuation benchmarks such as Price-to-Earnings (P/E) ratios and Return on Equity (ROE) focus on earnings.

Earnings, in turn, can be affected by market risk. Therefore, in addition to managing the level and growth of earnings, companies are becoming increasingly focused on earnings volatility. By managing earnings volatility, companies can better manage stock prices and shareholder value.

For example, when quarterly earnings exceed or fall short of expectations, or when market expectations on corporate earnings shift, stock prices move.² Given the adverse effects of earnings short-fall on stock prices, corporations need a methodology that can quantify the sensitivity of earnings to market risk factors. Understanding the dependence of earnings on risk factors (such as changes in market rates) puts corporations in a better position to guard against risk, and therefore to better manage shareholder value.

¹ In theory, firm value can be determined by discounting future earnings streams at the firm's cost of capital.

² For example, for U.S. registrants, SEC rules require quarterly reporting of earnings. Foreign registrants file reports in the U.S. with the same frequency as in their home country.

5.2.2 Measuring earnings volatility due to market risk

Most companies have a planning and budgeting process that targets specific levels of earnings over time (e.g., quarter by quarter, or annually) to achieve long-term growth in shareholder value. While the planning process may identify potential earnings shortfalls due to a few selected downside scenarios, the process typically does not budget for market risk in a way that accounts for any of the following:

- Volatility and correlation for all market rates to which the company is exposed
- Potential impact to firmwide earnings due to the combined effect of the entire company's market exposures, taking into account potential diversification effects
- The confidence level of downside earnings estimates

To address the need for a methodology to quantify the effects of market risk on earnings, we have included Earnings-at-Risk as one of the principal risk measures in the CorporateMetrics framework. An earnings-based approach centers on the various line items and components of a company's pro forma income statement (or *statement of operations*). CorporateMetrics defines the following measure of earnings volatility:

Earnings-at-Risk (EaR). The maximum shortfall of earnings, relative to a specified target, that could be experienced due to the impact of market risk on a specified set of exposures, for a specified reporting period and confidence level.

Since earnings are also usually reported on a per share of equity basis, many companies may prefer to use an **Earnings-per-Share-at-Risk (EPSaR)** measure.

Example 5.1 Interpreting Earnings-at-Risk

Company ABC has target earnings of \$2.25 per share in the next quarter. Using a 95% level of confidence and 3-month time horizon, ABC's EPSaR due to the market risk of the entire company's exposures is calculated to be \$0.35. This means that ABC is 95% certain that next quarter's earnings will not fall short of the target by more than \$0.35 due to the impact of market risk.

5.2.3 Different earnings targets used in risk measurement

A **relative risk measure** for a value quantifies the potential uncertainty of that value with respect to a specified reference level for the value. As defined above, EaR and EPSaR are relative risk measures.³ Thus, to calculate EaR and EPSaR, we need to specify reference levels of earnings or **target earnings**.

In the corporate environment, many companies focus on **budgeted earnings** as targets.⁴ These targets are, in general, regularly prepared (e.g., annually) by companies for internal planning purposes. A plan may include pro forma income statements for several scenarios, such as an expected "base" case, optimistic "upside" case, or pessimistic "downside" case. The **budget rates** for the various

³ It is of course also possible to define earnings risk measures that are absolute, i.e., measures that focus on the actual levels of earnings. However, based on our discussions with a number of companies, there is significant focus on specific target earnings and the risk factors that could lead to missing those targets. Because of this, we have decided to define in CorporateMetrics, measures that quantify relative risk.

market rates used for calculation purposes may be based on spot rates, forward rates, consensus estimates by internal economists or analysts, or whatever rates are deemed appropriate by the company. By using budgeted earnings as the target value in EaR or EPSaR calculations, a company can forecast the maximum potential shortfall of future earnings relative to the budget. As discussed in Chapter 2 and illustrated by the examples in Chapter 9, EaR and EPSaR can be measured for particular components of earnings or for consolidated earnings, depending on the scope of analysis a company applies.

Measures such as EaR and EPSaR provide managers with important information about the uncertainty of achieving their goals. While target earnings could in theory be any arbitrary amount, the most useful targets will typically be reference levels that managers focus on. In addition to budgeted earnings, other targets may include:

- **Expected earnings based on “expected” market rates**—the level of earnings forecasted for a specific reporting period, as calculated from the mean values of the forecasted market rate distributions. As discussed in Chapter 7, companies need to make assumptions about and specify which market rate probability distributions will be used to generate scenarios in the risk measurement process. The expected values (or *means*) for the different market variables at different points in time can be calculated from these probability distributions. Target earnings can then be calculated using the expected values of the market rates.

Depending on how companies coordinate the process for setting their budget rates and the process for specifying market rate probability distributions for risk measurement, the budget rates and expected market rates may differ, especially in those cases where companies use a uniform budget rate throughout the entire forecasting period.

- **Hedged earnings based on forward rates**—the level of earnings forecasted for a specific reporting period, as calculated using market forward rates. Earnings that are calculated from the assumption that forward rates are “locked-in,” can (and often do) differ from budgeted earnings to the extent that a company’s budget rates are different from the market forward rates.
- **Analyst forecasts**—earnings forecasts made by equity research analysts who provide information and research reports to investors. Analyst forecasts for the earnings of public companies are closely followed by the market and help form the market’s expectations of companies’ upcoming earnings. Empirical evidence has shown that such forecasts are heavily used by institutional investors. Consensus forecasts condition the market’s expectations for corporate performance.⁵ As such, many corporate managers monitor business results with respect to consensus forecasts.

Analysts typically base their forecasts on both industry research and direct communication with managers at the companies they cover. By using analyst forecasts as a target, a company can estimate the amount by which earnings may fall short of market expectations.

- **Earnings associated with a base case hedging strategy**—the level of earnings expected, as calculated from a company’s budgeted plans and assuming a base case hedging program is implemented. (As discussed in Chapter 3, some companies have corporate policies that specify a particular portion or range of exposures to be hedged.) If a company’s budgeted or

⁴ Budgeted earnings are the level of earnings forecasted for a specified reporting period, as calculated from a company’s target operating results (e.g., sales volumes, or purchasing volumes), using internal budget rates for foreign exchange rates, interest rates, commodity prices, and equity prices.

⁵ Among the services that regularly release such data are I/B/E/S, Inc. and FirstCall.

expected earnings already accounts for base case hedges, then the earnings associated with a base case hedge will be the same as budgeted or expected earnings targets.

The expected earnings and EaR associated with a base case hedge are useful for comparison with the expected earnings and EaR for alternative hedging strategies.

The choice of an earnings target, whether one of the five noted above or some other target specified by a company, sets the reference level of earnings on which any potential shortfall measure is based.

5.3 Cash flow

Cash flow ties together a company's operating, investing and financing activities. When cash cannot be generated in sufficient amounts and at the right times, companies may have to delay their investment plans or, in the worst case, face financial distress and even bankruptcy.⁶ The importance of cashflow management to the functioning of a business compels most companies to monitor and forecast the sources and expenditures of their cash.

Cash flow is also very important to analysts and investors who often use it in addition to earnings in order to determine company valuations. Furthermore, cash flow provides information about a company's liquidity and profitability; therefore, a statement of cash flow is always included in a public company's reported financial statements.

To address a company's need to quantify the impact of market risk on cash flow, CorporateMetrics defines the following measure of cashflow volatility:

Cash-Flow-at-Risk (CFaR). The maximum shortfall of net cash generated, relative to a specified target, that could be experienced due to the impact of market risk on a specified set of exposures, for a specified reporting period and confidence level.⁷

As with EaR, CFaR is defined here as a relative risk measure, with risk being measured relative to a target level of cash flow. A target level for future cash flow can be estimated by first constructing a pro forma statement of cash flows (a procedure which some companies use in their planning processes) or by modeling specific activities that generate or use cash (e.g., modeling specific revenue generating operations or forecasting the cash needs of specific investments).⁸ With a cashflow forecasting model in place, a target level of cash flow can be calculated by applying budget rates, spot rates, forward rates, or whatever market rates and prices are deemed appropriate by a company, to the anticipated operating, investing, and financing activities for the period. Alternatively, analyst forecasts or cash flow associated with a base case hedge could also be used as reference points for target cash flow.

⁶ *Financial Accounting* (1988, p.162).

⁷ Here, cash flow is defined as the net change in cash balances.

⁸ For example, the magnitude and timing of cash flow from sales revenue can be modeled by applying assumptions for the size and collection period for the accounts receivable that will be booked.

Example 5.2 Interpreting Cash-Flow-at-Risk

Company ABC projects that it will generate \$15mm of cash flow during the upcoming year. Using a 95% level of confidence and 1-year horizon, ABC's CFaR is calculated to be \$3mm. This means ABC is 95% certain that the net change in cash will not fall short of projections by more than \$3mm due to market risk.

The impact of hedging activity on earnings and cash flow

It is worth noting that accounting and reporting standards for derivative instruments can affect EaR. The use of derivative contracts that fail to qualify for hedge accounting treatment can increase EaR because of their requirement to recognize the changes in fair values in reported earnings from one reporting period to the next. However, the contracts may reduce CFaR if the derivatives' cash flows net against other forecasted cash flows from underlying positions, thus lowering overall cashflow volatility. Under certain circumstances, CFaR can therefore be more reflective of a company's long term economic risks than EaR. This effect can arise when accounting rules do not fully reflect the intended economic impact of certain hedging activities on long-term earnings and cash flow.

5.4 Summary of risk measures

In this chapter, we specified two financial performance measures, earnings and cash flow, which CorporateMetrics uses to measure market risk in the corporate environment. These measures are summarized in Table 5.1.

*Table 5.1***CorporateMetrics financial performance and risk measures**

Performance measure	Risk measure	Definition
Earnings	EaR EPSaR	The maximum shortfall of earnings, relative to a specified target, that could be experienced due to the impact of market risk on a specified set of exposures, for a specified reporting period and confidence level.
Cash flow	CFaR	The maximum shortfall of net cash generated, relative to a specified target, that could be experienced due to the impact of market risk on a specified set of exposures, for a specified reporting period and confidence level.

We have defined these measures to provide a common language for communicating about risk in the corporate environment.

Other measures of value and market risk

Corporate risk measures can be based on numerous other measures of value, including shareholder value, portfolio value, and balance sheet translation. While risk measures for these financial measures are not a formal part of the CorporateMetrics framework, we review them below, given their frequent mention in the corporate environment.

Shareholder value

In the corporate context, the term *value* is often used in reference to shareholder value or firm value. Given that the fluctuations in a firm's value can be modeled in terms of earnings volatility, it is reasonable to assume that fluctuations in shareholder value can also be derived from earnings volatility.

For example, one approach to estimating the volatility of firm value is to use a **corporate valuation model** to calculate firm value under many different scenarios for future earnings. From the resulting distribution, the uncertainty of the firm's value could be inferred.

Alternatively, a simple “back-of-the-envelope” estimate could be made by using the following simple relationship for changes (Δ) in firm value:

$$\Delta \text{Market value of the firm} = (\text{Forward price/Earnings ratio}) \times (\Delta \text{Earnings expectation}),$$

in which we calculate the implied Forward price/Earnings ratio (P/E) by using the current stock price and consensus earnings estimates for the upcoming year. Once forward P/Es are calculated, one way to estimate “market Value-at-Risk” (i.e., worst-case Δ Market value of the firm) is to substitute EaR for (Δ Earnings expectation) in the above equation as a measure of the maximum difference between actual earnings and expected future earnings, which yields

$$\text{Market Value-at-Risk} = (\text{Forward price/Earnings ratio}) \times \text{EaR}.$$

The estimate assumes the forward P/E value remains unchanged, which is not always the case, as we discuss below.

Although our discussion suggests two possible conceptual approaches to estimating the volatility of firm value, CorporateMetrics does not include a definitive risk measure based on shareholder value. In addition, CorporateMetrics does not specify any particular valuation model or approach, given the variety of corporate valuation models that are used and modified according to industry type and to developers' preferences. Furthermore, while P/E ratios are useful in valuation, their tendency to change over time reduces their reliability to relate earnings volatility to the volatility of a company's market value. In our view, the estimation of the volatility in shareholder value is best left to the institution seeking an understanding of this risk. Thus, different companies can use the valuation models most appropriate for their particular situation.

Portfolio value (VaR)

In Chapter 2, we outlined several aspects of portfolio-level risk analysis. Many companies, in addition to corporate-level risk analysis, are interested in portfolio-level analysis for the following reasons:

- To manage excess liquid funds by investing in portfolios of financial instruments, such as money market instruments and debt instruments. Portfolio VaR is therefore a useful measure of risk for this activity.

- To determine how fluctuations in the value of pension assets can have a material effect on a company's financial commitments.
- To use portfolio VaR in regulatory reporting.

For a complete discussion on a framework for measuring portfolio value VaR due to market rate and price changes for portfolios of financial instruments, see the *RiskMetrics—Technical Document*. The RiskMetrics Group's CorporateManager application specifically addresses long-horizon risk measurement as well as portfolio VaR.

Balance sheet translation

In certain instances, companies may need to forecast the potential fluctuations in the translated value of their equity investments in foreign subsidiaries and affiliates as a function of foreign exchange rates. In consolidated balance sheets, the assets and liabilities of investments in foreign subsidiaries and affiliates are translated at prevailing exchange rates. From period to period, their translated values will change as exchange rates change.⁹ Different companies will have varying degrees of concern regarding these net values on the consolidated balance sheet. Some companies elect to hedge the value of their foreign equity investments. Situations in which fluctuations of value are scrutinized may include:

- **Potential sale or divestiture of foreign subsidiary**—In these situations, managing the translated value of foreign subsidiaries or affiliates can lead to improved total returns upon sale or divestiture.
- **Sensitivity to balance sheet ratios**—For example, some companies must ensure that ratios such as debt-to-equity remain above a certain level in order to comply with debt covenants. Large potential adjustments to the *cumulative translation adjustments* account from one reporting period to the next can contribute to the breaching of such ratios and, therefore, are a source of risk that needs to be managed.

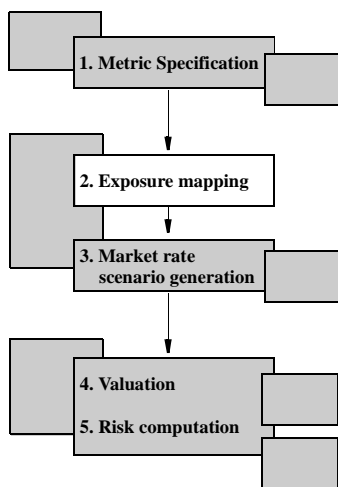
Some companies may therefore elect to measure the risk of potential fluctuations in the translated value of consolidated foreign assets net of liabilities. One possible risk measure is

Balance Sheet Translation Risk (BSTR). The maximum shortfall of the translated value of foreign assets net of liabilities, relative to a specified target, due to foreign exchange risk, for a specified reporting period and confidence level.

As with EaR and CFaR, BSTR is defined here as a relative risk measure, with risk being measured relative to a target value for foreign investments. The target value for foreign investments is the anticipated future value of the entity, taking into account both targeted retained earnings for the entity during the analysis period and qualified translation hedges, calculated using target exchange rates as specified by the user (e.g., budget rates, forward rates, or spot rates).

⁹ Changes in translated values are booked as translation adjustments that affect the *cumulative translation adjustments* account.

Chapter 6. Exposure mapping



The second step in the market risk measurement process, **exposure mapping**, assumes that the corporation has specified the financial results it will forecast (earnings and/or cash flow) and will calculate the corresponding risk measures: EaR, EPSaR, CFaR (outlined in Chapter 5).

Exposure mapping is the process of identifying how fluctuations in market rates (i.e., the random variables) affect each financial result. The mapping can be done in the form of equations, models, or pro forma financial statements, all of which are referred to in this publication by the general term **exposure maps**.

In general, exposure maps are unique for each company and for each situation. For example, as discussed in Chapter 1, different companies may choose to apply different scopes of analysis depending on the type of risk analysis needed, ranging from specific positions or business groups, all the way to firmwide consolidated analysis. Also, the quantitative relationships between market variables and financial results can take on various forms. In the most basic cases, the relationships can be assumed to be linear; in econometric modeling, they can be more complicated. Finally, different accounting conventions across countries and industries result in a wide variety of rules for calculating earnings.

Our goal in this chapter is to discuss a broad range of factors that companies need to consider when constructing the relationship between market rates and financial results.

6.1 Overview of exposure mapping

An exposure map defines how market rates operate on the components of earnings or cash flow. For example, the following simple equation represents an exposure map defining the effect of foreign exchange rates on the translated value of a company's foreign sales:

$$[6.1] \quad \text{Revenue (a component of earnings)} = \text{Foreign sales (business variable)} \\ \times \text{foreign exchange rate (market rate).}$$

Once an exposure map is constructed, market rate scenarios (foreign exchange rates in the above example) are entered into the map one at a time. For each scenario, the financial result being simulated (revenue in the above example) is calculated and plotted in a histogram from which market risk is then computed. These steps involve market rate scenario generation, valuation, and risk computation, which are discussed in Chapters 7 and 8.

6.1.1 Market risk versus business risk

The exposure map in Eq. [6.1] has up to two variable components: the amount of foreign sales generated and/or the future foreign exchange rate, depending on how the company chooses to model the risk of its foreign sales activity. Three choices are available:

- **Pure market risk**—Assume that the notional amount of foreign sales is fixed (e.g., DM 1,000,000 next year for a U.S. company) so that translated revenue is purely a function of exchange rate movements.¹

¹ Another example of a “pure market risk” would be the fluctuation in value due to foreign exchange risk of an account receivable (A/R) in foreign currency. Once the A/R is booked, its notional amount is fixed. However, gains and losses can arise as the A/R is valued from period to the next as exchange rates fluctuate (until the cash due is collected). This type of exposure is referred to as a **transaction exposure**.

- **Market risk with known effect on business variables**—Assume that fluctuations in exchange rates affect sales volume in a known way (e.g., for a 10% drop in value of the DEM against the USD, the company's sales volume in Germany will decline by 1%) so that translated revenue can still be expressed as a function of just one variable (which in our example is an exchange rate). However, a constant is introduced to reflect the effect of foreign exchange rates on sales volume. This is illustrated in Example 6.3 on page 43.
- **Market and business risk**—Assume that sales volumes and exchange rates are two separate random variables, so that the translated revenue function must be expressed as a function of two random variables.

Of the three modeling choices shown, the first two (pure market risk and market risk with known effect on business variables) ultimately express revenues as functions of market variables only. The third choice, however, adds more complexity by assuming that business variables (such as sales volume in Eq. [6.1]) are random variables.

This edition of CorporateMetrics focuses on techniques that deal with the first two choices: either pure market risk, or market risk with known effects on business variables. An overview of the CorporateMetrics techniques for generating the corresponding market rate scenarios is provided in Chapter 7; a complete technical discussion is provided in the *LongRun Technical Document*. (Note that the third choice, market and business risk, is not being considered in the current edition of CorporateMetrics because of its company-specific nature. For example, to account for pure business risk and other market-independent variables, companies would have to generate scenarios containing both future market levels and future business volumes. To properly generate the scenarios, however, requires making assumptions about company-specific information, i.e., about variables that are related to business volume and about the variables' relationship to the market. This type of modeling is, for now, left to the individual companies to consider for potential use.

In the sections that follow, we will explore how different assumptions about a company's operating environment can be modeled in exposure maps for the components of earnings and cash flow. We consider a number of different exposure mapping situations, including:

- Simple linear relationships between the translated value of foreign revenues/cash flow and exchange rates (Examples 6.1, 6.2, and 6.4)
- Simple linear relationships between foreign sales price and exchange rates, resulting in a non-linear relationship between the translated value of foreign revenues and exchange rates (Example 6.3)
- Cash flows arising from an interest rate swap transaction (Example 6.5)

6.1.2 Techniques for exposure mapping

Regardless of the approach to exposure mapping, companies have the choice of using equations, models, or pro forma statements to construct the exposure maps. When analyzing risk for multiple market risks or on a consolidated firmwide basis, it is useful to combine component exposure maps into a larger exposure map, i.e., a pro forma financial statement. This is a set of equations that describe an array of financial components, with specific rules that link the components together (e.g., accounting rules for calculating earnings). Pro forma financial statements are a useful way to create exposure maps that can make clear how different input variables and assumptions ultimately affect projected financial results. Naturally, for risk analysis of individual components or line items within pro forma financial statements, more specific exposure maps or individual equations can be used.

6.2 Exposure mapping for the components of earnings

Earnings, like other financial results, can be viewed as a portfolio of components whose values change as market rates vary. Table 6.1 lists a few earnings components that could make up a typical “portfolio,” and which types of market risk affect them.

Table 6.1

Market risk sensitivities to selected earnings components

Earnings component	Market risk
Revenues across different businesses and countries	Foreign exchange, commodity
Costs of goods sold across different businesses and countries	Foreign exchange, commodity
Operating expenses across countries and businesses	Foreign exchange, commodity
Interest expenses	Interest rate
Gains and losses on re-valuation of accounts receivable/payable	Foreign exchange
Gains and losses on financial contracts	Foreign exchange, interest rate, commodity, equity

Below, we examine different approaches to constructing exposure maps for components of earnings and discuss the benefits and limitations of each approach. For a summary of the individual components of earnings, formulas for calculating the components of earnings, and market risk factors, see Appendix C.

6.2.1 Modeling earnings as a linear function of market rates

The most basic approach to creating exposure maps for the components of earnings assumes that each component is a linear function of market rates. For instance, the simplest linear relationship is the modeling of pure market risk, in which a company assumes that business variables, such as foreign sales volume, are fixed. Thus, for different future exchange rates, future revenues will simply vary directly with the rate at which foreign revenues are converted into home currency. Example 6.1 illustrates exposure mapping for relating the translated value of foreign sales revenue (a component of earnings) to foreign exchange rates.

Example 6.1 U.S. company with sales in Canada

A U.S. company with sales in Canada estimates that each quarter, it will sell 1,000 units of its product at C\$100, for revenues of C\$100,000 per quarter (see Chart 6.1).

Chart 6.1

Budgeted revenues for a U.S. company with sales in Canada

Revenue summary Canadian sales (C \$000's)		Quarter-end exchange rate (CAD per USD)		Revenue summary U.S. financial statements (\$000's)	
Revenue				Revenue	
Q1	100		X(1)	Q1	100/X(1)
Q2	100		X(2)	Q2	100/X(2)
Q3	100		X(3)	Q3	100/X(3)
Q4	100		X(4)	Q4	100/X(4)

The company assumes that it will *not* adjust sales prices as exchange rates fluctuate. The company uses a linear approach to modeling revenues and assumes that its quarterly revenues, in U.S. dol-

lars, will simply be the quarterly Canadian dollar revenues translated at the average daily CAD/USD exchange rate during the quarter.

Given the above assumptions, the company creates an exposure map that relates the expected revenues in USD resulting from Canadian sales R_c to exchange rates as follows:

$$\begin{aligned}
 R_c &= \text{CAD revenue each quarter, translated back to USD} \\
 [6.2] \quad &= \frac{(\text{C\$100 per unit}) \times (1,000 \text{ units})}{(X_1 + X_2 + X_3 + X_4)},
 \end{aligned}$$

where X_i is the average daily CAD per USD exchange rate during quarter i .

Using this exposure map (Eq. [6.2]), the company can calculate its Canada-related revenues for any market rate scenario that comprises four successive forecasts for average daily CAD/USD exchange rates. This formulation assumes zero variability in anticipated sales volume (i.e., zero business risk).

Linear exposure mapping can be easily implemented and focuses attention on market risk factors, assuming other variables (such as sales volumes) are held fixed. A limitation of a linear approach, though, is its lack of flexibility in modeling more complex relationships for market-sensitive business volume functions.

The following example also depicts a linear relationship between revenues and market rates. The example illustrates one way to model sales volumes that vary as exchange rates vary in a known way.

Example 6.2 Modeling sales and revenue as a function of exchange rates

Company IJK manufactures CD-ROM games in Japan and sells the games to U.S. customers through its Web site. Each CD-ROM costs ¥2500 to produce and IJK targets a 100% gross margin in yen. IJK projects that 10,000 copies can be sold this month at a retail price of the USD equivalent of ¥5000 at today's JPY/USD exchange rate, such that its targeted revenues are ¥50mm this month. However, as the JPY/USD exchange rate fluctuates, IJK plans to adjust its USD retail prices daily on the Web, and will always look to charge the equivalent of ¥5000 per copy. Due to its USD pricing policy, IJK expects its sales volume to be lower than target if the yen appreciates during the month and higher than target if the yen depreciates during the month. IJK assumes its sales volume function in the upcoming month to be

$$\begin{aligned}
 \text{SalesVolume} &= \text{projected base sales volume} \times \text{foreign exchange rate factor} \\
 [6.3] \quad &= 10,000 \text{ units} \times \frac{X_1}{X_0},
 \end{aligned}$$

where X_0 (a constant) is the current level of the exchange rate in JPY per USD, and X_1 (a random variable) is the projected end-of-month exchange rate. The sales volume is described in terms of a foreign exchange rate factor $\frac{X_1}{X_0}$, whose value is driven by X_1 , and a projected base sales volume (10,000 units), which arises from IJK's business assumptions.²

² Note that the projected base sales volume has some degree of uncertainty, and could be modeled as a random variable relating to pure business risk. For the purpose of this example, we assume the volume assumption to be fixed.

As shown, the change in sales volume relative to the projected base sales volume is assumed to be directly proportional to the month-on-month percentage change in the exchange rate.³

IJK's revenue function for the upcoming month is therefore,

$$\begin{aligned}
 \text{Revenue (in yen)} &= 5,000 \text{ yen} \times \text{Sales Volume} \\
 [6.4] \qquad \qquad \qquad &= 5,000 \text{ yen} \times 10,000 \text{ units} \times \frac{X_1}{X_0}.
 \end{aligned}$$

Equation [6.4] represents a simple exposure map for IJK's revenues since it defines a component of earnings (revenue) in terms of a market variable that is assumed to drive sales volume as shown in Eq. [6.3].

As Examples 6.1 and 6.2 illustrate, CorporateMetrics focuses on modeling pure market risks and market risks combined with business risk in the form of explicitly modeled relationships between market rate changes and business volumes. As discussed above, in order to account for pure business risk, companies can extend the risk analysis by modeling sales volume as a random variable to account for the uncertainty in business volumes arising from pure business risk.

6.2.2 Non-linear relationships and other functions in exposure mapping

The modeling of business variables as functions of market variables (as in the preceding example), rather than as fixed notional amounts allows for more complex exposure mapping. The relationship between market rates and operating results is company specific, and depends on a number of different factors, such as the company's ability to change product prices in response to market moves, perceived hedging strategies for a company's competitors, and the level of consumer or business demand for products and services under different market and business conditions. Example 6.2 showed how we could model such relationships linearly. Example 6.3, below, shows a non-linear approach. (While CorporateMetrics provides a risk measurement framework, it does not provide or advocate any particular modeling approach. Exposure mapping requires a thoughtful analysis of the many approaches that are possible and an assessment of their benefits and limitations. Only then can a company select an approach that makes sense for its business.)

Example 6.3 Non-linear mapping: Multi-period exposure mapping with price elasticity

For a U.S. company with foreign sales, a stronger-than-expected dollar can have direct impact on translated revenues, which in turn, affect earnings. To the extent the company raises its foreign prices in order to protect margins, the company may recoup some of the potential foreign exchange-related shortfalls in revenue, but sales volume may be weaker than expected if customers switch to locally produced brands or imports whose prices have been kept stable (which is possible if foreign competitors have hedged foreign exchange or they are "buying" market share).

One approach to mapping revenues to market rates is through price elasticity estimates.⁴ Price elasticity is the rate of change of product prices with respect to changes in market rates. For example, a U.S. company with sales in Canada might assume that if the CAD weakens (strengthens), the company will raise (lower) sales prices to compensate for the foreign exchange-related revenue shortfalls (windfalls) without affecting sales volumes. If the company assumes a price elasticity of 0.5, then for every 1% depreciation (or appreciation) of the CAD, sales prices will drop (or rise) by

³ Another way of characterizing this model is to say that IJK assumes both a USD sales price elasticity of 1.0 with respect to exchange rate changes and a volume elasticity of 1.0 with respect to price changes

⁴ For further discussion on modeling cash flows using economic pricing models and elasticity concepts, see G. Hayt and S. Song (1995, p. 95).

0.5%. To ensure that revenues are accurately forecasted under different market scenarios, the company would specify its pricing policy in its exposure maps.

Returning to the company described in Example 6.1, let us assume that if the CAD depreciates with respect to the USD during any given quarter, the company will incrementally raise its local CAD prices to compensate for the negative impact of CAD depreciation on revenue. Similarly, the company will lower local prices if the CAD appreciates. Due to local competition, the company does not pass through to prices all the potential impact of exchange rate movements. The company's price adjustment policy is to raise (lower) prices by 0.5% for every 1% depreciation (appreciation) in the CAD each quarter as a partial hedge of foreign exchange risk. This policy implies a price elasticity of 0.5 with respect to exchange rate moves. By using the policy, the company assumes that sales volume, V , can be maintained at a fixed level of 1000 units per quarter.

During the first quarter, the company assumes it will sell its product at the unit price of $P_1 = \text{C\$}100$. Assuming the company translates Canadian sales revenues back to USD using quarter-end exchange rates,⁵ the company's first-quarter revenue R_1 from Canadian sales, expressed in USD, would therefore be

$$\begin{aligned} R_1 &= P_1 V X_1 \\ [6.5] \quad &= \text{C\$}100 \times 1000 \text{ units} \times X_1, \end{aligned}$$

where X_1 (a random variable) is the exchange rate at the end of the first quarter.

The company assumes that it will adjust its local sales price at the beginning of the second quarter based on the net percentage change in the CAD/USD exchange rate during the first quarter. The new local sales price, P_2 , at the beginning of the second quarter can be expressed as

$$\begin{aligned} P_2 &= (\text{initial price}) \times [1 + (\text{price elasticity}) \times (\text{percent change in exchange rate})] \\ [6.6] \quad &= (\text{C\$}100 \text{ per unit}) \times \left[1 + 0.5 \left(\frac{X_1}{X_0} - 1 \right) \right], \end{aligned}$$

where X_0 (a constant) is the current (i.e., beginning of the first quarter) CAD per USD exchange rate.

Anticipated revenue, expressed in USD, for the second quarter, R_2 , would therefore be

$$\begin{aligned} R_2 &= P_2 V X_2 \\ [6.7] \quad &= (\text{C\$}100 \text{ per unit}) \times \left[1 + 0.5 \left(\frac{X_1}{X_0} - 1 \right) \right] \times (1000 \text{ units}) \times X_2. \end{aligned}$$

Note that the revenue function includes a term that depends on the product of the two random variables X_1 and X_2 . Therefore, R_2 is a non-linear function of the exchange rates. For each successive quarter, we can construct similar expressions for the expected sales prices and revenue functions, taking into account the cumulative impact of the company's pricing policy on prices. For any future quarter i , the sales price and anticipated revenue for that quarter are given by

⁵ Many companies use average daily exchange rates for the purpose of revenue translation. For simplicity, we have elected to use end-of-quarter exchange rates in this example.

$$[6.8a] \quad P_i = P_{i-1} \times \left[1 + 0.5 \left(\frac{X_{i-1}}{X_{i-2}} - 1 \right) \right]$$

$$[6.8b] \quad R_i = P_i \times V \times X_i.$$

Note: To model a series of exposure maps such as those shown above (relating revenue and foreign exchange rates) it is common to use either a pro forma revenue model or an income statement with quarterly entries. In this example, the price and revenue functions for a given quarter would link back to the values associated with the previous period to capture the impact of the company's cumulative pricing policy on revenues. Total revenue for multiple, successive periods can then be calculated by summing each period's revenue. This period-by-period approach is illustrated in Chart 6.2, where we show the results for one particular market rate scenario, in which the CAD per USD exchange rate starts at C\$1.35, then fluctuates to C\$1.37, C\$1.36, C\$1.385, and C\$1.43 over four quarters.

Chart 6.2

Exposure mapping for revenue using a multi-period modeling approach

Pro Forma Revenue	Current	End Q1	End Q2	End Q3	End Q4	Total
Simulated quarter-end rate (CAD per USD)	1.35	1.37	1.36	1.385	1.43	
Previous-quarter price (CAD)		–	100.00	100.74	100.37	
Price multiplier		–	1.0074	0.9964	1.0092	
Sales price (CAD)		100.00	100.74	100.37	101.30	
Sales volume		1,000	1,000	1,000	1,000	4,000
Revenue (CAD)		100,000	100,741	100,373	101,296	402,409
Revenue (USD)		\$72,993	\$74,074	\$72,472	\$70,836	\$290,374

Price adjustment periods

The preceding examples show the different ways in which companies can adjust prices in response to changes in foreign exchange rates. In general, the time it takes for a company to adjust prices (price adjustment period) is specific to the company and the industry, and accounts for competitive pricing pressures.

A major factor that can affect the length of price adjustment periods is the company's hedging policy. For example, if companies hedge anticipated foreign revenues to lock in desired levels of home-currency returns, the horizon covered by the hedges will affect the amount of time that business units have to adjust product prices or business strategy before the insurance benefits of foreign exchange hedges roll off. The way in which different companies manage pricing and hedging strategy is a function of the way they measure their own performance, which can vary significantly across different companies.

Exposure mapping should take into account the company's business and hedging policies in order to help realistically model the price adjustment responses the company would take in different market rate environments.

So far, we have shown two relatively straightforward examples of exposure maps relating revenue to market rates. There is no limit to the complexity that a revenue function, or any other function for a component of earnings, can take. As discussed, the way in which exposures are mapped is

specific to an individual situation. Exposure mapping can account for any number of variables, including market rates, price elasticity, and seasonality, to name a few.

The benefit of constructing exposure maps that rely on a variety of different functions between earnings components and market rates is the ability to flexibly model relationships that the company believes are applicable. However, the process can be time consuming since it may require substantial analysis of past data, regression analysis, econometric modeling, or other techniques to facilitate forecasting. Nevertheless, many companies have, at the least, a feel for the functional relationship between earnings and market rates for specific exposures in their business, which can guide the process of designing the exposure map. In some cases, detailed analyses may already be done in corporate planning departments and can therefore be used as inputs into the exposure mapping. When deciding upon the complexity of an exposure map, companies need to assess the trade-off between realistic modeling and the speed of preparing the exposure map, depending on the ultimate application of risk measures obtained from the corporate risk measurement process. In short, companies need to understand the advantages and limitations of the assumptions used in exposure mapping.

6.2.3 Accounting for position rollover

For an exposure map to capture the dynamic nature of business transactions relating to a company's anticipated rollover of positions—such as short-term debt, investments in money market securities, hedges, and other periodic exposures—it should reflect how such transactions can affect earnings (or cash flow if CFaR is to be measured). For example, if all of a company's short-term debt is expected to be of 90-day duration and rolled over on a quarterly basis, the exposure map for interest expense should be a function of the forward 90-day borrowing rates for each period. In short, when firmwide consolidated earnings risk analysis is performed, all business activities and transactions with market risk that are expected to occur within a given analysis period should be modeled in exposure maps to ensure an accurate depiction of firmwide market risk.

6.2.4 Earnings components versus firmwide consolidated earnings

By analyzing the different components of earnings and specifying their relationship to market variables, a company can obtain an exposure map for each component of earnings. For companies looking to measure business-specific or firmwide consolidated EaR, these component exposure maps can be combined to form an exposure map for business-specific or consolidated earnings, for example, in the form of a pro forma income statement. For most multi-national companies, a pro forma income statement will be a very complicated model with numerous inputs associated with business activities and market variables across a number of different countries and markets. Depending upon how companies are organized, pro forma income statements can either be prepared at the parent company level, or they can be prepared for smaller operating units, such as a country or business unit.

6.3 Exposure mapping for cash flow generating/using activities

On a forward-looking basis, cash flow is conceptually straightforward to forecast. Any operating, investing, and financing activities that generate or use cash can be modeled using a pro forma statement of cash flows or another form of exposure map. Regardless of the technique chosen, exposure maps for projected cash flows should express the cash flows as functions of the market rates.

In practice, it is notoriously difficult to forecast the timing of cash flows. The number of cash payments and receipts is often enormous for most companies, and the days on which receipts or payments occur are difficult to pinpoint. Nevertheless, some degree of exposure mapping for cash flows can be useful to highlight cash flow patterns for corporate activities and the potential impact

of market risk on the cash flows associated with a particular set of exposures or activities, or for a company's activities as a whole.

Cash flow can be viewed as a portfolio of components whose values change as market rates vary. Table 6.2 lists a few cash flow components that could make up a typical "portfolio" and which types of market risk affect them.

Table 6.2

Market risk sensitivities to selected earnings components

Cashflow component	Market risk
Revenue	Foreign exchange, commodity
Cost of goods sold	Foreign exchange, commodity
Cash needs for other expenses, contractual obligations, and taxes	Foreign exchange
Investing activities	Foreign exchange, interest rate, commodity, equity
Financing activities	Foreign exchange, interest rate, equity

Below, we examine the key sources and uses of cash and summarize the key issues for modeling cash flows in exposure mapping.

6.3.1 Cash flow from operations

Cash flow from operations is equal to the cash received from *sales of goods and services* less the cash paid for *operating goods and services*. Cash flow typically arises from the following:

- **Revenue**—Cash proceeds from the sales of product or the provision of services can be received either at the time of sale or at an agreed upon date after the time of sale. In cash flow calculations, the actual dates of receipts of cash must be known. Hence, if payment is deferred, and an account receivable is booked, the date of cashflow receipt must be projected from the settlement date for the account. As with the exposure mapping of revenues for earnings calculations, any assumed functional relationships of sales volumes, prices, and market rates to cash flows from revenues should be modeled accordingly in the exposure map.
- **Cost of goods sold**—Cash payments for operating goods and services can occur either upon receipt of the goods and services or on a deferred basis. In cashflow determinations, the actual date of the payment of cash is necessary must be known. Hence, if payment is deferred, and an account payable is booked, the cashflow payment date must be projected from the settlement date for the account. Any assumed relationships of input volumes to market rates should be modeled in the pro forma statement of cash flow.
- **Cash needs for other expenses, contractual obligations, and taxes**—Other operating cash flow may arise from items such as operating expenses, pension expenses, taxes, interest expense and income, and contractual cash flows for derivative contracts.

For an exposure map to accurately project the net cash flow for a given set of exposures in a given period, the company must specify its policies concerning the repatriation of cash from foreign operations, rollover assumptions for interest-rate sensitive debt, assets, and derivative contracts, and other policies with cashflow implications.

Example 6.4 Foreign sales: Linear exposure mapping approach for cash flow

Revisiting the U.S. company with sales in Canada described in Example 6.1, let us assume that for the sales of any given quarter, cash is actually collected at the end of the first month of the following quarter. Assume that the analysis date is January 1. Thus, the company expects to collect cash from

last quarter's sales on January 31. Similarly, cash due on sales in the first quarter will be collected April 30. Assuming the company sold 1000 units at C\$100 per unit last quarter, and expects to sell 1000 units at C\$100 per unit in each quarter this year, the exposure map for the company's cash flow from foreign sales in the upcoming 12 months CF_c expressed in USD, is

$$CF_c = (\text{C\$100 per unit}) \times (1000 \text{ units}) / (X_1 + X_4 + X_7 + X_{10}),$$

where X_i is the end-of-month CAD per USD exchange rate for month i . Note that cash due from this year's fourth-quarter sales will not be collected until the following quarter and, thus, does not appear in the exposure map for a 12-month horizon.

6.3.2 Cash flow from investing

Cash flow from investing is equal to cash received from sales of *investments* and *property, plant, and equipment* less cash paid for acquisition of *investments* and *property, plant, and equipment*. The acquisition of noncurrent assets, particularly plant, property, and equipment, usually represents a major ongoing use of cash. Funding for investment activity is typically obtained from existing cash, sales of existing noncurrent assets, and new sources of financing.

Below is an overview of market rates and prices that affect the level of cash flow from investing:

- **Commodity prices**—Anticipated transactions involving the sale and purchase of commodities (e.g., precious metals) should be expressed in terms of the corresponding commodity prices to allow for estimation of the future proceeds or payments.
- **Foreign exchange rates**—Cash flow relating to planned capital expenditures or sales/acquisitions of foreign currency denominated investments should be mapped to foreign exchange rates to estimate their potential realized value in home currency terms.
- **Interest rates**—Based on the projected nominal values of interest-rate sensitive assets to be sold or purchased, the pricing formulae for the positions should capture the functional dependency on market interest rates. This allows for accurate estimation of potential future values of proceeds or payments.
- **Equity prices**—Based on the projected volume of third-party equities to be sold or purchased relating to investing activities, the anticipated transactions should be expressed in terms of the corresponding equity prices to allow for estimation of the future proceeds or payments.

6.3.3 Cash flow from financing

Cash flow from financing is equal to cash received from the *issue of debt or capital stock* less cash paid for *dividends* and *reacquisition of debt or capital stock*. A cash flow exposure map should describe any relationship of projected cash flow from financing activities to market rates in order to model potential financing transaction cash proceeds or uses.

6.3.4 The impact of derivatives on cash flow

As discussed in Chapter 5, cash flow relating to derivatives has a direct effect on net cash flow and hence, can affect CFaR. The cash flow or “payoffs” associated with any derivative contracts into which a firm has entered should be specified and expressed in terms of market rates in exposure maps in order to model potential cash flows. In addition, the use of derivative contracts can some-

times result in cash flows relating to margin or collateral calls. These occur as market rates move and derivative contract fair values fluctuate.

Example 6.5 Exposure mapping for a cashflow hedge: Interest rate swap

Suppose a company has just issued \$100mm of ten-year fixed-rate debt and enters into \$100mm notional value receive fixed/pay 6-month floating interest rate swap to modify its interest rate risk profile. The company can use the following simple exposure map to project this year's cash flows relating to the interest rate swap:

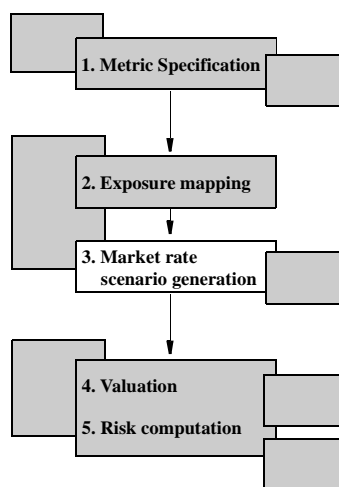
$$\text{Interest rate swap cash flow} = \$100\text{mm} \times 0.5[(6.5\% - R_6) + (6.5\% - R_{12})],$$

where R_6 and R_{12} are the 6-month LIBOR rates, 6 and 12 months from the analysis date, respectively, and 6.5% is the fixed-leg interest rate for the swap.

6.3.5 Balance sheet considerations

When the probability distribution of cash flows required to calculate CFaR is generated, situations may arise in which projected cash payments in a given currency exceed the projected amount of cash on hand for that currency. To provide for a more realistic simulation of cash flow activity, the analyst may wish to specify funding assumptions that allow for the conversion of other cash sources to the currency required. In this type of analysis, initial balance sheet values and company policies for funding and currency conversions should be taken into consideration.

Chapter 7. Market price and rate scenarios



As discussed in Chapter 2, the risk measurement process requires market price and rate scenarios in order to forecast financial results under a range of different market conditions.¹

Market rate scenario generation requires first specifying probability distributions for market prices and rates at different horizons,² then sampling from each distribution. (In this publication, we use the terms **market price and rate probability distributions** and **market rate distributions** interchangeably.)

Given the substantial mathematical modeling that is required for forecasting market rate distributions and simulating long-horizon scenarios, we first consider the qualitative aspects of the scenario generation process. In this chapter we

- review the role of market rate scenarios in the risk measurement process,
- summarize the issues related to the choice of model for specifying the market rate distribution (forecasting), and
- provide an overview of the process for generating market rate scenarios from market rate distributions (simulation).

The complete methodology for generating long-horizon scenarios is explained in *LongRun*, which we have published as a companion document. *LongRun* focuses exclusively on the mathematical modeling of market rate distributions under different assumptions and the generation of market rate scenarios. *LongRun* provides risk managers with a comprehensive framework for generating scenarios, which are a necessary input to risk management. The framework includes guidelines for capturing the appropriate input data, choosing a forecasting strategy, and simulating prices and rates across a variety of asset classes. *LongRun*'s primary purpose is to provide industry professionals with a flexible, consistent and transparent mechanism to create scenarios that serve as inputs to any risk management system.

7.1 Market rate scenarios and risk measurement

In CorporateMetrics, a **market rate scenario** is defined as a path for one or more market variables over a specific horizon, for example, the evolution of a foreign exchange rate over a 3-month period. A market rate scenario for multiple market variables specifies a set of simultaneous paths for the evolution of the variables over the same horizon, as illustrated below.

Example. If we require a market rate scenario for the month-end values for the DEM/USD and SGD/USD exchange rates over the next three months, we can construct a table (or a graph) of foreign exchange rates as a function of time, as shown in Chart 7.1. The table (or graph) represents a possible scenario for how the two exchange rates could evolve simultaneously in the next three months.

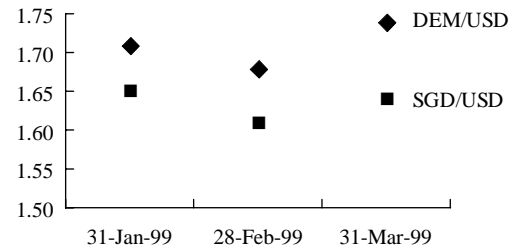
¹ This chapter is based on *LongRun* (Chapter 1, 1999) and was written by J. Kim, A. Lee, A. Malz, and J. Mina.

² A probability distribution determines the likelihood that a random variable will take on a particular value within a specific range of values. Thus, the probability distribution for a market rate such as DEM/USD would define a function that specifies the likelihood that DEM/USD reaches a particular value.

Chart 7.1

Market rate scenario for DEM/USD and SGD/USD*Three-month horizon*

Horizon	DEM/USD	SGD/USD
31-Jan-99	1.71	1.65
28-Feb-99	1.68	1.61
31-Mar-99	1.74	1.64



In our example, we have chosen to specify the scenario in terms of monthly values. However, a market rate scenario can consist of more frequent values (e.g., daily or weekly) or less frequent values (e.g., quarterly), depending on the application.

By developing many different scenarios for each market variable, we obtain paths that characterize the range of possible values that the variables could take over the specified horizon in a manner consistent with the market rate distributions from which the values were obtained. In the CorporateMetrics framework, the market rate scenarios are used as inputs in exposure maps to obtain a distribution of financial results.

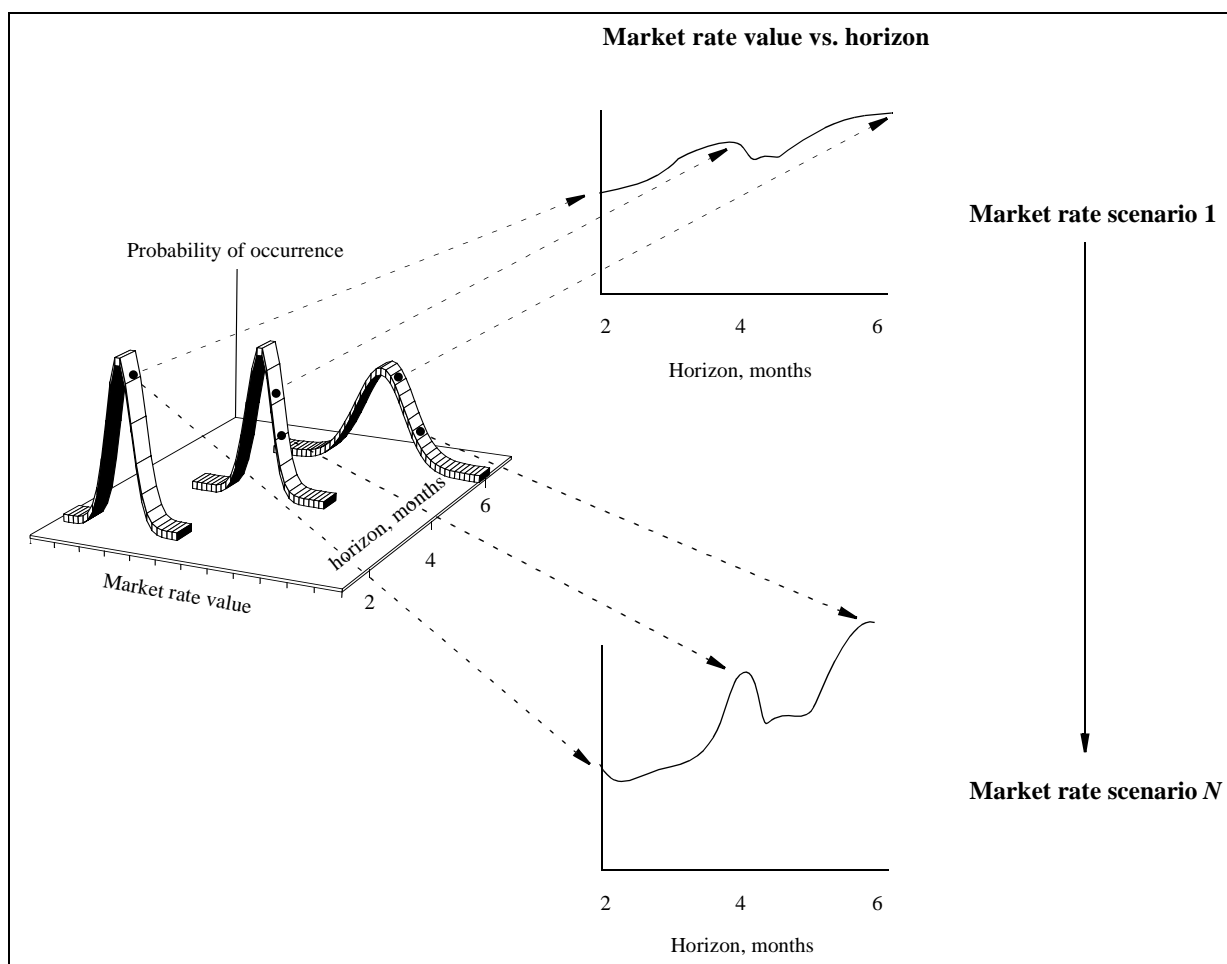
7.2 Generating market rate scenarios

Market rate scenarios are generated by sampling points from market rate distributions. For example, a company that needs to measure the risk of one market rate at 2-, 4-, and 6-month horizons first requires a probability distribution for the market rate at each horizon, as shown in Chart 7.2.

Note that forecasting the mean and standard deviation of the probability distribution at each horizon enables a company to model how market rates may evolve over time. For example, in Chart 7.2 the mean value of the probability distribution (i.e., the mean value of the market rate) increases over time, and the standard deviation of the probability distribution (i.e., spread in market rate) increases over time. Once the probability distributions are specified, they are used to generate a set of market rate scenarios for each variable such that the statistical characteristics of the scenarios (i.e., mean, standard deviation, and so forth) reflect those of the source probability distributions.

Market price and rate scenarios (such as those shown in Chart 7.2) can be generated by using *LongRun*'s procedures. In the remainder of this section, we provide a qualitative discussion of *LongRun*'s scenario generation procedure.

Chart 7.2
Generating market rate scenarios



7.2.1 Forecasting market price and rate distributions

While it is easy to agree that market risk measurement requires information about market price and rate probability distributions, it is far more difficult to agree on a method for determining these distributions. It is important to keep in mind that *LongRun*'s final objective in producing forecasts is to assess market risk at long horizons. A wide variety of forecasting procedures are available, and it is very important to note that no single model is universally applicable. Since there is no 'best' forecasting procedure, it is desirable to forecast under different sets of assumptions so that the results from different methods (which could have unique theoretical underpinnings) can be compared and contrasted, allowing risk managers to assess the merits of different forecasting techniques.

To avoid prescribing a particular method, we designed the CorporateMetrics framework to be compatible with any long-horizon forecasting methodology. A complete discussion of each forecasting method is beyond the scope of this publication. However, we do outline the theoretical basis of several forecasting techniques and highlight their benefits and limitations. We believe that this information will be a useful guide to corporate risk managers when they assess the relative merits of different techniques.

In general, companies may consider using more than one method in order to meet a diverse set of risk management objectives. The choice of methods may be based on the following concerns:

- Perceived accuracy in specifying the distribution of future market rates
- Ease of implementation
- Closeness to market views or consensus
- Ability to
 - incorporate proprietary information or views on market relationships,
 - test extreme events,
 - incorporate current market information (e.g., forward rates, option implied volatility), and
 - account for macroeconomic conditions.

In *LongRun*, we present two forecasting methodologies: one based on current market information, the other based on econometric models. These methodologies differ not only in their underlying assumptions, but also in the data sets used to obtain the forecasts. The forecasts based on current market information make intensive use of current spot, futures, forwards and options price data and apply some basic facts about derivatives theory, while the forecasts based on economic structure rely on historical time series of financial and/or economic data and the econometric modeling of time series.

In addition to using *LongRun*'s two forecasting approaches, analysts can devise their own forecasting models, inputs, and scenarios. Each approach, whether it is *LongRun* or user-defined, has its advantages and limitations, as summarized in Table 7.1.

Table 7.1

Summary of methods for forecasting market rate distributions

Class	Type	Description	Benefits	Limitations
Current market information	Random walk with and without drift	Based on current market information, such as implied volatility and forward rate data.	<ul style="list-style-type: none"> • Ease of implementation. • Use of market-indicated values to deduce probability distribution functions. 	Lack of comprehensive data across all markets, especially for emerging markets.
Economic structure	Econometric modeling	Uses historical financial market and macroeconomic data. Examples include the Vector Error-Correction Model (VECM) described in <i>LongRun</i> .	Models features such as <ul style="list-style-type: none"> • macroeconomic fundamentals • structural regimes • cointegrating relationships 	More difficult to implement in comparison to random walk-based models.
User defined scenarios	User's own model and information	Applies user-defined scenarios.	Tests specific scenarios based on special concerns, insights, or other assumptions.	Difficult to assess probabilities of scenarios occurring.

7.2.1.1 Current market information and the efficient markets hypothesis

Forecasts based on current market information are founded in the notion that market expectations are embedded in an up-to-date way in current spot and derivatives prices. Therefore, it is possible to study what the market “thinks” by analyzing current spot, forward, futures and option prices.

For example, let us ask ourselves the question “Does the market believe U.S. Treasury rates will rise or fall over the next year?” Market professionals frequently answer such questions by observing the term structure of interest rates. An upward-sloping term structure indicates that rates are expected to rise, while a downward-sloping term structure indicates falling rates. In this view, information about market expectations of future interest rates is embedded in current bond prices.

The common approach of using market-implied forecasts applies, in principle, to any traded asset. Modern financial theory views asset prices as forward-looking; the diverse beliefs of market participants concerning the future are filtered through the market process (i.e., the buying and selling

of financial assets by market participants) and are therefore embedded in market prices. A decent approximation of market dynamics is the view that markets are *efficient*, so that asset prices accurately reflect the consensus market view. Formally, this assumption is known as the *efficient markets hypothesis*, which we outline below.

7.2.1.1.1 *Efficient markets hypothesis*

The *efficient markets hypothesis* states that everything currently known about the future prospects of an asset is embedded in market prices. The hypothesis is often treated as a tautology, which merely validates whatever market prices prevail. To have real empirical content, the hypothesis must exclude certain types of market behavior, for example:

- The possibility of long lags between perturbations and the onset of a new equilibrium level. The efficient markets hypothesis implies that markets react instantly to new information concerning the asset's future prospects. More realistically, markets adjust quickly to perturbations, which excludes the possibility of long lags between the arrival of news and the attainment of new equilibrium prices.
- Responses to fads and fashions. Prices are determined, in part, by market participants' tastes, that is, their willingness to bear risk over various time horizons. There is a presumption that tastes are stable, so fads and fashions do not rule the market. Current research implements this part of the hypothesis empirically by using the assumption of rational expectations.

The efficient markets approach seeks to resolve one of the paradoxes of financial markets: On the one hand, all currently available information relevant to future returns is already impounded in current returns. On the other hand, returns are random and unpredictable. The paradox's solution is that, if current prices contain all available information, only new information can have an impact on next period's prices. New information is, by nature, random and unpredictable—until it arrives: we can as easily imagine news provoking a price decline as a rally.

As implied above, current market information incorporates not only the market's views, but also the risk preferences of market participants. For example, different market participants will have different appetites for or aversions to the future returns implied by current market information. In the next section, we describe how forecasts based on current market prices reflect aggregate risk preferences as well as aggregate views about the future in the form of *risk-neutral probabilities*.

7.2.1.1.2 *Risk-neutral probabilities*

We can extract the mean, volatility, and even the entire probability distribution of future spot prices from forward, futures, and option prices. In an efficient market, the probabilities underlying these forecasts are referred to as *risk-neutral probabilities* and may differ from the “market consensus” means, volatilities, and distributions. The difference resides in the fact that the risk-neutral parameters contain information about the risk preferences of the agents in the economy and thus we cannot disregard risk aversion when interpreting risk-neutral probabilities and the forecasts obtained by using them. In other words, in addition to “market consensus” probabilities, the risk-neutral probabilities contain information about aggregate risk preferences, supply, and demand.

To understand the concept of risk neutrality and the link with the efficient markets hypothesis, we make use of a simple example:

Suppose that you are a bookmaker accepting bets on a football game (team A vs. team B), and you believe that both teams have the same probability of winning the game (we can even assume that you know with certainty that the probabilities are equal, i.e., $1/2$). It seems fair to receive one dollar now, pay two dollars to gamblers who bet on the winning team, and nothing otherwise. Let us assume that there are 80 people betting on team A and 20 people betting on team B. If you were willing to accept bets based on the *true probabilities* (i.e., $1/2$) of victory, you will lose 60 dollars if team A wins ($\$100$ received from bets – $80 \text{ people} \times \2) and make 60 dollars

if team B wins ($\$100 - 20 \times \2). Is this position desirable for you? Of course you will break even *on average* if you play the game *several* times, but you will bear risk for any individual game. Ideally, a bookmaker would like to charge a small amount in excess of the original \$1 and lock that profit in without risk.

Let us consider what happens when you change the odds in the following way: for every dollar bet on team A you will pay \$1.25 if team A wins and nothing otherwise; and for every dollar bet on team B the payoff will be \$5 in case team B wins and zero if it loses. Now, if team A wins, your profit is $\$100 - 80 \times \$1.25 = \$0$; if team B wins, your profit is $\$100 - 20 \times \$5 = \$0$. You now have a riskless position. In fact, by changing “the odds,” you imposed on the gamblers a set of market implied **risk-neutral probabilities**, which are prescribed by the relative supplies of bets on the two teams, reflecting in this way, the “market consensus.” These **risk-neutral probabilities** of victory are 4/5 for team A and 1/5 for team B.

Spot and derivatives prices contain information about the risk-neutral probabilities because all relevant or available information about market participants’ beliefs concerning the future and their risk preferences are compacted into current market prices. By analogy, the payoff on the bet therefore does not depend on your personal view—or the view of any individual gambler—of the real probabilities. Under the risk-neutral probabilities, you assign the payoffs based on the collective views and risk preferences of all the gamblers. Market participants, like the bookmaker, can take on or lay off risk at prevailing market prices and rates. If a market participant’s risk appetite or view of the future differs from what is expressed in current market prices and risk-neutral probabilities, he can tailor his position accordingly at prevailing prices.

It is important to remember that the study of the information content of current market prices and rates is still being conducted by researchers, with much work remaining to be done. In addition, certain markets are illiquid or non-existent, so market price data is not as abundant as one would desire, placing a constraint on the universal applicability of forecasting using current market information. Despite the efficient markets hypothesis, many researchers support the idea that macroeconomic variables and past asset price data have some forecasting power. Therefore, a large part of our efforts to forecast long-term market price and rate distributions will rely on a methodology based on econometric models of asset price determination, which is described in the next section.

7.2.1.2 Forecasts based on economic structure

Forecasting **models based on economic structure** involve parametric models based on historical information. These forecasting models rely heavily on econometric techniques and time series analysis, which incorporate macroeconomic variables into the models.

The data required by the econometric forecasting models used in *LongRun* falls into two general categories: financial time series and economic time series. Financial time series data include historical spot and forward rates and prices of financial assets, whereas economic time series data include macroeconomic variables such as measures of output (e.g., industrial production) and money supply. Time series of prices and rates are the most widely available type of data.

In our context, we are concerned with constructing a tractable model that describes as accurately as possible the evolution of the variables of interest. One usually defines a model that is consistent with economic theory and the empirical behavior of the time series, and fits the data to the chosen model. The first step in the construction of a model is to define its functional form, that is, we need to write an equation describing how the asset prices relate to all the possible economic variables and how those prices evolve over time. The second step is to choose the economic variables we want to include in our model. In practice, this process is done iteratively since the quality of our choices can only be assessed empirically.

A widely used time series model in finance and economics is the **autoregressive (AR)** model. The idea behind an autoregressive process is that the current value of the time series depends on its im-

mediate past values together with a random error. For example, we can model the price of a stock tomorrow as the price of the stock today plus some random noise. However, since we are concerned with modeling multiple assets that are related to one another and depend on a number of factors, we need a model that takes into account the co-movement in financial and economic variables. In the **Vector Autoregressive Model (VARM)**, each variable depends on its own past values as well as on the past values of all the other variables in the system, allowing for joint forecasts of future values.

Jointly forecasting a set of related financial variables is often complicated because some properties of the time series, such as mean and variance, are not stable and change continuously through time. Most of the time series theory is built around stable time series, and the analysis often requires one to transform a non-stable time series into a stable one.

A popular approach to addressing the non-stationarity of individual time series is known as **co-integration**. Economic theory conjectures that there are long-run equilibrium forces that prevent some economic series from drifting too far apart. The basic notion behind co-integration is the existence of a stable relationship between variables, so that even if the individual time series appear to move in a random manner, we can use any long-term stability in their co-movements to make forecasts. This co-integrating relationship is said to provide an error-correction mechanism and gives the foundation for what are called **error correction models (ECM)**.

In order to make the best use of the macro fundamental variables and their long-term cointegration relationship, we describe in *LongRun* a model under the VARM and ECM framework called the **Vector Error Correction Model (VECM)**.

Forecasts provided by econometric and time series models reflect the properties of the historical period used to estimate the model's parameters. Sometimes the historical data set used to estimate the model is too short to represent the future economic regime (i.e., monetary policy and business cycles regimes), and other times the history is so long that too many regimes are represented in the data. Regime-switching/detection models are used to capture changes in structural regimes, and the idea behind them is that the model changes in time according to the prevailing economic regime. *LongRun* uses regime switching/detection models where we either try to forecast regimes using historical information or simply identify historical regimes.

7.2.1.3 User-defined scenarios

User-defined scenarios for future market rates can be constructed to model situations of special interest to a company. For example, user-defined scenarios may include shocks to market rates and thus quantify large negative shocks to the company's most significant exposures, or they may include consensus forecasts generated from a survey of a company's managers or in-house researchers. User-defined scenarios may also be useful for companies with expertise in a particular type of forecasting (e.g., mining companies whose business activities provide specific insights into likely commodity price levels).

The process of formulating and selecting user-defined scenarios can be a time-consuming one and usually results only in point-estimates of market rates at a particular forecast date. Without a complete probability distribution function, it is difficult to assess the likelihood of occurrence for these scenarios. In order to construct a distribution of market rate values from multiple user-defined scenarios, probabilities of occurrence for each scenario need to be specified.

7.2.2 Simulation

Once we have forecasted the price and rate distributions using methods such as those described in Section 7.2.1, we use Monte Carlo methods to simulate price and rate scenarios for the forecast horizon.

LongRun's simulation procedure is divided into two steps:

- **Level I simulation** involves simulating prices and rates on the dates for which market rate distributions are specified (e.g., weekly, monthly, or other frequency). We refer to the dates as *forecast dates*. Chart 7.3 shows three hypothetical scenarios that consist of monthly forecasts.
- **Level II simulation** refers to a process for simulating daily prices, which may be needed by some institutions (e.g., to simulate the value of path-dependent options). Assuming the Level I forecasts are non-daily, Level II simulation can be used to “fill-in-the-gaps” between Level I forecast dates, and to force the daily rates to “go through” each of the Level I forecasts.³ (This approach is based on a Brownian Bridge model, which is discussed in *LongRun*, Chapter 5.) Chart 7.4 illustrates Level II simulated daily prices, which coincide with the Level I forecasts shown in Chart 7.3.

Both Level I and II simulations require that we simulate from multivariate distributions that take into account the correlation structure between variables. The forecasting procedures introduced in this chapter address the means and volatilities of market rates and prices, but not correlations among assets. The procedure for constructing a covariance matrix that is consistent with *LongRun*'s forecasts is presented together with the simulation techniques in Chapter 5 of *LongRun*.

7.3 *LongRun*: The long-horizon forecasting framework

The RiskMetrics Group has developed *LongRun* as a framework for generating market rate scenarios over long horizons. *LongRun* is not specific to CorporateMetrics since its framework describes how to generate scenarios that are usable in any context requiring long-horizon forecasts, such as market risk analysis, credit risk analysis, or asset liability management. However, *LongRun* is intended as a companion framework to CorporateMetrics and is recommended for those who are interested in the techniques surveyed in this chapter and who would like more details on implementing the approach.

Note that the RiskMetrics framework for portfolio market risk measurement provides market volatility estimates for short-term periods (up to three months). While it is possible to scale the RiskMetrics volatility estimates to use as input into generating the long-horizon scenarios necessary for corporate risk measurement, simple scaling rules fail to incorporate economic factors such as long-term trends, or the tendency of some prices to revert to their long-term means. *LongRun*'s forecasting methodology can account for these observed relationships and is therefore more suited for long-horizon risk measurement.

³ In theory, Level I simulation can be used to generate daily scenarios. This requires forecasting market rate distributions for each day in the forecast period, and involves a very large amount of data and modeling (e.g., to generate scenarios spanning a 6-month period requires 180 days' worth of probability distributions for each scenario). *LongRun* provides Level II simulation as a more efficient process for generating daily scenarios.

Chart 7.3

Level I simulation: simulated prices at three forecast dates

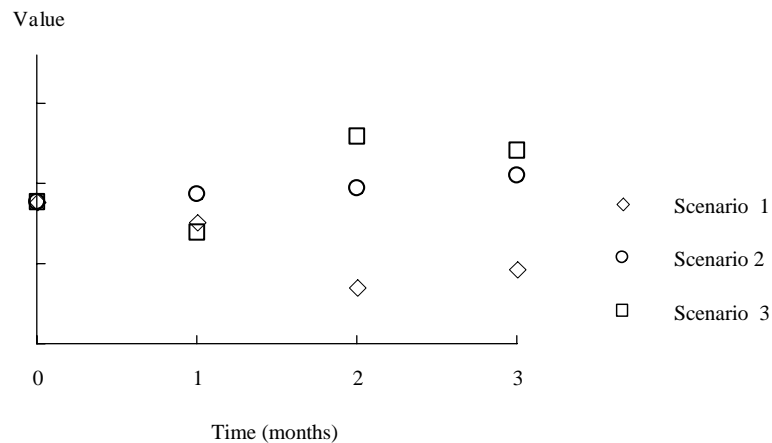
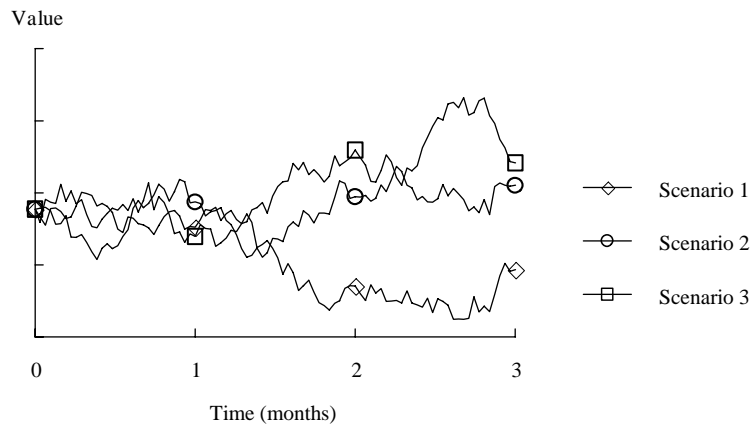


Chart 7.4

Level II simulation: simulated daily prices



In summary, the *LongRun* long-horizon forecasting framework provides the following:

- **LongRun Technical Document**—a framework for long-horizon forecasting
LongRun's scenario generation procedure is done in two separate steps: forecasting and simulation. LongRun consists of two alternative forecasting procedures based on different data sets. The first is based on current market data and relies on implied (risk-neutral) parameters to obtain forecasts, while the second uses historical financial and economic data and is constructed around econometric modeling. Once we obtain price and rate forecasts, we can choose to simulate scenarios either at the same horizons for which we obtained forecasts (Level I simulation), or at any arbitrary date between forecast horizons (Level II simulation).

LongRun covers

- construction of forecasting models,
- backtesting of forecasting models,
- simulation techniques, and
- applications of long-horizon forecasting.

- **Data**

The historical market and macroeconomic data necessary for implementing econometric forecasting techniques can be obtained from the DataMetrics service offered by the RiskMetrics Group. In addition, implied volatility and forward rate information is available on a daily basis to facilitate forecasting using current market information.

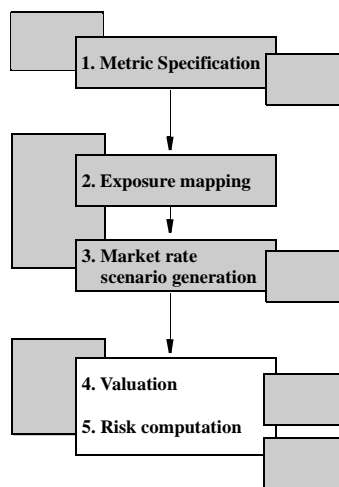
- **Web site**

A Web site providing access to DataMetrics, selected long-horizon forecasts, and methodologies is available at <http://www.riskmetrics.com>.

- **Software implementation**

The analytics described in the *LongRun Technical Document* and the interfaces to the DataMetrics historical market and macroeconomic data will be incorporated in the CorporateManager application to facilitate the implementation of long-horizon forecasting methodologies.

Chapter 8. Valuation and risk computation



The final steps in the risk measurement process are

- the valuation of financial results using exposure maps and market rate scenarios to create a distribution of financial results, and
- the computation of risk measures from distributions of financial results.

8.1 Valuation

Valuation, in the simplest terms, involves either using an equation to calculate earnings, or cash flow, or their respective components as a function of forecasted market rates, or updating a pro forma statement with a new market rate scenario in order to project financial results. In either case, the process can be represented as an exposure map being recalculated under different market rate values from a large set of market rate scenarios.

For example, returning to the exposure map shown in Example 6.1, the expected revenues R_c in USD resulting from a company's Canadian sales can be modeled as a function of exchange rates as follows:

$$\begin{aligned}
 R_c &= \text{CAD revenue each quarter, translated back to USD} \\
 [8.1] \quad &= \frac{(\text{C\$100 per unit}) \times (1,000 \text{ units})}{(X_1 + X_2 + X_3 + X_4)},
 \end{aligned}$$

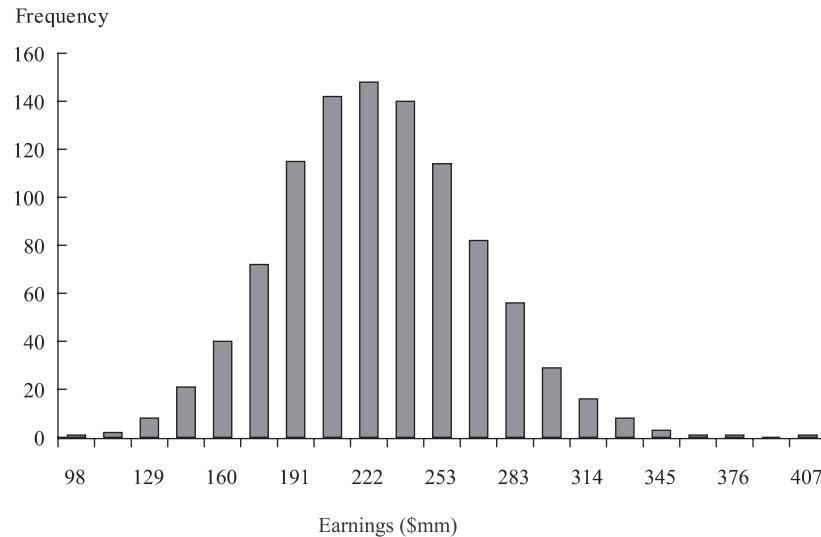
where X_i is the average daily CAD per USD exchange rate during quarter i from the analysis date. In order to obtain a distribution of the possible revenues, valuation is performed for a large number of different CAD/USD exchange rate scenarios, where each scenario consists of sequential estimates of the average daily CAD/USD exchange rate for each of the four quarters. Assuming, for example, that 1,000 different exchange rate scenarios have been generated, the exposure map needs to be re-calculated using the values in each of the different scenarios.

If the exposure maps have been constructed as pro forma financial statements, they can be easily valued by a commonly used method, i.e., constructing an “assumptions page” for the pro forma financial statements, which lists the assumed values for the market rates and prices to which a company is exposed. For each iteration in the valuation process, the market rates in the assumptions page are updated with the market rate values specified in the new scenario. If some other form of exposure map is being used (e.g., an equation or other model), then for each iteration of the valuation process, the market rate values in the scenario are entered and the exposure map is recalculated.

The outputs of each iteration (e.g., the output values for the components of earnings or cash flow being analyzed) are recorded to produce a distribution of financial results.¹ An example of this is shown in Chart 8.1, in which a histogram of future earnings outcomes is obtained from the valuation of a company's consolidated earnings. The data was obtained by re-calculating a pro forma statement under market rate values from each of 1,000 scenarios, which results in 1,000 different earnings outcomes.

¹ By using scenarios generated from market rate probability distribution functions such as those discussed in Chapter 7, the resulting distribution of financial results will reflect the market risk implied by the market rate probability distribution functions.

Chart 8.1
Distribution of future earnings
1,000 trials, 12-month horizon



From the distribution of financial results, risk measures can be calculated as explained in Section 8.2.

8.2 Risk computation

As discussed in Chapter 2, a number of different risk statistics can be calculated from a distribution of financial results. Examples include: standard deviation, confidence level, maximum shortfall relative to target (relative risk), and average shortfall. In this section, we describe all four statistics, with particular emphasis on the third one (relative risk), since it best characterizes the CorporateMetrics risk measures (EaR, EPSaR, CFaR). Finally, we discuss how measures of relative risk are computed.

8.2.1 Types of risk measures

Using the distribution of financial results obtained from valuation, we can calculate different sample statistics to obtain a variety of risk measures. The measures below describe different aspects of any given distribution of financial results and can contribute different perspectives to our understanding of the market risk that a company faces.

- **Standard deviation:** This is a symmetric measure of dispersion from the expected (or mean) value of the financial result being forecasted. If financial results are distributed normally (or according to some other known distribution that is completely characterized by its mean and standard deviation), the confidence level for a particular level of financial results can be inferred from standard deviation measures.² However, if the financial results are non-normally distributed, it is generally not possible to determine the confidence level for a particular level of financial results using only the standard deviation. Also, since the standard

² For example, if the mean and standard deviation for a hypothetical corporate cashflow distribution are \$10mm and \$2mm respectively, and we know the cash flows are normally distributed, then we can say with 95% confidence that cash flow will not be less than $\$10\text{mm} - 1.65 \times \$2\text{mm} = \$6.7\text{mm}$.

deviation statistic is a symmetric measure of dispersion, it does not distinguish between the above-mean and below-mean sides of the distribution.

- **Confidence level:** This reflects the likelihood that a financial result will not fall below a specified level.³ The interpretation of confidence level is straightforward and more intuitive than for standard deviation. For example, the likelihood that cash flow will not fall below the 95th confidence level of cash flow is, by definition, 95 percent. There is no particular confidence level that is “best” (e.g., 95%, 99.0%, 99.5%, and so forth.). The particular level used is a company’s choice, and depends mostly on how the risk measure will be applied. To calculate a confidence level for non-normal distributions, the full distribution of financial results is generally required, as opposed to just the standard deviation.
- **Maximum shortfall relative to target, for a specified confidence level:** This measures the maximum amount by which earnings or cash flow can fall short of a target level, for a specified confidence level, due to market risk. To calculate this measure, confidence level analysis is needed first in order to determine on an absolute basis the likelihood of different levels of financial results. The level of financial results corresponding to a specified level of confidence is then compared against the target, from which maximum shortfall can be deduced. This type of relative risk measure is useful in the corporate context since it conveys information about the likelihood of an outcome and it enables companies to measure risk relative to a target.
- **Average shortfall:** This statistic is defined as the expected level by which financial results can fall short of a specified level. For example, if the average shortfall for an earnings distribution is \$10mm relative to a specified level of \$25mm, this means that conditional upon the outcome that earnings are \$25mm or less, the expected amount by which earnings will fall short of \$25mm is \$10mm (i.e., the expected level of earnings is \$15mm, conditional upon a level of earnings below the target). While this does give some intuition about risk, it does not have quite as concrete an interpretation as a confidence level. For instance, we still do not know the likelihood that quarterly earnings will be \$15mm or less.

The above statistical measures (or others) can be calculated from any distribution of financial results. In this document, we will focus on maximum shortfall relative to target, for a specified level of confidence, since the CorporateMetrics risk measures are defined in these terms. However, it is important to note that once a distribution of financial results is obtained from the valuation process, any sample statistics that provide meaningful insights to risk can be calculated.

The calculation of relative risk measures requires two steps: (1) confidence level analysis, which measures absolute risk, and (2) using the results of confidence level analysis to compute risk relative to a target. These steps are discussed in the following sections.

8.2.2 Confidence levels and absolute risk measures

Confidence level measures are examples of **absolute risk measures** in that they identify a level of earnings or cash flow for which we know the probability of that level being exceeded or underperformed. In general, to calculate an absolute risk measure, we need to calculate the worst case potential value or result for a particular level of confidence.⁴ Value-at-Risk, as defined in RiskMetrics,

³ Another way to think of confidence levels is with respect to percentile levels (e.g., the probability that a financial result falls below the 5th percentile is by definition 5%). When we refer to the $x\%$ confidence level result, it is the same thing as referring to the $(100-x)$ percentile result. Either viewpoint is equally valid. Our choice in defining the confidence level perspective is based on its apparent popularity amongst corporate risk managers.

⁴ Mathematically, for a financial result R (random variable), calculating the worst case result R_w with a level of confidence α requires determining the value of R_w from the following relationship: $\text{Probability}(R > R_w) = \alpha$

is an example of an absolute risk measure. Another example of an absolute risk measure would be the worst case EPS for a given period with a particular level of confidence.

8.2.2.1 Deducing confidence levels from distributions of financial results

Using a tabular approach, it is possible to obtain confidence levels from a distribution of earnings or cash flow by ordering the results by value and identifying the result corresponding to the desired confidence level. For example, to estimate the worst case earnings result with 95% confidence (which corresponds to the $100\% - 95\% = 5\text{th}$ percentile result) using 1000 trials, we would order the results and identify the level of earnings such that 5% of the 1000 results (50) are below that threshold and 95% of the 1000 results (950) are above that threshold.

Example 8.1 Worst case earnings estimate

Table 8.1 shows a distribution of consolidated earnings obtained from valuation, and ranked from best to worst.

Table 8.1

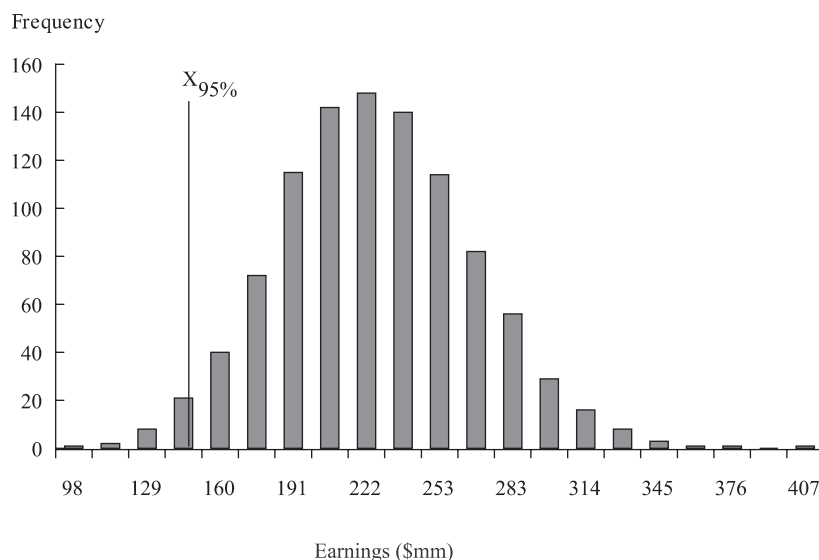
Computing confidence intervals

Rank	Earnings, \$mm	Rank	Earnings, \$mm
1	407.00	990	135.00
2	402.00	991	133.00
3	397.00	992	131.00
4	393.00	993	124.00
5	389.00	994	118.00
6	385.00	995	112.00
.		996	108.00
.		997	104.00
.		998	102.00
950	151.00	999	99.00
951	150.00	1000	98.00
.			

In 1,000 trials, earnings range from \$407mm to \$98mm for the forecast period. To estimate the worst case earnings with 95% confidence, we need to identify a threshold $X_{95\%}$ such that 95% of the 1000 trials (950) show earnings greater than $X_{95\%}$ and the remaining 5% of the 1000 trials (50) show earnings less than $X_{95\%}$. For the scenarios shown, this threshold is between \$150mm and \$151mm. Similarly, with 99% confidence, the worst case earnings would be at a threshold of $Y_{1\%}$ such that 99% of the trials (990) have earnings greater than $Y_{1\%}$ and the remaining 1% of the trials (10) have earnings less than $Y_{1\%}$. For the scenarios shown, this threshold is between \$133mm and \$135mm.

When Table 8.1 is converted to a histogram (Chart 8.2), the worst case result would be the point on the x-axis such that the number of outcomes to the right of the point is equal to the number implied by the confidence level specified. For example, the 95% worst case result would be the value $X_{95\%}$, for which the number of outcomes to the right of the value is equal to 95% of the total number of trials in the histogram.

Chart 8.2

Calculating absolute risk—earnings result at 95% confidence level**8.2.2.2 Precision of confidence level estimates**

Note that the risk measures obtained from a simulation-based approach are subject to fluctuations, depending on the number of market rate scenarios used. In other words, a given set of scenarios may not produce a 95% worst case result for the sample which is equal to the true 95% worst case result. It is important to quantify, given the number of scenarios which are generated, how close we expect our estimates of various sample statistics to be to their true value. In fact, a reasonable way to choose the number of scenarios to be generated is to specify some desired level of precision for a particular statistic, and generate enough scenarios to achieve this. Quantifying the precision of simulation based statistics is detailed in Appendix B.

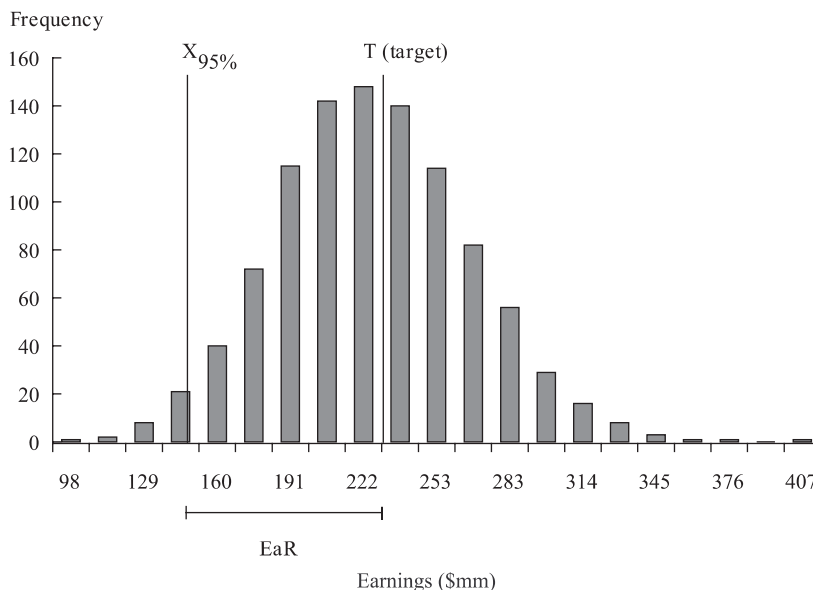
8.2.3 Relative risk—maximum potential shortfall relative to target

Relative risk measures quantify, at a specified level of confidence, the maximum potential shortfall of earnings or cash flow relative to a target level. Relative risk measures quantify the degree to which actual performance could fall short of a specified target level or benchmark.

Example 8.2 Computing relative risk: Earnings-at-Risk (EaR)

Suppose the company noted in Example 8.1 has target earnings of \$222mm for the forecast period, as shown in Chart 8.3. As shown in the preceding section, the 95% confidence level earnings result is \$151mm. The company's Earnings-at-Risk (which is a measure of maximum potential shortfall relative to a target) at the 95% confidence level is therefore $\$223\text{mm} - \$151\text{mm} = \$82\text{mm}$.

Chart 8.3

Calculating relative risk: Earnings-at-Risk*1,000 trials, 95% confidence*

All of the CorporateMetrics risk measures defined in this document (EaR, EPSaR, and CFaR) measure the maximum potential shortfall of financial results relative to a target level, for a specified level of confidence, due to market risk. As noted above, in order to calculate such measures, confidence level analysis is first needed, from which potential shortfalls relative to target can be measured.

Depending upon the risk measure being used, the confidence level analysis needed is as follows:

- EaR and EPSaR require determining the worst case level of earnings (or level for the component of earnings being analyzed, e.g., revenue or expenses) for the specified level of confidence.
- CFaR requires determining the worst case level of cash flow (or level for the component of cash flow being analyzed) for the specified level of confidence.

Once the result at the desired confidence level result is determined, it is subtracted from the specified target level, thus yielding the maximum potential shortfall. For example, in the case of earnings, if $X_{\alpha\%}$ is the worst case level of earnings for a specified confidence level α and T is the target earnings level, then the magnitude of EaR is calculated as $T - X_{\alpha\%}$. Chart 8.3 illustrates the computation of EaR at the 95% confidence level. Graphically, the distance between T and $X_{95\%}$ as shown is equal the magnitude of EaR.

Note that the calculation of relative risk measures makes sense only for target values $T > X_{\alpha\%}$. Otherwise, there would be no potential shortfall, since the “worst case” result would exceed the target level. In general, if the value of the target financial result is too low, the probability of underperformance may or may not be zero, depending on the shape of the distribution of financial results. Hence, the choice of market rates (e.g., budget rates, forward rates, or VECM forecasts) used as input to calculate target levels directly affects the resulting risk measures. If the expected means of the market rate distributions that are used for scenario generation are also used as inputs to calculate target levels, then $T > X_{\alpha\%}$ will generally be true for choices of confidence level that are sufficiently large (e.g., 90% or higher) and for distributions of financial results that are not strongly skewed.

However, if the distribution of financial results is calculated by using scenarios from one set of market rate probability distribution functions, and the target result is calculated from a different set of market rate assumptions, there could be instances where $T < X_{\alpha\%}$. Since some companies may be using one set of internally-set budget rates to calculate targeted earnings and cash flow and another set of assumptions to generate scenarios (e.g., VECM, current market information, and so forth), the companies will need to understand that the possibility of $T < X_{\alpha\%}$ may arise because the methodologies behind the setting of budget rates differ from the methodology used for scenario generation. For detailed examples demonstrating the calculation of risk, see Chapter 9.

Part III

Examples and Backtesting

Chapter 9. Examples

9.1 Illustrating the CorporateMetrics approach

In this section we present a series of detailed examples illustrating the calculation of Earnings-at-Risk (EaR), Earnings-per-Share-at-Risk (EPSaR), and Cash-Flow-at-Risk (CFaR) for a variety of different exposures. We start with examples that focus on individual exposure types, such as a particular component of earnings or cash flow. We conclude with an example of how to measure risk across multiple exposure types by illustrating the computation of market risk for the consolidated exposures of a fictitious company, ABC Corporation (“ABC”), which we assume is a U.S.-based multinational.

For long-horizon forecasting, we used the Vector Error Correction Model (VECM), which is an econometric forecasting model provided in the *LongRun* framework, to specify market rate probability distributions. Using these distributions, we generated 10,000 market rate scenarios that describe the paths for foreign exchange rates, interest rates, and commodity prices to be used in the examples. The analysis date is assumed to be 30 September 1998, and the 12-month period covered by the analysis is 1 October 1998 to 30 September 1999. Historical market and macroeconomic data from 1988–1998 has been used as the basis for determining parameters for the market rate probability distributions corresponding to each forecast horizon.

By convention, all revenue-related items and cash in-flows to ABC will be shown as positive amounts, and all expense-related items and cash out-flows paid by ABC will be shown as negative amounts. In the examples, we specify that ABC uses the internal budget rates shown to set target levels for different components of earnings and cash flow. By design, we have made the budget rates different from the mean market rate and price forecasts provided by the VECM model to show how companies can interpret risk measures that use both internally specified rates and scenarios generated using the methodologies outlined in *LongRun*.

We assume that ABC is a public company with 5,000,000 common shares outstanding.

Example 9.1 Earnings-at-Risk (EaR) due to commodity price risk—gold expenses

This example shows how fluctuations in commodity prices can affect a company's cost of goods sold, which in turn affects earnings. Suppose that ABC sells industrial products that use gold as the principal raw material. ABC buys gold throughout the year to feed into its production process. ABC's internal budget rate for gold is fixed at \$300 per Troy ounce. ABC would like to analyze the potential effect of gold price risk on earnings during the period covering 1 October 1998 to 30 September 1999.

Step 1: Metric specification

ABC elects to calculate EaR due to fluctuations in gold prices, and therefore, to measure maximum potential shortfall relative to target with 95% confidence. The time horizon over which ABC will calculate risk is 12 months.

Step 2: Exposure mapping

Suppose ABC purchases gold at the end of each quarter during the year. The gold purchased at the end of any given quarter is both expensed and used for production in the following quarter. The amounts of gold that ABC anticipates purchasing to meet the production needs in the upcoming four quarters are shown below:

Gold purchases	30-Sep-1998	31-Dec-1998	31-Mar-1999	30-Jun-1999
Troy oz.	5,000	5,004	5,004	4,979

If ABC assumes that the above purchase quantities are fixed, then ABC's gold expenses G for the given year can be summarized by the following equation:

$$[9.1] \quad G = -5,000P_0 - 5,004P_1 - 5,004P_2 - 4,979P_3,$$

where P_i is the spot price of gold at the end of the i -th quarter from today. The spot price on the analysis date, 30 September 1998, is $P_0 = \$297$ per Troy oz. Equation [9.1] explicitly shows how future gold prices will affect gold expenses for the upcoming 12 months. Since gold expense is a component of earnings, we can use this equation as an exposure map to calculate EaR due to gold risk.

Step 3: Scenario generation

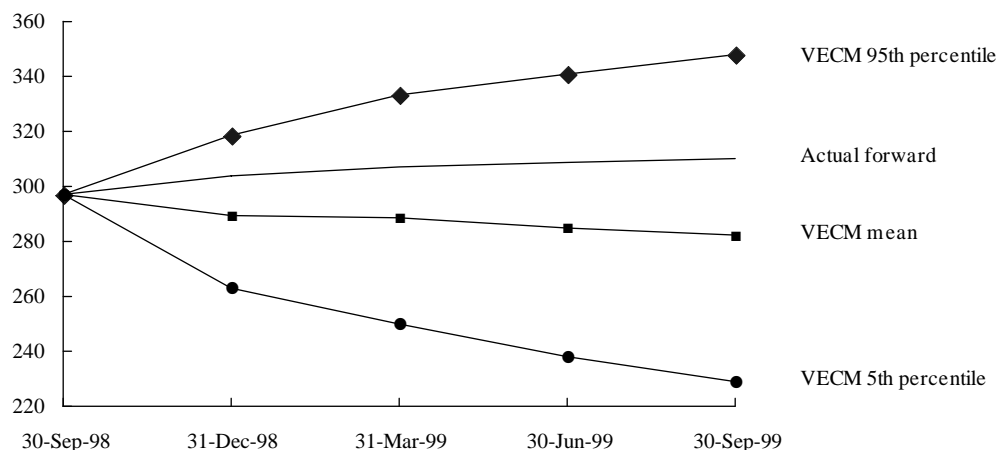
Since ABC's gold purchases happen once at the end of each quarter, we need the actual gold price on the analysis date (30 September 1998, which is an end-of-quarter date) and gold price scenarios that consist of price projections at the following three horizons: 31 December 1998, 31 March 1999, and 30 June 1999. In order to generate the scenarios, we first specify market price distributions for gold prices at each end-of-quarter horizon using the VECM approach. Chart 9.1 shows several parameters of the VECM distributions, including the mean and the 5th and 95th percentile levels. For reference, the chart also shows the actual gold forward prices that prevailed in the market on the analysis date.

Chart 9.1

Gold price probability distribution parameters and forward prices

Analysis date: 30 September 1998

\$ per Troy oz.



Using the above VECM gold price probability distributions and *LongRun's* Level I scenario generation algorithms, we simulated 10,000 possible paths for quarterly gold prices during the period covering 31 December 1998 to 30 June 1999.¹

Step 4: Valuation

The 10,000 scenarios generated in Step 3 form a distribution of ABC's projected gold prices for the upcoming four quarters. Substituting these prices into the exposure map produces a distribution of the possible gold expenses.

We will illustrate this with one sample scenario. Let us assume that one of the 10,000 generated paths for gold prices is the following:

Gold-price scenario	30-Sep-98	31-Dec-98	31-Mar-99	30-Jun-99
USD per Troy oz.	\$ 297	\$ 290	\$ 292	\$ 305

If gold prices follow this path, the gold expenses for the year would be as follows:

Possible gold expenses	4Q 1998	1Q 1999	2Q 1999	3Q 1999	Total
Purchases, Troy oz.	5,000	5,004	5,004	4,979	19,988
USD per Troy oz.	297	290	292	305	
Expenses, \$000s	\$ (1,485)	\$ (1,451)	\$ (1,461)	\$ (1,519)	\$(5,916)

Thus, for the above scenario for gold prices, the outcome would be a total expense of (\$5.9mm) for the upcoming 12 months.

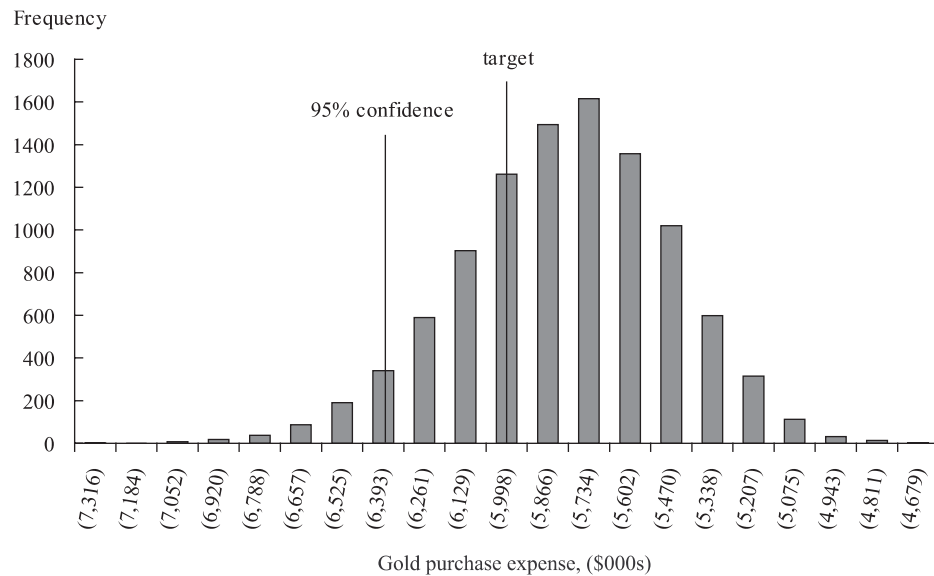
¹ For a detailed discussion of scenario generation from probability distributions, see *LongRun*, Chapter 5.

By calculating gold expenses for each price scenario, we obtain the distribution of gold expenses shown in Chart 9.2. As shown, the 95% confidence level for gold expenses is (\$6.38mm).

Chart 9.2

Distribution of gold expenses, 4Q 1998–3Q 1999

10,000 trials



Step 5: Risk computation

To calculate the maximum gold expense in excess of budget, we need the target level of expense and the 95% confidence level of expense.

The target level of gold expense is given by ABC's budgeted plan. ABC's internal budget rate for gold is \$300 per Troy ounce. Given ABC's planned purchases and budget rate, the budgeted gold expense is therefore (\$6.0mm), as shown in Table 9.1.

Table 9.1

ABC Co.'s budgeted gold expense

	4Q 1998	1Q 1999	2Q 1999	3Q 1999	Total
Purchases, Troy oz.	5,000	5,004	5,004	4,979	19,988
USD per Troy oz.	300	300	300	300	
Expenses, \$000s	\$ (1,500,00)	\$ (1,501)	\$ (1,501)	\$ (1,494)	\$ (5,996)

Based on the target expense and the 95% confidence level gold expense, the maximum overrun on gold expense at 95% confidence is (\$6.0mm) – (\$6.38mm) = \$387,000.

ABC assumes that no adjustments to sales prices will be made to compensate for increased raw material costs (e.g., ABC's product markets are very competitive and are characterized by price stability). Therefore, a \$1 overrun on gold expense has a \$1 negative impact on pre-tax earnings relative to target. From its expense risk calculations shown above, ABC therefore determines that the company has a pre-tax EaR of \$387,000 due to gold price risk.

Alternatively, assuming ABC has 5,000,000 common shares outstanding, ABC's gold expenses have a pre-tax Earnings-per-Share-at-Risk (EPSaR) of \$0.08. In other words, at 95% confidence, ABC's earnings in the next four quarters could fall short of target by at most \$0.08 per share due to gold price risk.

A note on Cash-Flow-at-Risk (CFaR)

If we assume ABC pays its gold suppliers in full at the time of each purchase, then the actual cash flow associated with the purchases occurs in the period prior to the period in which ABC recognizes expenses. Thus CFaR and EaR due to gold risk for a given period may be slightly different given the time lag between the recognition of expenses and the actual payment of cash.

However, if ABC pays its gold suppliers on a delayed basis such that the cash payments occur during the same quarter in which ABC recognizes expenses for a given gold purchase, gold price fluctuations affect earnings and cash flow identically (i.e., EaR and CFaR due to gold risk are the same).

In general, as the duration of payment terms increases, the potential difference in magnitude between EaR and CFaR for a given period increases. Understanding the effect of payment terms can help companies understand the potential differences between different types of risk measures.

Example 9.2 EaR of gold price risk—incorporating the effect of hedges

This example shows how the use of options can affect the level of commodity price risk for a company that has an underlying stream of commodity purchases. Suppose ABC intends to hedge planned gold purchases (as discussed in Example 9.1) by entering into the following option contracts on the analysis date, 30 September 1998:

- Long call options on gold, strike price \$310 per Troy ounce, notional amount of 5,000 Troy ounces, with maturities of 3, 6, and 9 months.
- Short put options on gold, strike price \$280 per Troy ounce, notional amount of 5,000 Troy ounces, with maturities of 3, 6, and 9 months.

The effect of these contracts will be to lock into a range ABC's anticipated gold expenditures for 1Q99, 2Q99, and 3Q99. ABC's expenditure for 4Q98 is already locked in since the company purchases the gold needed during 4Q98 on the analysis date.

Step 1: Metric specification

ABC elects to calculate EaR due to fluctuations in gold prices, taking into account the combined effect of the company's underlying expense on gold purchases, net expense on option premia, and the potential payoffs associated with option contracts. The time horizon over which ABC will calculate risk is 12 months and the confidence level used is 95%.

Step 2: Exposure mapping

Assume that gold option implied volatility levels and gold lease rates on the analysis date are as follows:

Option maturity	31-Dec-98	31-Mar-99	30-Jun-99
Implied volatility, % p.a.	13.75	14.63	15.51
Lease rate, % p.a.	0.8338	1.5325	1.6600

Using a standard Black-Scholes approach for valuing the gold options and assuming a fixed risk free rate of 5.53% for option valuation purposes, the expenses and proceeds related to option premia on the analysis date are assumed to be the following:

Expenses and proceeds	Maturity:			Total
	3m	6m	9m	
Call costs, \$000s	(22)	(46)	(69)	(137)
Put proceeds, \$000s	8	19	29	15
Total	\$ (14)	\$ (27)	\$ (40)	\$ (82)

Given the individual option expenses and proceeds, ABC estimates that the net expense CP for option premia is (\$82,000).

The payoff V_C , associated with ABC's long positions in call option contracts, is given by the following equation:

$$[9.2] \quad V_C = 5000[\max(P_1 - 310, 0) + \max(P_2 - 310, 0) + \max(P_3 - 310, 0)],$$

where P_i is the spot price of gold at the end of the i -th quarter from the analysis date. Similarly, the payoff V_P , associated with ABC's short positions in put option contracts, is given by the following equation:

$$[9.3] \quad V_P = 5000[\min(P_1 - 280, 0) + \min(P_2 - 280, 0) + \min(P_3 - 280, 0)] .$$

The total payoff V_{CP} , from ABC's option contracts, is therefore the sum of V_C and V_P .

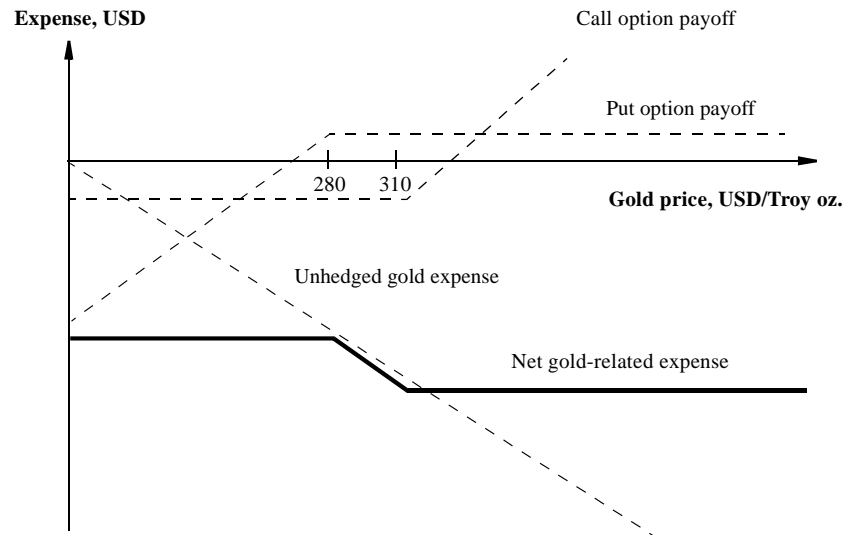
Using the definition of G for ABC's gold purchase expense as shown in Eq. [9.1], ABC's total gold-related expense (purchases, net option premia expense, option payoffs) E_G is given by:

$$[9.4] \quad E_G = G + CP + V_{CP} .$$

Since the above equations show how gold prices will affect ABC's total gold-related expenses (which in turn will have an impact on reported earnings), we can use these equations as exposure maps.

Chart 9.3 illustrates how ABC's planned purchasing activity and hedging strategy combine to modify the company's gold expense profile as compared to the unhedged profile discussed in Example 9.1. The chart shows the expense profile for the period covering 1 January 1999 to 31 March 1999.

Chart 9.3
Gold expense profile, including option hedges, 1Q 1999



Step 3: Scenario generation

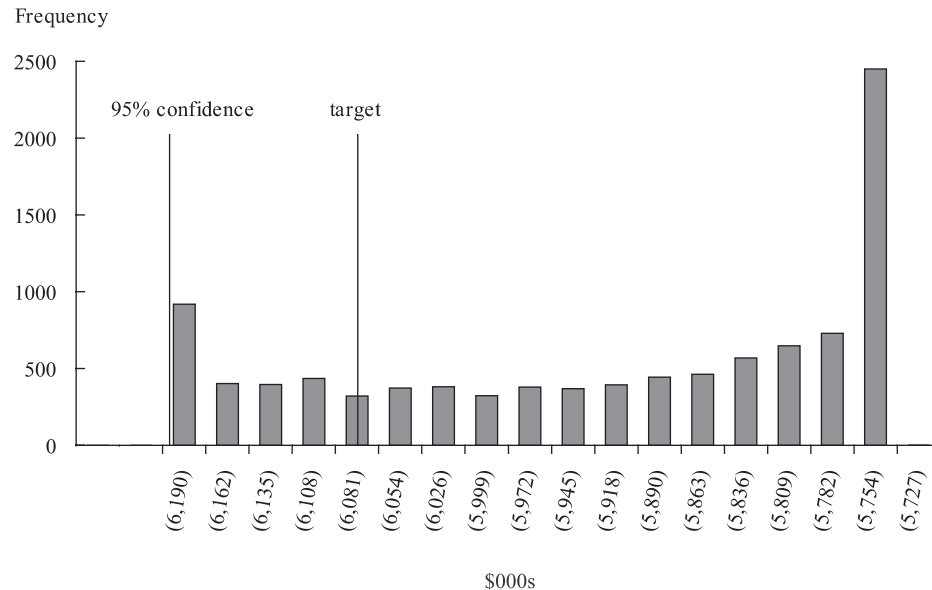
The gold price scenarios used in Example 9.1 can also be used in this example to calculate the different possible joint combinations of gold purchase expenses and option payoffs.

Step 4: Valuation

For each scenario of gold prices, the cumulative net option payoffs (gold option payoffs less expenses for option premia, CP) and underlying gold expenses can be projected simultaneously for each of the upcoming four quarters by using Eq. [9.4]. The distribution of hedged gold expenses is shown in Chart 9.4. The 95% confidence level for gold expenses is (\$6.212mm).

Chart 9.4

Distribution of combined gold expenses and net option-related payoffs, 4Q 1998–3Q 1999
 10,000 trials



The large frequencies in the lower- and upper-most bins of the histogram are due to the fact that the option strikes of \$280 and \$310 per Troy oz. represent a fairly tight range around the mean gold prices predicted by VECM at each horizon date. The minimum (or “worst case”) outcome out of 10,000 scenarios was (\$6.213mm) and the maximum outcome was (\$5.76mm). Since the range is narrow, a significant percentage of the scenarios results in either the long position in call options paying off or the short put option positions incurring payment obligations. Note that over 50% of the outcomes are based on scenarios in which average gold prices are less than ABC’s assumed budget rate of \$300 per Troy oz. This helps to explain why the frequency of outcomes in the upper-most bin (–\$5.78mm to –\$5.75mm) is larger than the frequency of outcomes in the lower-most bin (outcomes below –\$6.19mm).

Given the nature of the positions and price distributions, the expense associated with the worst case outcome was only slightly more than the expense at the 95% confidence level: (\$6.213mm) vs. (\$6.212mm). This is due to the fact that the gold hedging strategy effectively caps the potential level of gold expenses.

Step 5: Risk computation

The target hedged gold expense is given by ABC’s budgeted plan expenses for gold purchases less the budgeted option premia (ABC’s budget rate of \$300 per Troy ounce implies that no net payoffs are anticipated for the option contracts used). Given ABC’s planned purchases at its budget rate less budgeted option premia, the budgeted gold-related expense is (\$6.078mm), as shown in Table 9.2.

Table 9.2

ABC Co. budgeted gold purchase and option expenses

	4Q 1998	1Q 1999	2Q 1999	3Q 1999	Total
Purchases, Troy oz.	5,000	5,004	5,004	4,979	19,988
Price per Troy oz., \$000s	300	300	300	300	
Purchase expense, \$000s	(1,500)	(1,501)	(1,501)	(1,494)	(5,996)
Option expense	–	(14)	(27)	(40)	(82)
Total, \$000s	\$ (1,500)	\$ (1,516)	\$ (1,528)	\$ (1,534)	\$ (6,078)

Based on the target hedged-expense and 95% confidence gold-related expense, the maximum over-run on hedged gold expense is $(\$6.078\text{mm}) - (\$6.212\text{mm}) = \$134,000$, with 95% confidence.

As in Example 9.1, if ABC assumes that no adjustments to sales prices will be made to compensate for increased input costs, then a \$1 overrun on hedged gold expenses has a \$1 negative impact on pre-tax earnings relative to target. Therefore, assuming ABC hedges its exposures using the options strategy described above, ABC's gold-related exposures result in a pre-tax EaR of \$134,000, or a pre-tax EPSaR of \$0.03, with respect to targeted expenses of (\$6.078mm).

In summary, if ABC does not hedge its gold purchases, then the company has an unhedged target expense of (\$6.0mm) and EaR of \$387,000 with respect to the unhedged target expense. If ABC hedges its gold purchases with the option contracts shown above, then the company has a hedged target expense of (\$6.08mm) and EaR of \$134,000 with respect to the hedged target expense. By spending (\$82,000) to hedge, ABC can therefore reduce maximum potential gold expense, with 95% confidence, from (\$6.38mm) to (\$6.21mm), which is a net risk reduction of \$171,000 relative the unhedged target expense.

With these risk measures as input, ABC can decide whether or not the (\$82,000) of additional expected expense is acceptable in order to reduce earnings risk due to gold price risk by \$171,000. ABC could also analyze the risk and expected return characteristics of other hedging strategies using the approach shown above.

Note that if ABC uses a different method to determine target expense levels, the resulting risk measures will correspondingly differ. For example, let us assume that ABC uses the VECM mean gold prices for each horizon instead of a flat \$300 per Troy ounce to determine target expenses. The VECM mean gold prices (shown in Chart 9.1) at each horizon are detailed below:

VECM mean gold price	30-Sep-98	31-Dec-98	31-Mar-99	30-Jun-99
USD per Troy oz.	297.00	289.45	288.63	284.85

Using these prices, ABC's target purchase expense would be (\$5.8mm) and (\$5.88mm) in the unhedged and hedged cases, respectively. With these targets as the new reference points and using the 95% confidence level absolute outcomes shown in Charts 9.2 and 9.4, ABC's EaR would be \$588,000 and \$334,000 with respect to the unhedged and hedged targets. Alternatively, if ABC uses the mean values of the expense distributions shown in Charts 9.2 and 9.4 as targets, which are (\$5.81mm) and (\$5.94mm) respectively, then ABC's EaR would be \$575,000 and \$274,000 respectively.

As discussed in Chapter 5 and illustrated above, the choice of methodology for setting target levels, as well as the choice of scenario generation methodology, directly affects the characteristics of the risk measures obtained from applying the CorporateMetrics framework. Companies may elect to either adopt a specific set of standards for risk measurement or to compare the results of different methodologies by running multiple analyses based on a variety of assumptions.

Example 9.3 EaR and CFaR due to foreign exchange risk—yen-denominated sales

This example shows how foreign exchange volatility can affect the translated value of foreign-currency denominated sales, which in turn can affect earnings and cash flow. Suppose ABC sells some of its products and services in Japan. For accounting purposes, assume that ABC books the sales revenues once per quarter at the quarter-end JPY/USD exchange rate. Cash due from sales generated in a given quarter is collected at the end of the following quarter (i.e., cash due from yen-denominated sales is collected on a 90-day deferred basis). Upon the collection of cash, the foreign currency is converted back to U.S. dollars at the then-prevailing JPY/USD spot exchange rate. ABC's budget rates for JPY/USD for each horizon are shown below:

Budget rate	31-Dec-98	31-Mar-99	30-Jun-99	30-Sep-99
JPY per USD	140	142	145	150

Step 1: Metric specification

For its yen-denominated sales, ABC elects to calculate EPSaR and CFaR due to fluctuations in the JPY/USD exchange rate. The time horizon over which ABC will calculate risk is 12 months and the confidence level used is 95%.

Step 2: Exposure mapping

ABC's projected quarterly sales revenue in yen is shown by booking date as follows:

Sales revenue	31-Dec-98	31-Mar-99	30-Jun-99	30-Sep-99
JPY 000s	200,000	199,800	199,800	200,200

The cash flows associated with ABC's collections of yen-denominated sales revenue are shown next:

Cash flow	31-Dec-98	31-Mar-99	30-Jun-99	30-Sep-99
JPY 000s	200,501	200,000	199,800	199,800

Note that on 31 December 1998, ABC expects to collect ¥200.5mm in cash associated with revenues that were booked at the end of 3Q 1998.

If ABC assumes that the above sales projections are fixed, then the translated value (in USD 000s) of the revenue R_J can be summarized by the following equation:

$$[9.5] \quad R_J = \frac{200,000}{X_1} + \frac{199,800}{X_2} + \frac{199,800}{X_3} + \frac{200,200}{X_4}$$

where X_i is the JPY/USD exchange rate, expressed in JPY per USD, at the end of i -th quarter from the analysis date.

Since ABC's cash collections occur on a 90-day deferred basis, ABC is also exposed to transaction related gains or losses on its yen accounts receivable (i.e., if the JPY/USD exchange rates on the revenue booking date and cash receipt date are different, ABC must report a foreign exchange related transaction gain or loss). Based on the above data, the total transaction gain or loss T (in USD 000s) for the upcoming 12 months is given by:

$$[9.6] \quad T = 200,501\left(\frac{1}{X_1} - \frac{1}{X_0}\right) + 200,000\left(\frac{1}{X_2} - \frac{1}{X_1}\right) + 199,800\left(\frac{1}{X_3} - \frac{1}{X_2}\right) + 199,800\left(\frac{1}{X_4} - \frac{1}{X_3}\right),$$

where X_0 is the JPY/USD exchange rate of ¥136.1 per dollar on the analysis date.

Since translated revenues and transaction gains/losses are components of earnings, Equations [9.5] and [9.6] can be used as exposure maps in the EaR calculation process.²

The translated value (in USD 000s) of the actual cash flow streams can be summarized by:

$$[9.7] \quad \text{Cash flow} = \frac{200,501}{X_1} + \frac{200,000}{X_2} + \frac{199,800}{X_3} + \frac{199,800}{X_4}.$$

Equation [9.7] can be used as the exposure map in the CFaR calculation process.

Step 3: Scenario generation

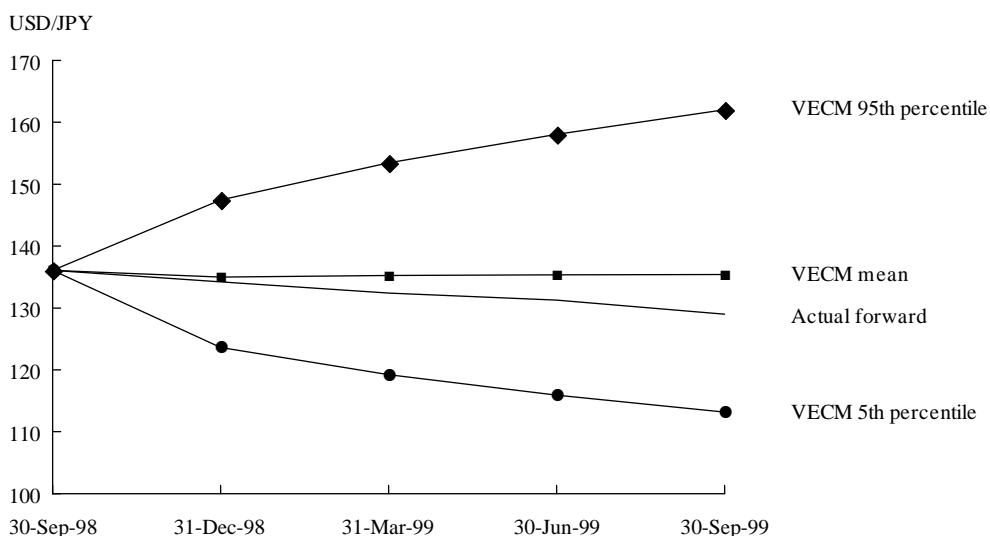
To project the revenue and cash flows for the upcoming four quarters, we need JPY/USD exchange rate scenarios that consist of four quarterly rate projections for: 31 December 1998, 31 March 1999, 30 June 1999, and 30 September 1999. In order to generate the scenarios, we need to specify market rate probability distributions for the JPY/USD exchange rate at each end-of-quarter horizon.

Chart 9.5 shows several parameters of distributions forecasted using VECM, including the mean and the 5% and 95% confidence levels. For reference, the chart also shows the actual JPY/USD forward prices that prevailed in the market on the analysis date.

Chart 9.5

JPY/USD exchange rate probability distributions parameters and forward rates

Analysis date: 30 September 1998



Using the above JPY/USD exchange rate distributions and *LongRun's* Level I scenario generation algorithms, we simulated 10,000 possible paths for the JPY/USD quarterly exchange rate during the period covering 31 December 1998 to 30 September 1999.

² In this example, we assume that ABC converts all foreign currency to USD upon receipt of cash and does not maintain any foreign currency balances. In general, if a company does maintain foreign currency cash balances, these would need to be measured in terms of the domestic functional currency for each reporting period, which can result in profits or losses that are reported in earnings.

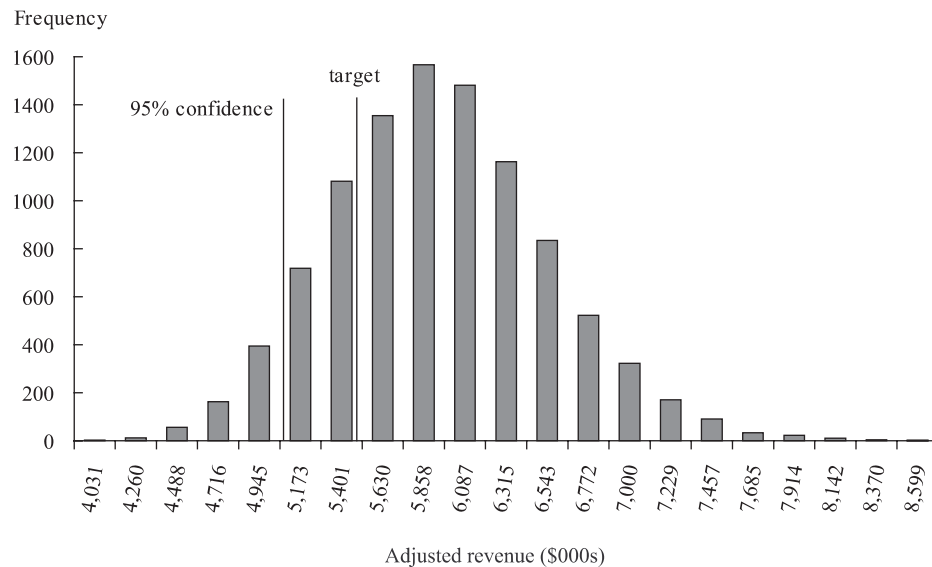
Step 4: Valuation

By jointly calculating the translated yen revenues and transaction gains/losses for each of the 10,000 JPY/USD scenarios generated from the distributions shown in Chart 9.5, we obtained a distribution of earnings contributions for the upcoming four quarters. As shown in Chart 9.6, the result at 95% confidence is \$5.0mm.

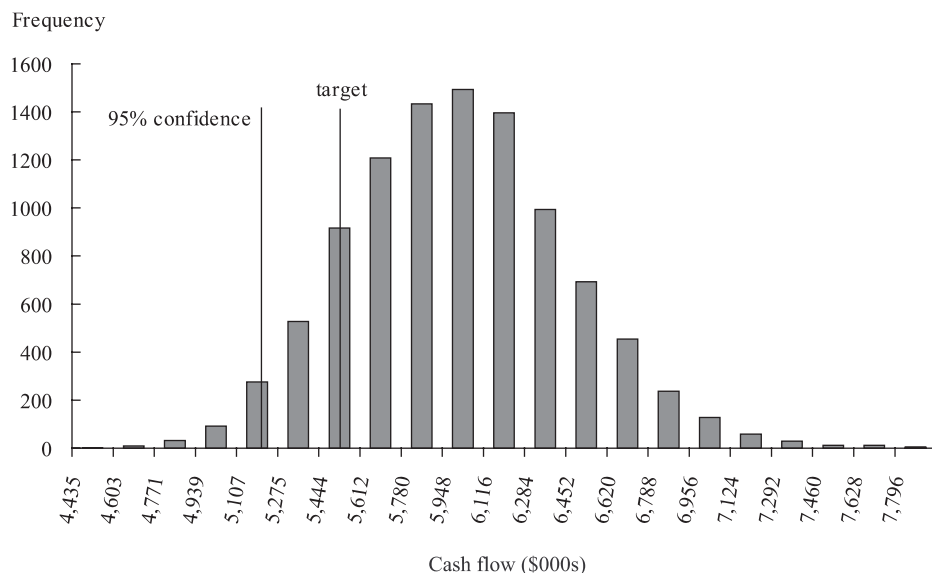
Similarly, the distribution of actual cash flows associated with the JPY/USD scenarios is shown in Chart 9.7. At 95% confidence, the cash flow is \$5.23mm.

Chart 9.6

Distribution of translated yen revenues and transaction gains/losses
10,000 trials

*Chart 9.7*

Distribution of cash flows from collections on yen-denominated revenues
10,000 trials



Step 5: Risk computation

Given ABC's projected sales volumes and JPY/USD budget rates, the company's target revenue and transaction gain/loss in USD, from yen-denominated sales is the following:

Yen sales revenue items	31-Dec-98	31-Mar-99	30-Jun-99	30-Sep-99	Total
Sales revenue (¥000s)	200,000	199,800	199,800	200,200	799,800
Budget rate (JPY per USD)	140	142	145	150	
Translated revenue (\$000s)	1,429	1,407	1,378	1,335	5,548
Transaction gain/loss (\$000s)	(41)	(20)	(29)	(46)	(136)
Total earnings impact (\$000s)	\$ 1,388	\$ 1,387	\$ 1,349	\$ 1,289	\$ 5,412

Given budgeted yen-related net revenues of \$5.41mm and a 95% confidence combined revenue and transaction gain/loss result of 5.0mm, the maximum potential shortfall relative to target is $\$5.41\text{mm} - \$5.0\text{mm} = \$408,000$.

ABC assumes that no adjustments to yen sales prices will be made to compensate for foreign exchange movements. Therefore, revenues from yen-denominated sales and transaction gains/losses are assumed to affect earnings directly, such that the effect of these exposures results in a pre-tax EaR of \$408,000. Assuming 5,000,000 shares outstanding, EPSaR is \$0.08.

ABC's target cash flow from yen-denominated sales is shown below:

Target cash flow	31-Dec-98	31-Mar-99	30-Jun-99	30-Sep-99	Total
Cash from sales (¥000s)	200,501	200,000	199,800	199,800	800,101
Budget rate (¥ per \$)	140	142	145	150	
Cash flow (\$000s)	\$ 1,432	\$ 1,408	\$ 1,378	\$ 1,332	\$ 5,551

Given a budgeted cash flow of \$5.55mm and a 95% confidence level cash flow of \$5.23mm, CFaR due to JPY/USD risk of yen sales is $\$5.55\text{mm} - \$5.23\text{mm} = \$319,000$.

Note that ABC's yen-sales EaR is larger than the CFaR for the analysis period. This can be attributed to the time lag between the recognition of revenues and the receipt of cash, which results in the accounting entries for transaction gains/losses that can contribute toward earnings volatility.

In this simple example, we assumed that ABC booked revenues and received cash once per quarter. Companies that book revenues more frequently (e.g., monthly) can apply the CorporateMetrics approach illustrated in this example by generating scenarios that consist of more frequent sampling points. For example, companies could specify market rate distributions for each monthly horizon covering the upcoming 12-months. From these distributions, companies could generate scenarios consisting of 12 successive JPY/USD rates.

Example 9.4 Debt financing—interest rate and foreign exchange risk

This example is intended to illustrate the market risks associated with raising debt in domestic and foreign capital markets. Suppose ABC needs to raise \$40mm to fund ongoing operations. ABC is considering raising floating rate debt in either the USD or JPY capital markets. Assume that there are no arbitrage opportunities between the two funding alternatives and that ABC is focused on the relative riskiness of the two alternatives. In either case, ABC plans to raise debt indexed to 3-month interest rates, with a one-year maturity. ABC plans to issue the debt on 1 October 1998. In either market, assume that ABC will pay a spread of 200 basis points over the interbank interest rate. For budgeting purposes, ABC assumes that U.S. 3-month interbank rates will be constant at 5.3125% and Japanese 3-month interbank rates will be constant at 0.639%. ABC's budget rates for JPY/USD for each horizon are shown below.

Budget rate	31-Dec-98	31-Mar-99	30-Jun-99	30-Sep-99
JPY per USD	140	142	145	150

Step 1: Metric specification

ABC elects to calculate CFaR to evaluate the risk characteristics for the two funding alternatives. ABC uses a time horizon of 12 months and a 95% confidence level for its analysis.

Step 2: Exposure mapping

ABC's principal cash flows for a USD financing would be as follows:

Principal	1-Oct-98	31-Dec-98	31-Mar-99	30-Jun-99	30-Sep-99
\$000s	40,000				(40,000)

In either the USD or JPY capital markets, assume that quarterly interest payments are paid in arrears and coupons are set based on the prevailing market interest rates on 30 September 1998, 31 December 1998, 31 March 1999, and 30 June 1999. Interest expenses I_{US} for a USD financing are given in \$000s as follows:

$$[9.8] \quad I_{US} = -40000 \left(\frac{R_0 + R_1 + R_2 + R_3}{4} + 0.02 \right),$$

where R_i is the 3-month interbank rate, expressed in percentage terms, at the end of the i -th quarter from the analysis date and 2% is the credit spread.

ABC's projected cash flows for a JPY financing are expressed below. Based on the prevailing exchange rate of ¥136.1 per USD on the analysis date, ABC is considering raising ¥5.45bn, which would result in cash flows relating to principal as shown below:

Principal	1-Oct-98	31-Dec-99	31-Mar-99	30-Jun-99	30-Sep-99
¥ mm	5,445				(5,445)

As a result, the gain or loss on repayment of principal in \$000s is given by:

$$[9.9] \quad \text{gain/(loss)} = 5445000 \left(\frac{1}{X_0} - \frac{1}{X_4} \right),$$

where $X_0 = 136.1$ is the JPY per USD exchange rate on the analysis date and X_4 is the JPY per USD exchange rate on 30 September 1999.

Total interest expenses I_J for JPY financing are given in \$000s by

$$[9.10] \quad I_J = -5445000 \cdot \sum_{i=0}^3 \frac{J_i + 0.02}{4X_{i+1}},$$

where J_i is the 3-month Japanese interbank rate, expressed in percentage terms, at the end of the i -th quarter from the analysis date, and X_i is the JPY/USD exchange rate, expressed in JPY per USD, at the end of i -th quarter from the analysis date. Equations [9.8] and [9.10] will be used as the exposure maps for valuing the cash flows associated with different interest rate and foreign exchange scenarios.

Step 3: Scenario generation

Chart 9.8 shows selected parameters (the means and the 5% and 95% percentiles) of the VECM probability distributions for 3-month U.S. interbank rates for each quarter. Also shown, for reference, are the actual implied forward rates prevailing in the market on the analysis date.

Chart 9.8

Forward 3-month interbank rate probability distributions parameters and implied forwards
Analysis date: 30 September 1998

U.S. interest rates

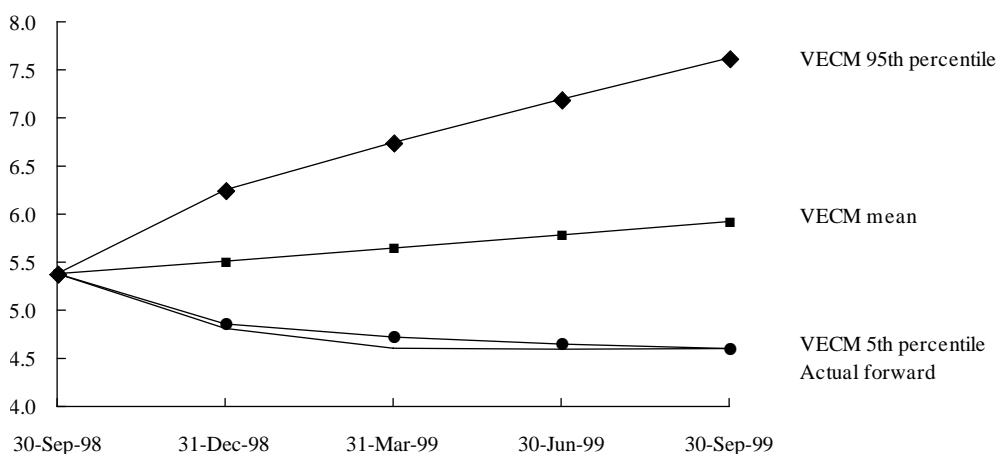


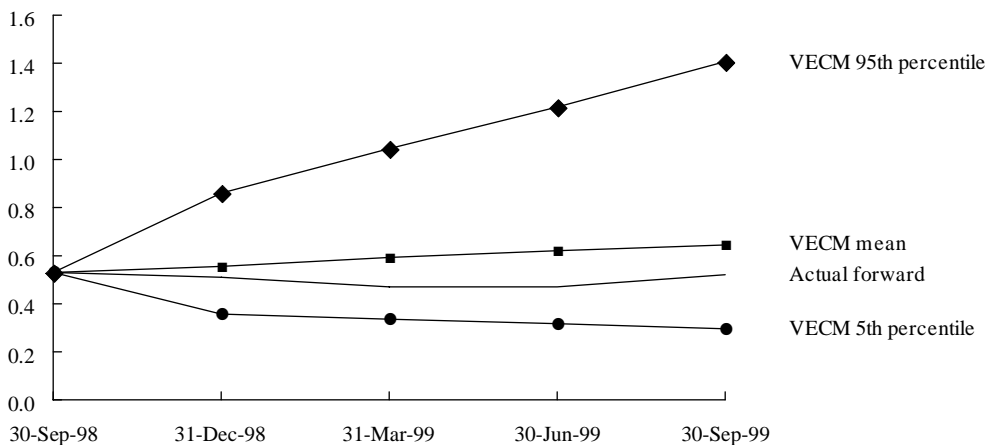
Chart 9.9 shows selected statistical parameters (the means and the 5% and 95% percentiles) of the VECM distributions for 3-month Japanese interbank rates for each quarter. Also shown, for reference, are the actual implied forward rates prevailing in the market on the analysis date.

Chart 9.9

Forward 3-month JPY interbank rate probability distribution parameters and implied forwards

Analysis date: 30 September 1998

JPY interest rates



Using the above USD and JPY interest rate probability distributions and *LongRun*'s Level I simulation algorithms, we simulated 10,000 possible paths for USD and JPY quarterly interest rates during the period covering 31 December 1998 to 30 September 1999.³ To account for the foreign exchange risk associated with a JPY financing, ABC will also require JPY/USD scenarios for the same period. The scenarios from Example 9.3 can be used for this purpose.

Note that the JPY/USD exchange rate, U.S interest rate, and Japanese interest rate scenarios have been generated in a way that reflects the historical correlations of the returns of these market rates. As discussed in Chapter 5 of *LongRun*, the following process is used to generate scenarios that reflect the historical correlation between prices and rates:

1. Specify probability distributions

Using the methodologies outlined in Chapter 7 of this document, specify the probability distributions for rates and prices at each forecast horizon (e.g., econometric, current market data, or user-defined approaches). The distributions shown in Charts 9.5, 9.8, and 9.9 have been used for this example.

2. Level I simulation

Simulate paths of rates and prices covering the forecast horizons required (e.g., monthly, or quarterly) using the probability distributions in step 1, the autocorrelations for the time series, and the historical correlation among monthly rates and prices.

In *LongRun*, historical autocorrelations and correlations among *monthly* rates and prices have been selected as the standard correlation input for Level I simulation. Even when generating the quarterly rate and price forecasts required for this example, we first specify monthly parameters, from which the longer term scenarios are generated. Companies that would prefer to use parameters corresponding to periods other than monthly can adapt the principles outlined in *LongRun* to suit their

³ Although we simulated four quarters of interest rate scenarios, we only need three quarters to determine interest expense since coupons are set 90-days prior to actual cash payment. However, we simulated four quarters to have a consistent time frame with the foreign exchange scenarios to facilitate comparative analysis.

preferred time frames. Selected historical monthly correlations assumed for the examples in this chapter are shown in Table 9.3.

Table 9.3

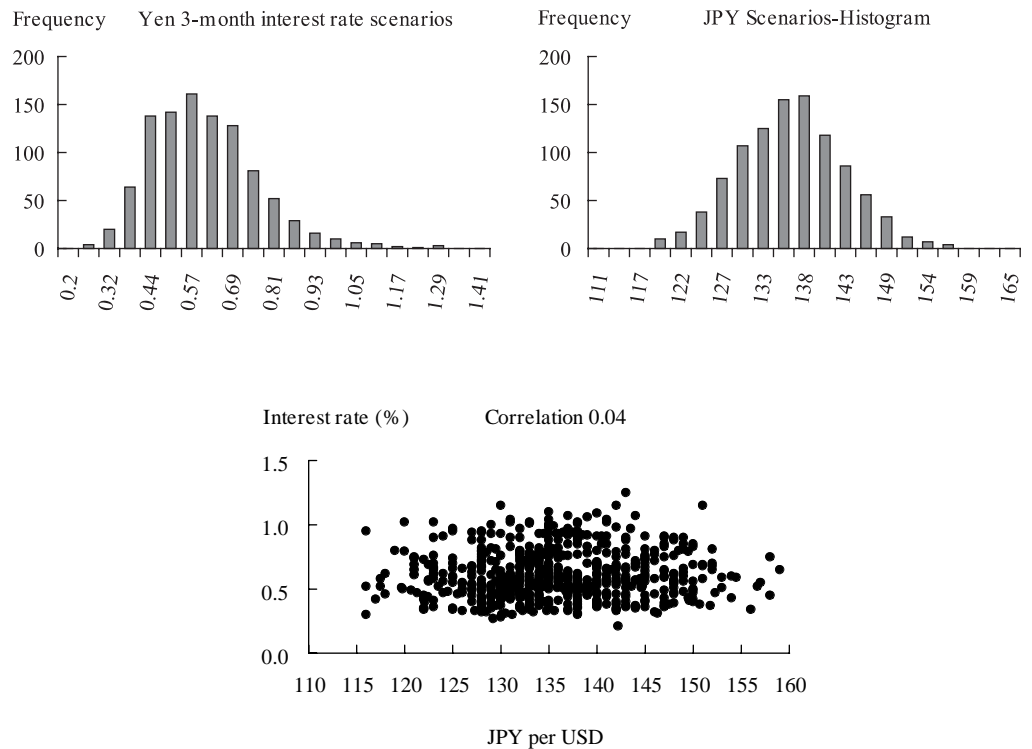
Cross-market monthly historical correlations

	JPY	ZAR	Gold	USD-IR	JPY-IR
JPY	1				
ZAR	-0.02	1			
Gold	-0.31	-0.21	1		
USD-IR	-0.07	0.07	-0.20	1	
JPY-IR	0.04	0.30	-0.06	0.08	1

Chart 9.10 shows the JPY/USD exchange rate and JPY 3-month interest rate scenarios for the first horizon date, 31 December 1998, obtained by applying Steps 1 and 2. The correlation of the simulated quarterly returns for the two time series is 0.04.

Chart 9.10

Histograms and scatter plot for the JPY/USD exchange rate and JPY 3-month interest rate
10,000 trials; horizon: 31 December 1998



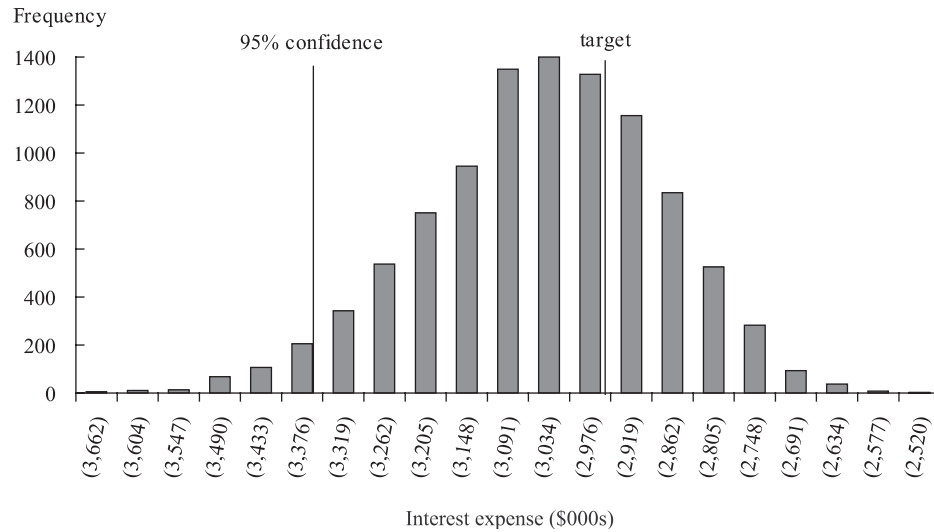
For further information on scenario generation, see *LongRun*, Chapter 5.

Step 4: Valuation

By calculating the cash flow for interest expense for each of the 10,000 U.S. interest rate scenarios, we obtain the distribution of cash flows as shown in Chart 9.11. At 95% confidence, the cash flow is (\$3.33mm).

Chart 9.11

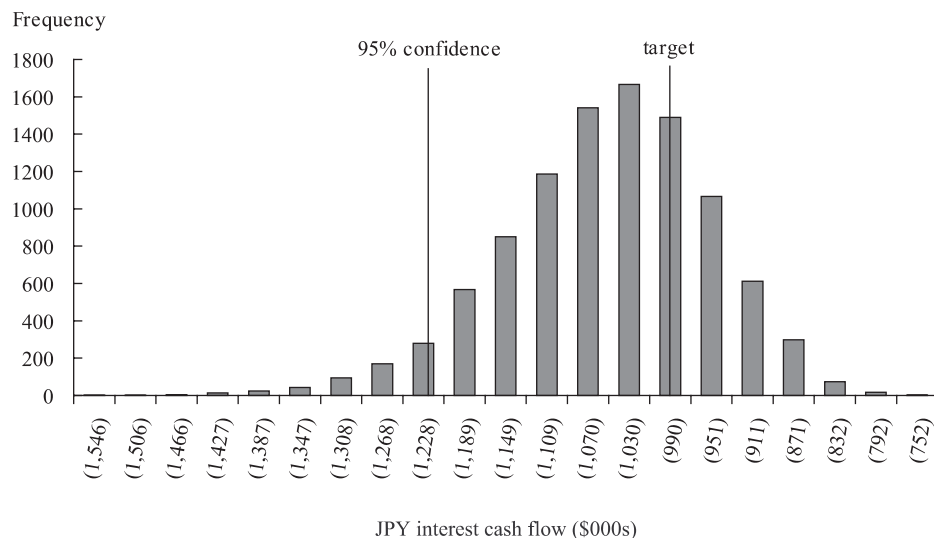
Distribution of cash flows due to U.S. interest expenses
 10,000 trials



Similarly, by calculating the translated cash flows for interest expenses for each of the 10,000 joint Japanese interest rate and JPY/USD exchange rate scenarios, we obtain the distribution of cash flows as shown in Chart 9.12. As shown, the cash flow at the 95% confidence level is (\$1.22mm).

Chart 9.12

Distribution of U.S. equivalent cash flow due to yen interest expense
 10,000 trials



The distribution of the foreign exchange transaction gain/loss on the repayment of ¥5.45bn principal on 30 September 1999 is shown in Chart 9.13. As shown, the 95% confidence level loss is (\$8.21mm).

Chart 9.13

Distribution of U.S. dollar equivalent cash flow for repayment of principal, yen financing
10,000 trials

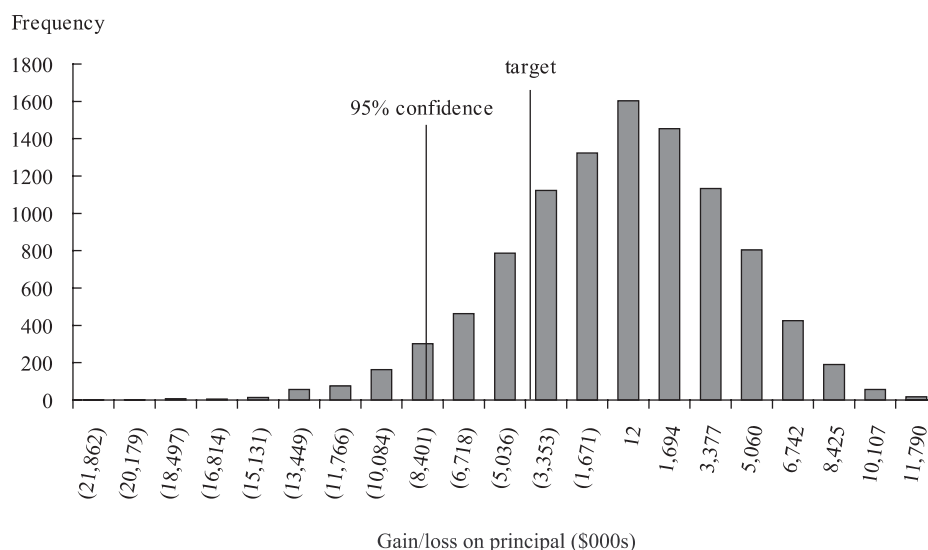
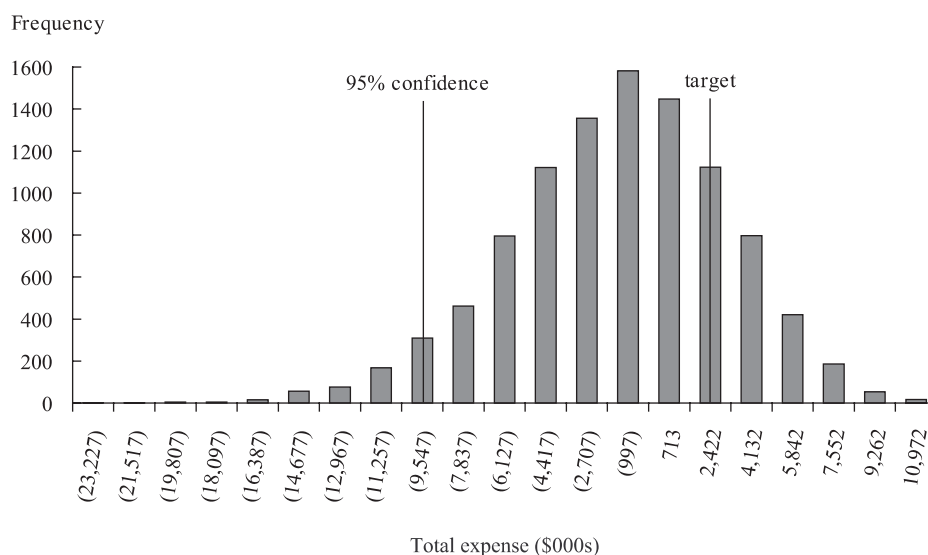


Chart 9.14 shows the distribution of the total Japanese financing-related expenses (translated yen interest expenses and foreign exchange transaction gain/loss on the repayment of ¥5.45bn principal). As shown, the 95% confidence level cash flow is (\$9.4mm).

Chart 9.14

Distribution of total cash flows related to JPY financing
10,000 trials



Step 5: Risk computation

For budgeting purposes, ABC assumes a constant 5.3125% U.S. 3-month rate and 200 basis point spread for the upcoming four quarters. The budgeted cash flows of the U.S. financing option are as follows:

Budgeted cash flows:						
U.S. financing option	1-Oct-98	31-Dec-98	31-Mar-99	30-Jun-99	30-Sep-99	Total
Principal (\$000s)	40,000				(40,000)	0
Interest (\$000s)		(731)	(731)	(731)	(731)	(2,925)
Total (\$000s)	\$ 40,000	\$ (731)	\$ (731)	\$ (731)	\$ (40,731)	\$ (2,925)

The U.S. financing option has no foreign exchange risk to principal since ABC's reporting currency is U.S. dollars. Given ABC's target cash flows relating to U.S. interest expense and the 95% confidence level cash flows relating to interest expense, the CFaR of the U.S. financing option is $(\$2.925\text{mm}) - (\$3.33\text{mm}) = \$406,000$.

We emphasize that the Cash-Flow-at-Risk measure shown above is a nominal measure of risk and does not calculate the present value of any cash flows. Companies that wish to assess the present-value implications of interest rate or other risks may consider the use of VaR-type measures to gauge these effects.

For budgeting purposes, ABC assumes a constant 0.639% Japanese 3-month rate and 200 basis point spread for the upcoming four quarters. ABC's JPY/USD budget rates per quarter are also shown. The budgeted cash flows for the Japanese financing alternative are given below:

Budgeted cash flows:						
JPY financing option	1-Oct-98	31-Dec-98	31-Mar-99	30-Jun-99	30-Sep-99	Total
Principal (¥000s)	5,445				(5,545)	0
Budget rate (¥ per \$)	136.1	140	142	145	150	
Principal (\$000s)	40,000				(36,299)	3,701
Interest (¥000s)		(35,922)	(35,922)	(35,922)	(35,922)	(143,688)
Interest (\$000s)		(257)	(253)	(248)	(239)	(997)
Total (\$000s)	\$ 40,000	\$ (257)	\$ (253)	\$ (248)	\$ (36,538)	\$ 2,705

By using the JPY financing strategy, ABC anticipates generating a \$2.7mm profit since the company's budget rates for JPY/USD call for a weakening of the JPY over the next four quarters as shown above. However, the 95% confidence level cash flows for principal and interest are (\$9.4mm) due to foreign exchange and interest rate risk, as shown in Chart 9.14.⁴ Thus, the CFaR of the Japanese financing alternative relative to the budgeted cash flow is $\$2.7\text{mm} - (\$9.4\text{mm}) = \$12.1\text{mm}$ due to foreign exchange and interest rate risk.

Using this information, ABC can assess the risks versus expected costs of the two different financing strategies. The U.S. financing strategy will, with certainty, result in a net interest expense, with some variability in the amount due to interest rate risk. The JPY funding strategy has an anticipated

⁴ Note that if we assume the above JPY quarterly coupons to be fixed (i.e., zero interest rate risk), the distribution of interest and principal cash flows, taking into account only foreign exchange risk, also yields a 95% confidence level cash flow of approximately (\$9.4mm).

net profit due to ABC's expectation of a weakening yen. Based on its budget rates, ABC's expected return from the JPY strategy is greater than the return from the USD funding strategy. However, the combined foreign exchange and interest rate risk results in a larger CFaR for the JPY funding strategy relative to the USD funding strategy.

It should be noted that a significant portion of the CFaR is due to the difference between the budget rates for JPY/USD and the VECM 5th percentile exchange rate forecasts. However, even if ABC were to use the VECM mean of ¥135.4 for the JPY/USD rate on 30 September 1999 as its budget rate, CFaR would still be large given that the VECM 5th percentile forecast for JPY/USD on 30 September 1999 is ¥113.2. This shows the significant magnitude of the variance in the 12-month JPY/USD distribution.

Example 9.5 Interim summary—consolidated risks for ABC-USA

In the preceding examples, we have shown how market risk can be assessed for individual components of the earnings and cash flow of ABC's U.S.-based activities ("ABC-USA"). By combining the examples, we can perform a consolidated market risk analysis for ABC-USA. Suppose ABC-USA has the following market risks:

- Foreign exchange risk due to yen-denominated sales (cash collection on 90-day deferred basis)
- Gold price risk due to gold purchases (ABC elects not to hedge these purchases)
- Interest rate risk due to the financing of \$40mm in U.S. dollar denominated short-term debt

This example shows how to aggregate the above risks in order to determine a consolidated risk measure. ABC's budget rates for gold, JPY/USD, and interest rates are as shown in the previous examples.

Step 1: Metric specification

ABC-USA will report EPSaR for the above market risks. A 12-month horizon and 95% confidence level are specified.

Step 2: Exposure mapping

The exposure maps shown in Examples 9.1, 9.3, and 9.4 are combined to produce an exposure map accounting for each of ABC-USA's market risks. Let ABC-USA's pre-tax earnings E_{US} for the upcoming four quarters be given by:

$$[9.11] \quad E_{US} = (R_{US} + R_J + T) + (G + SGA + I_{US} + D_{US}),$$

where

R_{US} , a constant, represents ABC-USA's budgeted revenues from projected U.S. sales of \$56.035mm for the upcoming four quarters (\$14mm, \$14.035mm, \$14.035mm, and \$13.965mm, respectively)

R_J represents the translated revenues from yen-denominated sales, as given by Eq. [9.5]

T is the net transaction gains and losses on yen accounts receivable, as given by Eq. [9.6]

G represents gold purchase expenses, as given by Eq. [9.1]

SGA , a constant, represents general expenses of (\$39.9mm) for the upcoming four quarters (−\$10mm, −\$10mm, −\$10mm, and −\$9.9mm, respectively)

I_{US} represents the interest expenses from the USD financing, as given by Eq. [9.8]

D_{US} , a constant, represents ABC-USA's depreciation expenses of (\$0.5mm) each quarter for a total of (\$2.0mm) for the upcoming four quarters.

Step 3: Scenario generation

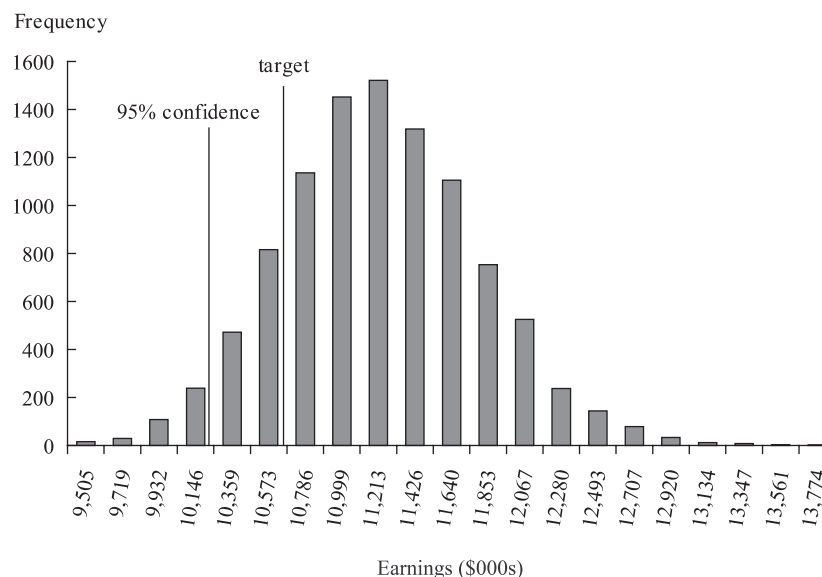
The scenarios generated from Example 9.1 through Example 9.4 using the VECM forecasts are used. As discussed in Example 9.4, Step 3, the market rate scenarios for the various foreign exchange rates, gold prices, and interest rates reflect the historical correlations of these market rates and prices.

Step 4: Valuation

By calculating ABC-USA's pre-tax earnings E_{US} for each of the 10,000 market rate scenarios for quarterly JPY/USD rates, U.S. 3-month interbank rates, and gold prices, we obtain the distribution of 12-month earnings shown in Chart 9.15. The 95% confidence level earnings is \$10.3mm, or \$2.06 per share.

Chart 9.15

Distribution of ABC-USA 12-month earnings—total market risks
10,000 trials

**Step 5: Risk computation**

ABC-USA's budget rates and target pre-tax earnings are calculated below.

ABC-USA: Pro Forma Income Statement

Consolidated (\$000s)	4Q 1998	1Q 1998	2Q 1999	3Q 1999	Total 4 Qtrs
Revenue					
Revenue US	14,000	14,035	14,035	13,965	56,035
Revenue Japan, ¥000s	200,000	199,800	199,800	200,200	
Budget rate, (¥ per \$)	140	142	145	150	
Revenue Japan	1,429	1,407	1,378	1,335	5,548
Total Revenue	15,429	15,442	15,413	15,299	61,583
Expenses					
Gold purchase, Troy oz.	5,000	5,004	5,004	4,979	
Budget rate, USD per oz.	(300)	(300)	(300)	(300)	
Gold expense	(1,500)	(1,501)	(1,501)	(1,494)	(5,996)
General expense	(10,000)	(10,000)	(10,000)	(9,900)	(39,900)
Transaction gain/loss	(41)	(20)	(29)	(46)	(136)
Interest expense	(731)	(731)	(731)	(731)	(2,925)
Depreciation	(500)	(500)	(500)	(500)	(2,000)
Total expenses	(12,772)	(12,753)	(12,762)	(12,671)	(50,957)

ABC-USA: Pro Forma Income Statement

Consolidated (\$000s)	4Q 1998	1Q 1998	2Q 1999	3Q 1999	Total 4 Qtrs
Pre-tax Earnings	2,656	2,689	2,651	2,629	10,626
EPS (5,000,000 shares) (USD)	\$ 0.53	\$ 0.54	\$ 0.53	\$ 0.53	\$ 2.13

Given ABC-USA's target earnings of \$10.6mm (or \$2.13 per share) and 95% confidence level earnings of \$10.3mm, ABC-USA's EaR due to consolidated market risk is \$317,000, or \$0.06 per share.

By combining the results shown above, we can construct a summary risk report of ABC-USA's market risks as shown in Table 9.4, which summarizes EPS contributions versus EPSaR by risk category.

Table 9.4

Summary of ABC-USA earnings and risks

95% confidence level, 12-month horizon

Risk categories	Earnings contribution	EPSaR contribution
Commodity:		
Gold purchase	(\$ 1.20)	\$ 0.08
Foreign exchange:		
JPY sales-related	\$ 1.08	\$ 0.08
Interest rate:		
U.S. 3-mo	(\$ 0.59)	\$ 0.08
<i>Diversification benefit</i>	<i>not applicable</i>	<i>\$ (0.18)</i>
Total	\$ 2.13*	\$ 0.06

* Refers to ABC-USA total EPS, not just risk-sensitive earnings components.

The **diversification benefit** of the portfolio of exposures is the difference between the total risk and the simple sum of the component risks. As shown, the component EPSaR is \$0.08 for each risk type—commodity, foreign exchange, and interest rate risks—resulting in an undiversified total (i.e., simple sum) of \$0.24. Since the calculated total EPSaR is \$0.06, the diversification benefit is $\$0.06 - \$0.24 = (\$0.18)$.

Note that the total EPSaR across all market risks is only \$0.06 in this example even though the component commodity, foreign exchange, and interest rate risks are all equal to \$0.08 per share. As shown in Table 9.3, gold price changes are negatively correlated (approximately -20% to -30%) with changes in the JPY/USD exchange rate and U.S. interest rates for the time period sampled. Furthermore, the monthly correlation between the JPY/USD exchange rate and U.S. interest rates is low (-7%). These combined factors result in a significant diversification benefit for ABC's total market risk.

Using an analytical approach similar to that shown above, if we assume ABC-USA substitutes the JPY debt financing described in Example 9.4 for the USD debt financing, then the company's risks

would be as shown in Table 9.5. As shown, the JPY financing strategy would increase EPSaR from \$0.06 to \$2.11 relative to the USD financing strategy.

Table 9.5

Summary of ABC-USA earnings risks, JPY financing strategy

95% confidence, 12-month horizon

ABC-USA: EPSaR Summary					
Exposure	FX	IR	Commodity	Diversification benefit	Total
JPY sales-related	\$0.08	–	–	–	\$0.08
Financing	\$2.42	\$0.02	–	(\$0.02)	\$2.42
Gold purchase	–	–	\$0.08	–	\$0.08
<i>Diversification benefit</i>	(\$0.35)	–	–		(\$0.47)
Total	\$2.15	\$0.02	\$0.08	(\$0.14)	\$2.11

Example 9.6 Foreign exchange risk—foreign subsidiary in South Africa

This example shows how foreign exchange risk can affect the translated value of earnings from a foreign subsidiary. Suppose XYZ is a South African company and a wholly owned subsidiary of ABC. The functional currency of XYZ is the South African rand (ZAR). XYZ generates revenues from domestic sales. XYZ's budget rates for the ZAR/USD exchange rate are assumed to be:

Budget rate	4Q 1998	1Q 1999	2Q 1999	3Q 1999
ZAR per USD	6.0	6.0	5.8	5.5

Step 1: Metric specification

ABC elects to measure the EPSaR for the translated value of XYZ's pre-tax earnings. ABC uses a 12-month horizon and 95% confidence level.

Step 2: Exposure mapping

As shown in XYZ's budgeted plans, the projected earnings per quarter are:

Projected pre-tax earnings (ZAR 000s)	4Q 1998	1Q 1999	2Q 1999	3Q 1999	Total
Sales	7,500	7,425	7,388	7,388	29,700
Cost of goods sold	(4,000)	(3,960)	(3,940)	(3,940)	(15,840)
Gross margin	3,500	3,465	3,448	3,448	13,860
Depreciation	(500)	(500)	(500)	(500)	(2000)
Pre-tax earnings	3,000	2,965	2,948	2,948	11,860

XYZ assumes that the above sales projections are fixed (e.g., XYZ has entered into fixed contracts in order to limit business risk). The parent company ABC reports the translated value of XYZ's earnings on a quarterly basis, using end-of-quarter exchange rates. Therefore, the translated value of the earnings E_{SA} (in USD 000s) can be summarized by the following equation:

$$[9.12] \quad E_{SA} = \frac{3000}{X_1} + \frac{2965}{X_2} + \frac{2948}{X_3} + \frac{2948}{X_4},$$

where X_i is the ZAR/USD exchange rate, expressed in ZAR per USD, at the end of the i -th quarter from the analysis date.

Since XYZ's translated earnings are a component of ABC's consolidated earnings, the above equation can be used as an exposure map in the EPSaR calculation process.

Step 3: Scenario generation

To project the translated earnings for the upcoming four quarters, we need ZAR/USD exchange rate scenarios that consist of projections for the following four horizons: 31 December 1998, 31 March 1999, 30 June 1999, and 30 September 1999. In order to generate the scenarios, we need to specify the market rate probability distributions for the ZAR/USD exchange rate at each end-of-quarter horizon. Chart 9.16 shows selected parameters of the VECM distributions we have used, including the mean and the 5th and 95th percentile levels.

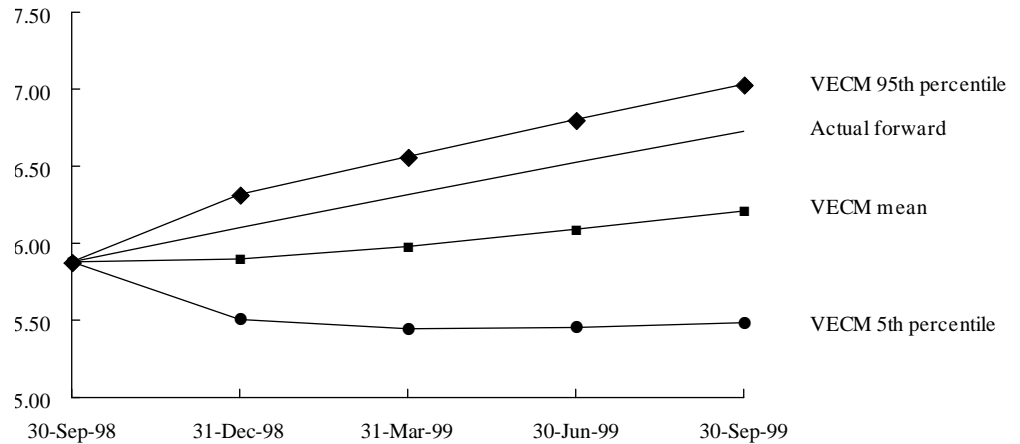
For reference, the chart also shows the actual ZAR/USD forward rates that prevailed in the market on the analysis date.

Chart 9.16

ZAR/USD exchange rate probability distributions parameters and forward rates

Analysis date: 30 September 1998

ZAR/USD



Using the above ZAR/USD exchange rate probability distributions and *LongRun*'s Level I scenario generation algorithms, we simulated 10,000 possible paths for the ZAR/USD quarterly exchange rate during the period covering 31 December 1998 to 30 September 1999.

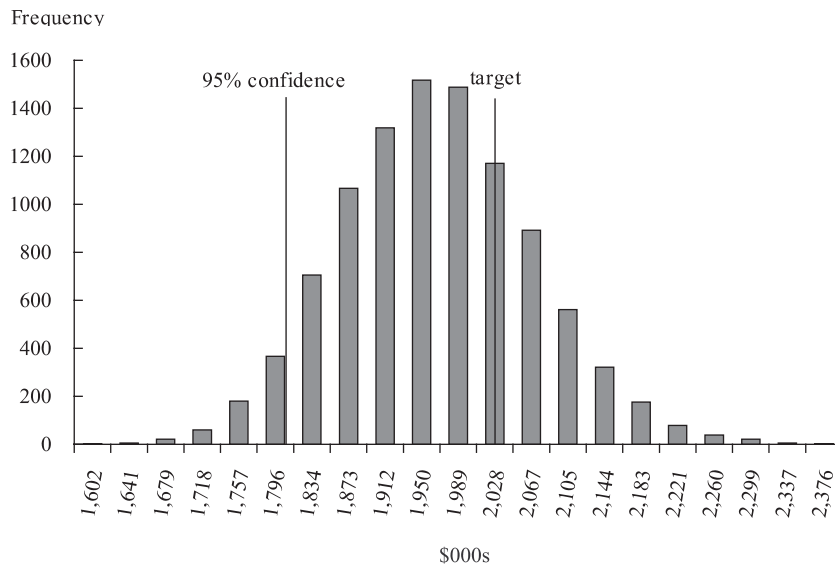
Step 4: Valuation

By calculating XYZ's translated earnings for each of the 10,000 ZAR/USD scenarios generated, we obtained the distribution of earnings for the upcoming four quarters as shown in Chart 9.17. The 95% confidence level result is \$1.80mm.

Chart 9.17

Distribution of the translated value of XYZ's earnings

10,000 trials



Step 5: Risk computation

The target earnings, in USD, from XYZ's operations is the following:

Target earnings	4Q 1998	1Q 1999	2Q 1999	3Q 1999	Total
Earnings (ZAR 000s)	3,000	2,965	2,948	2,948	11,860
Budget rate (ZAR per USD)	6.0	6.0	5.8	5.5	
Earnings (\$000s)	500	494	508	536	2,038

Given budgeted earnings of \$2.04mm and a 95% confidence result of \$1.8mm, the maximum short-fall relative to target is $\$2.04\text{mm} - \$1.8\text{mm} = \$236,000$. Assume that XYZ maintains stable product prices for the upcoming 12 months. Therefore, ABC assumes that XYZ's earnings directly affect ABC's pre-tax consolidated earnings. XYZ's operations contribute toward a pre-tax EaR of \$236,000, which translates into an EPSaR of \$0.05.

Example 9.7 Consolidated EaR for ABC Corporation

This example shows how to calculate the consolidated risks of a multinational corporation with U.S. and S. Africa operations. Suppose ABC has the following market risks:

- Foreign exchange risk due to yen-denominated sales (cash collection on 90-day deferred basis)
- Gold price risk due to gold purchases (ABC elects not to hedge these purchases)
- Interest rate risk due to the financing of \$40mm in U.S. dollar denominated short-term debt
- Foreign exchange risk due to the ZAR-denominated earnings of its subsidiary, XYZ.

ABC's budget rates for foreign exchange, gold prices, and interest rates are as previously shown.

Step 1: Metric specification

ABC reports EPSaR due to its consolidated market risks. A 12-month horizon and 95% confidence level are specified.

Step 2: Exposure mapping

The different exposure maps shown in Example 9.1 through Example 9.6 are combined to produce a composite exposure map that accounts for each of ABC's market risks. ABC's consolidated pre-tax earnings E is given by

$$[9.13] \quad E = E_{US} + E_{SA},$$

where

E_{US} represents the pre-tax earnings of ABC-USA, given by Eq. [9.11], and
 E_{SA} represents the pre-tax earnings of XYZ, given by Eq. [9.12].

Step 3: Scenario generation

The scenarios generated in Example 9.1 through Example 9.6 are used. As discussed in Example 9.4, Step 3, scenario generation for foreign exchange rates, gold prices, and interest rates takes into account the historical correlation of these market rates and prices.

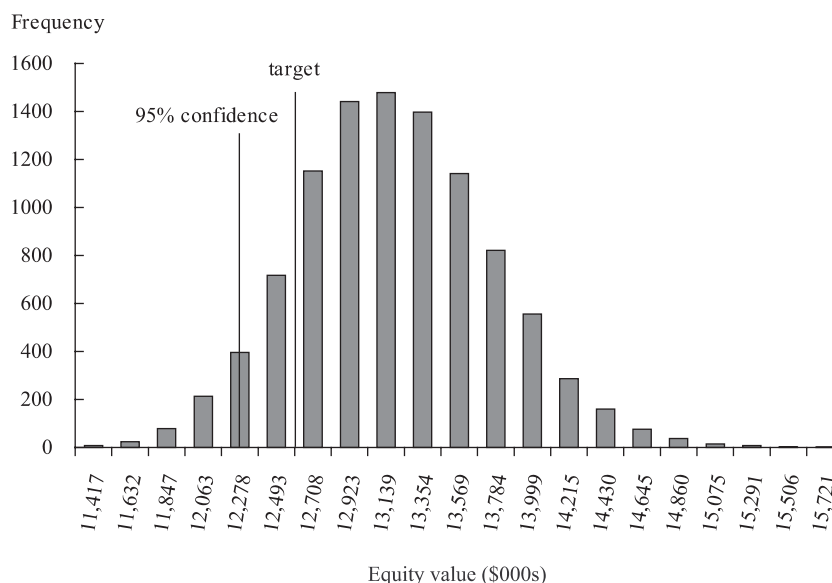
Step 4: Valuation

By calculating ABC's earnings for each of the 10,000 market rate scenarios for quarterly JPY/USD rates, ZAR/USD rates, U.S. 3-month interbank rates, and gold prices, we obtain the distribution of 12-month earnings as shown in Chart 9.18. The 95% confidence level earnings is \$12.3mm, or \$2.46 per share.

Chart 9.18

Distribution of ABC's 12-month earnings—total market risks

10,000 trials

**Step 5: Risk computation**

ABC's budget rates and target pre-tax consolidated earnings are calculated below.

ABC Corporation: Pro Forma Income Statement

Consolidated (USD 000s)	4Q 1998	1Q 1998	2Q 1999	3Q 1999	Total 4 Qtrs
Revenue					
Revenue US	14,000	14,035	14,035	13,965	56,035
Revenue Japan	1,429	1,407	1,378	1,335	5,548
Revenue S. Africa, ZAR 000s	7,500	7,425	7,388	7,388	
Budget rate, ZAR per USD	6.0	6.0	5.8	5.5	
Revenue S. Africa	1,250	1,238	1,274	1,343	5,105
Total Revenue	16,679	16,680	16,687	16,643	66,688
Expenses					
Gold expense	(1,500)	(1,501)	(1,501)	(1,494)	(5,996)
General expenses	(10,000)	(10,000)	(10,000)	(9,900)	(39,900)
Expense S. Africa, ZAR 000s	(4,000)	(3,960)	(3,940)	(3,940)	
Expense S. Africa	(667)	(660)	(679)	(716)	(2,722)
Transaction gain/loss	(41)	(20)	(29)	(46)	(136)
Interest expense	(731)	(731)	(731)	(731)	(2,925)
Depreciation, USA	(500)	(500)	(500)	(500)	(2,000)
Depreciation, S. Africa, ZAR 000s	(500)	(500)	(500)	(500)	
Depreciation, S. Africa	(83)	(83)	(86)	(91)	(344)
Total expenses	(13,522)	(13,496)	(13,527)	(13,478)	(54,024)
Pre-tax Earnings	3,156	3,184	3,159	3,164	12,664
EPS (5,000,000 shares)	(USD) \$ 0.64	\$ 0.64	\$ 0.63	\$ 0.63	\$ 2.53

Given ABC's target earnings of \$2.53 per share and 95% confidence level earnings of \$2.46 per share, ABC's EPSaR due to firmwide exposure to market risk is \$0.08.

By combining the results shown in the above examples, we can construct a summary risk report of ABC's market risks as shown in Table 9.6. Targeted earnings versus EPSaR by risk category are summarized.

Table 9.6

Summary of ABC Co. earnings per share and risk contributions
95% confidence level, 12-month horizon

Risk categories	EPS contribution	EPSaR contribution
Commodity:		
Gold	(\$ 1.20)	\$ 0.08
Foreign exchange:		
JPY sales-related	\$ 1.08	\$ 0.08
ZAR earnings	\$ 0.41	\$ 0.05
Total foreign exchange	\$ 1.49	\$ 0.13
Interest rate:		
U.S. 3-mo	(\$ 0.59)	\$ 0.08
<i>Diversification benefit</i>	<i>not applicable</i>	<i>\$ (0.21)</i>
Total	\$ 2.53*	\$ 0.08

* Refers to ABC's total EPS, not just risk-sensitive earnings components.

As discussed in Example 9.5, ABC's exposures, when combined, have a significant diversifications benefit for ABC's total market risk.

Example 9.8 Applying risk measures to assess hedging strategies

This example shows how earnings-based risk measures can be used to assess the relative merits of different hedging strategies. By estimating target EPS and EPSaR for a variety of strategies, ranging from “fully” hedged to unhedged, we show a range of outcomes with different return and risk characteristics. ABC’s budget rates are the same as shown in the preceding examples.

Step 1: Metric specification

ABC elects to report EPSaR due to its consolidated market risks arising from its global activities. A 12-month horizon and 95% confidence level are specified.

Step 2: Exposure mapping

In this example, the different exposure maps shown in Example 9.1 through Example 9.6 are used as the basis for analysis. In conjunction with the exposure maps, we apply several different hedging strategies. In each case, forward contracts are used to hedge exposures. The forward contracts are entered into on the analysis date at the prevailing forward rates and prices. The different cases analyzed are as follows (the bold letters labeling each case will be used throughout this example to identify the cases):

- **No hedging (N)**—This case is the same case that is discussed in Example 9.7 above wherein ABC’s gold, JPY sales, ZAR earnings, and USD interest rate risk are unhedged.
- **Hedge budgeted gold purchases (G)**—On the analysis date, ABC enters into forward purchase contracts for gold maturing 31 December, 1998, 31 March 1999, and 30 June 1999, in amounts equal to the budgeted amounts of gold purchases to be booked on those dates. All other exposures are unhedged.
- **Hedge anticipated JPY sales (J)**—On the analysis date, ABC enters into forward sales of JPY against USD maturing 31 December, 1998, 31 March 1999, 30 June 1999, and 30 September 1999 in amounts equal to the anticipated amounts of JPY sales to be booked on those dates. All other exposures are unhedged.
- **Hedge anticipated ZAR earnings (Z)**—On the analysis date, ABC enters into forward sales of ZAR against USD maturing 31 December, 1998, 31 March 1999, 30 June 1999, and 30 September 1999 in amounts equal to the anticipated amounts of ZAR earnings to be booked on those dates. All other exposures are unhedged.
- **Hedge floating USD debt (U)**—On the analysis date, ABC enters into a pay fix/receive floating USD interest rate swap, notional value \$40mm, quarterly reset. The fixed leg reference rate is assumed to be 5.20%. All other exposures are unhedged.
- **All-hedged (A)**—On the analysis date, ABC enters into all of the JPY, ZAR, gold, and U.S. interest rate contracts that are detailed in Cases G, J, Z, and U above, in order to hedge all of its anticipated market exposures.

The spot and forward rates and prices on the analysis date are summarized in Table 9.7.

Table 9.7

Spot/forward rates and prices, 30 September 1998*Italicized rates indicated linearly interpolated values*

	30-Sep-98	31-Dec-98	31-Mar-99	30-Jun-99	30-Sep-99
Gold, \$/Troy oz.	297.0	303.9	307.2	308.8	–
JPY per USD	136.1	134.2	132.4	<i>131.2</i>	129.0
ZAR per USD	5.88	6.101	6.316	<i>6.525</i>	6.728
Forward 3m					
\$-LIBOR	5.38%	4.81%	4.60%	4.60%	<i>4.60%</i>

Step 3: Scenario generation

The scenarios generated in Example 9.1 through Example 9.6 using the VECM forecasts are used.

Step 4: Valuation

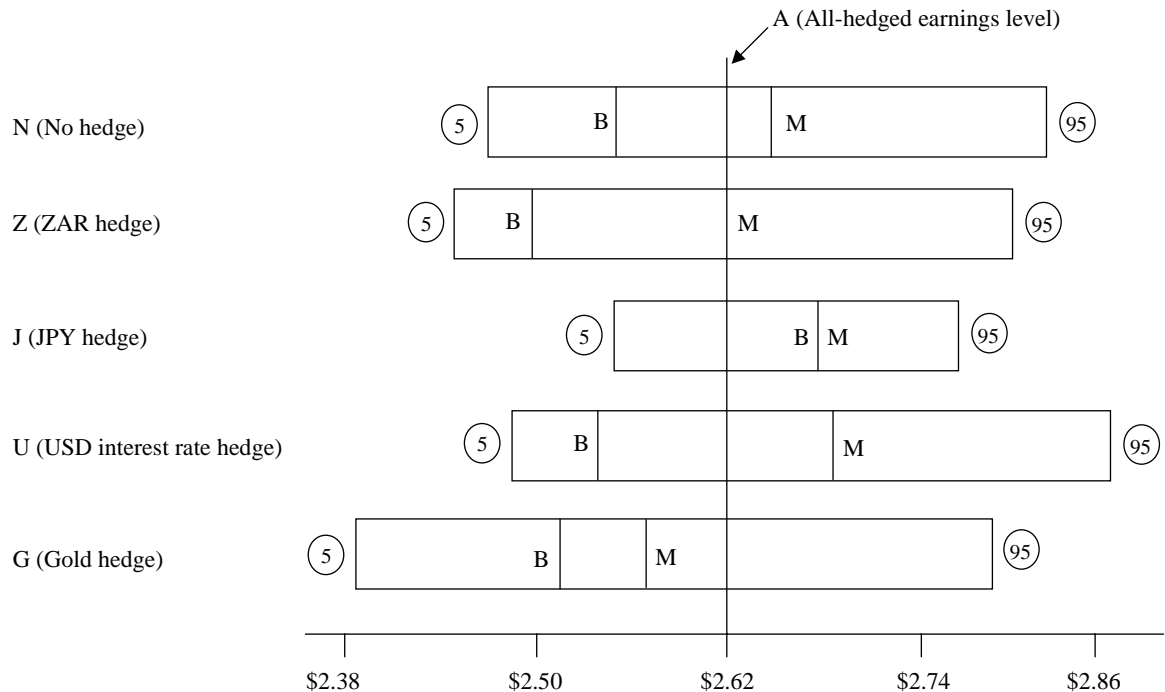
For each of the six cases in this example, we calculate ABC's earnings using each of the 10,000 *LongRun* scenarios for quarterly JPY/USD rates, ZAR/USD rates, U.S. 3-month interbank rates, and gold prices. Table 9.8 summarizes the 5th percentile outcome (i.e., 95% worst case outcome), the target earnings based on ABC's budget rates, the mean value of the resulting earnings distribution, and the 95th percentile outcome for each of the six cases. Chart 9.19 plots the earnings distribution statistics and budgeted earnings shown in Table 9.8.

Table 9.8

Summary of earnings distribution statistics and budgeted earnings*Per share amounts*

	5th percentile (<i>LongRun</i> scenarios)	Budgeted earnings (ABC budget rates)	Distribution mean (<i>LongRun</i> scenarios)	95th percentile (<i>LongRun</i> scenarios)
N (No hedge)	\$2.46	\$2.53	\$2.64	\$2.83
G (Gold hedge)	\$2.39	\$2.52	\$2.58	\$2.80
J (JPY hedge)	\$2.55	\$2.66	\$2.66	\$2.77
Z (ZAR hedge)	\$2.43	\$2.50	\$2.62	\$2.81
U (USD IR hedge)	\$2.49	\$2.54	\$2.67	\$2.87
A (All-hedged)	\$2.62	\$2.62	\$2.62	\$2.62

Chart 9.19

Summary of earnings distribution statistics and budgeted earnings

(5) - 5th percentile earnings

(95) - 95th percentile earnings

B - budgeted earnings

M - Earnings distribution mean

Step 5: Risk computation

Using the data in Table 9.8 and Chart 9.19, we can compare the risk and return characteristics of the six cases in several ways. One perspective is to set the target earnings level at the all-hedged level. Since forward rates are known with certainty on the analysis date, the all-hedged level of expenses can serve as a useful, indisputable benchmark to which other hedging strategies can be compared. For example, the business units of a company can use forward rates to calculate their budgets. By doing so, the business units can focus on business volumes, leaving treasury the responsibility for executing the financial contracts necessary to hedge the exposures generated by the business units and lock in the forward rates used for budgeting. If the treasury deviates from the budget by hedging less than the budgeted amounts, the treasury may improve returns but will incur market risk relative to its budget mandate.

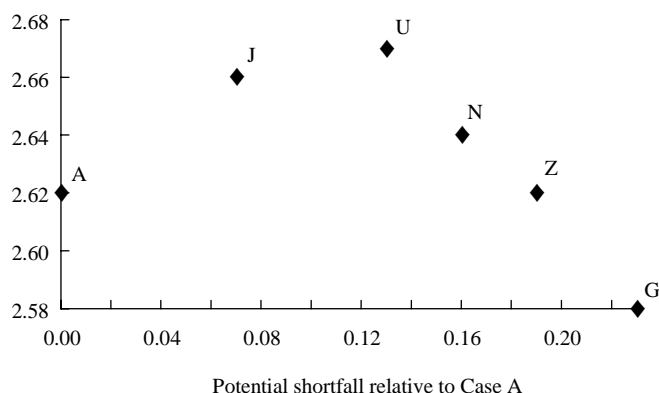
If we assume that the treasury's base case is the all-hedged case ("A"), then for each additional case, we can plot target earnings versus the 95% worst case amount by which actual earnings could fall short of all-hedged earnings ("potential shortfall"). This type of plot indicates to treasury the incre-

mental risk and return associated with various strategies that deviate from the all-hedged case. In Chart 9.20, we plot the simulated distribution means versus potential shortfall for each case.

Chart 9.20

Mean simulated earnings versus potential shortfall, relative to the all-hedged case

Mean earnings per share



For example, for Case U, Chart 9.20 shows that target earnings would increase from Case A's \$2.62 to \$2.67 per share if the company hedges USD interest rate risk and leaves all other exposures unhedged, but earnings could potentially fall \$0.13 short of Case A's earnings level (\$2.62–\$2.49 = \$0.13). As shown, three of the cases (J, U, N) offer higher expected returns than the all-hedged Case A, but with varying degrees of potential shortfall risk.

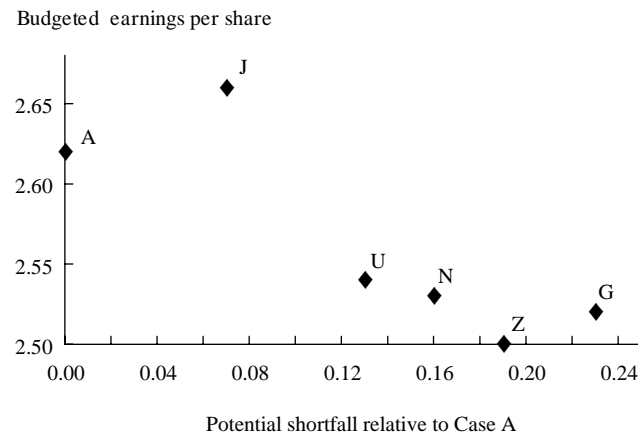
In Chart 9.20, the target returns are determined by the mean values of the earnings distributions obtained from the valuation and simulation process. However, we recognize that many companies use internal budget rates rather than forward rates, VECM forecasts, or distribution means to determine target earnings levels. Table 9.9 summarizes ABC's assumed budget rates. To illustrate how different methodologies for determining target earnings affect the analysis, Chart 9.21 shows budgeted EPS, as calculated using ABC's budget rates, versus potential shortfall relative to the all-hedged case for each case.

Table 9.9

ABC Co.'s budget rates

	30-Sep-98	31-Dec-98	31-Mar-99	30-Jun-99	30-Sep-99
Gold, \$/Troy oz.	300	300	300	300	–
JPY per USD	–	140	142	145	150
ZAR per USD	–	6.0	6.0	5.8	5.5
Forward 3m \$-LIBOR	5.1325%	5.1325%	5.1325%	5.1325%	–

Chart 9.21

Budgeted earnings versus potential earnings shortfall, relative to the all-hedged case

For example, by hedging ABC's USD interest exposure and leaving other exposures unhedged, Chart 9.21 shows that target earnings would fall from the all-hedged level of \$2.62 to \$2.53 per share (based on ABC's budget rates), and the potential shortfall would be \$0.13.

Whichever method a company uses to determine target earnings, the plot analysis shown above is one way to determine whether alternative hedging strategies offer sufficient return given the incremental market risks. We emphasize that the above analysis considers only market risk and does not account for the inherent uncertainty of ABC's business volumes.

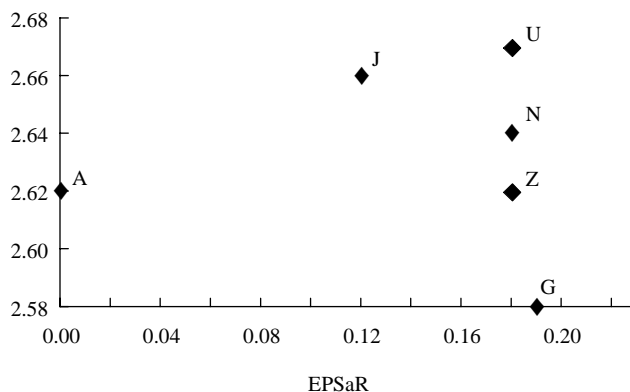
Another way of presenting the same underlying comparative information for the six cases is to plot target return versus absolute EPSaR with respect to each specific case. Plotting earnings versus earnings volatility in this fashion can be useful, for example, when considering alternative hedging strategies subject to an overall EPSaR limit.⁵ This plotting method distinguishes those cases in which EPSaR is below the company's pre-determined limit from those cases in which EPSaR exceeds tolerable levels. Furthermore, this plotting method clearly identifies those cases with the best target returns for a given level of risk. In Chart 9.22, we plot simulated earnings distribution means versus EPSaR for each case.

⁵ For a more general discussion on the use of EPSaR limits to manage overall earnings volatility, see Chapter 3.

Chart 9.22

Mean simulated earnings versus EPSaR

Mean simulated EPS



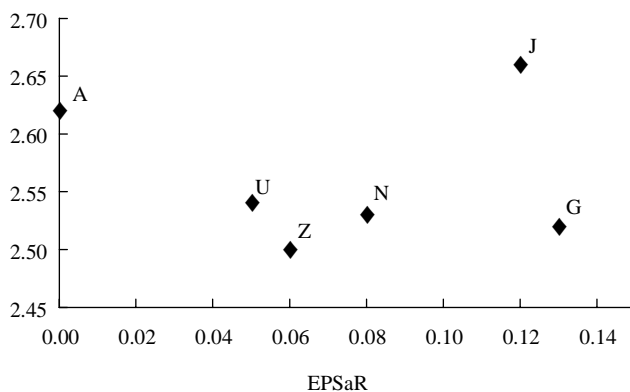
As shown, Cases U, N, Z, and G all have comparable levels of EPSaR relative to their respective distribution means, but Case U has the highest expected earnings. Cases A and J have lower expected earnings, but also lower levels of market risk associated with them.

Alternatively, Chart 9.23 plots budgeted earnings versus EPSaR for each case. Since the budgeted earnings are different from the mean earnings as determined using VECM scenarios, EPSaR levels also differ substantially between Chart 9.22 and Chart 9.23. As discussed above, the choice of target earnings levels greatly affects the nature of risk calculations and different companies will prefer different methods.

Chart 9.23

Budgeted earnings versus EPSaR

Budgeted Earnings



By plotting the risk and return characteristics of multiple hedging strategies such as partial hedges and different combinations of hedges, companies can obtain an even more detailed map of risk/return possibilities, which can provide useful information in decisions involving risk-taking and hedging strategies.

9.2 Summary

This chapter illustrated a number of practical applications of the CorporateMetrics framework in measuring commodity, foreign exchange, and interest rate risk. Our objective was to demonstrate

the principles at work and to suggest some examples of how risk management information can be aggregated and presented. The principles can be applied and customized to suit any given organizational situation.

Simple exposure maps (components of pro forma financial statements) were used to illustrate how changes in market rates would affect the projected value or level of specific financial results. For companies seeking to utilize more complex exposure mapping (e.g., taking into account price elasticities, business risk, and so forth.), the same conceptual approach applies, though the range of output values of course will be different and will be a function of the kinds of assumptions made for relating market rates to output variables.

In this chapter, the examples illustrated the use of econometric forecasting techniques (*LongRun's* VECM approach) to generate scenarios of quarterly market movements. Companies may elect to apply other forecasting techniques that are applicable in their institutions and can generate scenarios with more frequent intervals such as monthly or even daily market movements in order to align risk measurement practice with actual business reporting or review cycles.

For a discussion on the ways in which the outputs of the risk management process can be used to improve the way risk can be managed, refer to Chapter 3.

Chapter 10. Performance assessment

In this section, we discuss how companies can assess the accuracy of their implementation of the CorporateMetrics approach. Since the objective of the CorporateMetrics framework is to forecast the potential effect of market risk on financial results, it is important to perform a reality check on the approach to assess how accurate are the forecasted results and to identify the factors that may have caused their departure from the realized values. As is evident from the topics covered in this publication, risk management in the corporate environment is complex and involves a number of different assumptions and modeling decisions on the part of companies. Companies make choices regarding how exposure maps will be formulated and how market rate probability distributions will be specified. These modeling choices and assumptions can be refined over time. We describe some ways in which assumptions can be reviewed to obtain feedback for refining risk measurement models.

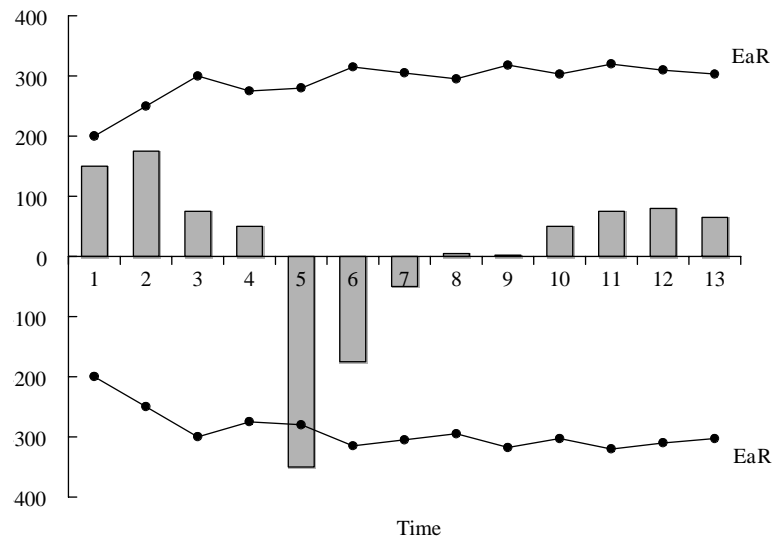
10.1 Backtesting actual financial results versus forecasted market risk

One approach to performing a general assessment of a corporate risk measurement model is to count the number of times that a risk measure under- or overpredicts shortfalls in financial results due to market risk. Chart 10.1 shows a sample graph of actual earnings surprises/shortfalls relative to target versus the EaR forecasted for the period, in each of a series of reporting periods. This is a convenient way of summarizing information for backtesting purposes.

Chart 10.1

Sample reporting format—actual earnings surprise/shortfall versus EaR

Earnings surprise/shortfall, \$000s



For example, when using EaR (95% confidence level) as a measure, it is useful to check the frequency of actual earnings shortfalls that exceed EaR estimates for each corresponding time period. If over time, significantly more than 5% of actual earnings results fall short of target by more than the predicted EaR value due to market risk, it may be an indication that the risk measurement method underestimates risk. Conversely, if the incidence of earnings shortfalls that exceed EaR estimates is significantly below 5% of the observed periods, it may be an indication that the risk measurement method overestimates estimates risk. In order to continually improve a risk measurement model, it is useful to track its performance over time and to identify the specific ways in which the model is either under- or overestimating market risk. Many companies identify the sources of

variance from budget for their financial results. It is common to identify the way in which market factors, business factors, or other factors contribute to performance that falls short of or exceeds budget or targets. Naturally, business risk can contribute to variability in financial results, and in many cases can be the largest risk. These factors are discussed in the following section.

10.2 Assessing model input assumptions

Given the many steps in the risk measurement process, there are several sources of potential model error that can affect the accuracy of market risk measures.

- **Forecasting methodology:** Since the choice of forecasting methodology determines the market rate distributions and scenarios used, it is possible to check actual ex-post market rate movements against the a priori forecasted distributions. If actual market rates are consistently exceeding the magnitude of the upper or lower confidence levels of the distributions, the forecasting model may be underestimating market rate volatility and/or specifying mean forecasts suboptimally. In contrast, if actual market rates are consistently within the confidence level bounds specified by the market rate distributions, the forecasting may be overestimating volatility.

For a complete discussion on performance assessment of long-horizon forecasting techniques, see *LongRun*, Chapter 4.

- **Applicability of exposure mapping:** By comparing actual financial results to the results predicted by exposure maps for a specific set of market rates, it is possible to assess how well exposure maps model the relationship between market rates and financial results. During periods of volatile market rates, valuable information can be obtained regarding the impact of market rate changes on business results, such as sales volumes. Many considerations enter into exposure mapping, including pricing policy and competitive strategy. By continually refining the formulation of exposure maps it is possible to improve risk measurement performance. One key challenge is to distinguish between errors that arise from the failure to model business risk and errors arising from inaccurate modeling of the relationships between business results and market rates.
- **Applicability of target levels:** When measuring risks relative to a target, it is important to assess the appropriateness of the assumptions used to determine the targeted levels of financial results. For example, if one forecasting approach is being used to construct market rate scenarios, and a different approach is being used to calculate and forecast target rates, the forecasted EaR or CFaR levels may be over- or underestimated. By tracking the forecasts produced by the different methodologies being used, companies can determine the methods that work best for the markets to which they are exposed and can refine the procedures being used to set target rates.

Appendix A. Analytical approaches to risk measurement

As mentioned in Chapter 2, an analytical approach to risk measurement can be used as an alternative to the simulation-based approaches discussed in this publication. We illustrate an analytical approach with the simple example below.

Suppose a company wants to measure the Earnings-at-Risk (EaR) due to the impact of aluminum price fluctuations on the cost of aluminum purchases. If the company purchases one metric ton of aluminum per month, its aluminum expenses C_T for the next three months can be expressed as

$$[A.1] \quad C_T = C_1 + C_2 + C_3,$$

where C_i is the price of aluminum per metric ton in the i -th month from the analysis date.

The variance function of C_T , $\text{VAR}(C_T)$, can be expressed as

$$[A.2] \quad \text{VAR}(C_T) = \sum_{i=1}^3 \text{VAR}(C_i) + 2 \sum_{i=1}^2 \sum_{j=i+1}^3 \text{COV}(C_i, C_j),$$

where $\text{COV}(\cdot)$ is the covariance function. Hence, estimates for the variance of aluminum prices one, two, and three months forward are needed, as well as estimates for the covariance between the prices. Once the variance of C_T is known, we define σ_T the standard deviation of C_T as

$$[A.3] \quad \sigma_T = \sqrt{\text{VAR}(C_T)}.$$

The mean of the total aluminum expense, μ_T , is given by

$$[A.4] \quad \mu_T = \sum_{i=1}^3 \hat{C}_i,$$

where \hat{C}_i is the expected value of aluminum prices in the i -th month from the analysis date. Hence, expected prices are also required for the analytical approach.

With information about the mean and standard deviation of C_T , the $n\%$ confidence level $C_{T,n}$ for C_T can be represented by

$$[A.5] \quad C_{T,n} = \mu_T + z_n \cdot \sigma_T,$$

where z_n is a constant.

One key challenge is determining the appropriate level of z_n to estimate the $n\%$ confidence level for C_T . If each of the C_i are assumed to be normally distributed, then C_T is normally distributed, in which case the level of z_n corresponding to the $n\%$ confidence level can be obtained from a standard table for normal distributions. For other distributions for which standard deviation characterizes the entire distribution, it is also possible to deduce confidence intervals using the standard deviation. If standard deviation is not sufficient to allow for the inference of confidence levels, there may be no analytic solution for determining confidence levels.

Assuming the company's target value for aluminum expense is T , then EaR with $n\%$ confidence is given by

$$[A.6] \quad EaR = C_{T,n} - T.$$

An analytical approach to risk measurement works well when financial results are assumed to be linear functions of future market rates and the probability distributions of future market rates are known and can be completely characterized by mean and standard deviation. However, a purely analytical approach lacks flexibility compared to simulation-based approaches when modeling certain market rate dynamics, such as mean-reversion or cointegrating relationships, which can lead to distributions that cannot be completely characterized by analytic techniques.

Appendix B. Precision of confidence level estimates

In Chapter 8, we presented a methodology for computing confidence levels from probability distributions of financial results obtained from simulation.¹ We mentioned that statistics which are estimated in this way are subject to random errors. In this appendix, we discuss how we may quantify the sizes of these errors, and thus discover how confident we may be of the risk estimates we compute.

In this section, we will use $V^{(1)}, V^{(2)}, V^{(3)}, \dots, V^{(N)}$ to indicate the values of financial results (e.g., earnings or cash flow) across scenarios and $V^{[1]}, V^{[2]}, V^{[3]}, \dots, V^{[N]}$ to indicate the same values sorted in ascending order (so that, for example, $V^{[2]}$ is the second smallest value).

Suppose we are trying to estimate the financial result at the 95% confidence level (or its equivalent, the 5th-percentile value), and let θ_5 be the true value at this level. At 95% confidence, each scenario that we generate then, by definition, has a 5% chance of producing a financial result less than θ_5 . Now let's consider 1000 independent scenarios, and let N_5 be the number of scenarios that produce financial results below θ_5 . Note that N_5 follows the binomial distribution. Clearly, the expected value of N_5 is $5\%(1000) = 50$ scenarios (i.e., 50 financial results below θ_5), while the standard deviation is $\sqrt{5\%(1000) \cdot (100\% - 5\%)} = 6.9$. For this many trials, it is reasonable to approximate the distribution of N_5 as being normal. Thus, at one standard deviation, we estimate with 68% chance that N_5 will be between $50 - 6.9 = 43.1$ and $50 + 6.9 = 56.9$ scenarios; the probability that N_5 will be between 43 and 57 scenarios is slightly higher than 68%. Since we are looking for a 95% confidence level result for a one-tailed distribution, we also need to know that N_5 falls between $50 - (1.65)(6.9) = 38.6$ and $50 + (1.65)(6.9) = 61.2$ with 90% chance.

At this point we have characterized the distribution of N_5 . This may not seem particularly useful, however, since N_5 is not actually observable. In other words, since we do not know the value θ_5 (this is what we are trying to estimate), we have no way of knowing how many of our scenarios fall below θ_5 . We assert that it is not necessary to know N_5 exactly, since we can gain a large amount of information from its distribution.

Observe that if N_5 is greater than or equal to 43, then at least 43 of our simulated financial results are less than θ_5 . This implies that θ_5 is at least as large as the 43rd smallest of our financial results. (Recall that in our notation, this scenario is denoted by $V^{[43]}$.) On the other hand, if N_5 is less than or equal to 57, then it must be true that θ_5 is no larger than the 57th smallest of the financial results (that is, $V^{[57]}$).

Thus, we have argued that the event

$$[B.1] \quad 43 \leq N_5 \leq 57$$

is exactly the same as the event

$$[B.2] \quad V^{[43]} < \theta_5 < V^{[57]}.$$

Now, since these two events are the same, they must have the same probability, and thus

¹ The material in this appendix is based on a similar discussion in the *CreditMetrics—Technical Document* (1997).

$$[B.3] \quad \Pr\{V^{[45]} < \theta_5 < V^{[57]}\} = \Pr\{43 \leq N_5 \leq 57\} = 68\%,$$

so we have a confidence bound for our estimate of θ_5 . To recap, for 1000 scenarios, we can estimate the true value of the 5th percentile financial result to be the 50th smallest simulated financial result, and state that we are 68% confident that the true value lies somewhere between the 43rd and 57th smallest simulated financial results.

In general, if we wish to estimate the true value at the p -th percentile using N scenarios, we first consider the number of scenarios that fall below the true value of this percentile. We characterize this number by the following measures:

$$[B.4] \quad \begin{aligned} \text{lower bound: } l &= Np - \alpha\sqrt{Np(1-p)} \\ \text{mean: } m &= Np, s = \sqrt{Np(1-p)} \\ \text{upper bound: } u &= Np + \alpha\sqrt{Np(1-p)} \end{aligned}$$

where α depends on the level of confidence that we desire. (That is, if we desire 68% confidence, then $\alpha = 1$; if we desire 90%, then $\alpha = 1.65$, and so forth.) If either l or m is not a whole number, we round it downwards, while if u is not a whole number, we round upwards. We then estimate our percentile by $V^{[m]}$ and state that at our desired level of confidence, the true value lies between $V^{[l]}$ and $V^{[u]}$.

For further discussion of these methods, see DeGroot (1986, p. 563). Note that the only assumption we make in this analysis is that the binomial distribution is well-approximated by the normal distribution. In general, this will be the case as long as the expected number of scenarios falling below the desired percentile (that is, Np) is at least 20 or so. In cases where this approximation is not accurate, we may take the same approach as in this section, but characterize the distribution precisely rather than using the approximation. The result will be similar, in that we will obtain confidence bands on the number of scenarios falling below the threshold, and then proceed to infer confidence intervals on the estimated percentile.

Appendix C. Components of earnings

The components of earnings can, in general, be depicted as

$$\begin{aligned}
 & \text{Earnings } (E) \\
 &= \text{Revenue } (R) \\
 &- \text{Cost of Goods Sold } (C) \\
 &= \text{Gross Margin} \\
 &- \text{Sales, General \& Administrative Expenses } (SGA) \\
 &- \text{Depreciation } (D) \\
 &- \text{Net Interest Expense } (I) \\
 &+ \text{Gains } (G) \\
 &- \text{Losses } (L) \\
 &= \text{Net Income Before Taxes} \\
 &- \text{Income taxes } (T)
 \end{aligned}$$

Alternatively,

$$[C.1] \quad E = R - C - SGA - D - I + G - L - T.$$

As shown, earnings can be viewed as a portfolio of components whose values can change in response to market rate changes. By expressing earnings components as functions of market rates, we have an expression for how earnings can change as a result of market rates changes. In other words, earnings can be expressed as a portfolio of market exposures.

Below, we examine each of the above components of earnings and discuss general considerations for formulating exposure maps for these components.

C.1 Revenues

Revenue (R) can be decomposed as follows, into the sales volume function (\vec{V}) multiplied by sales price function (\vec{P}) for all currencies (X) in which sales will be made during the fiscal period, for all countries (i) in which sales are made and for all products or services (j) sold:

$$[C.2] \quad R = \sum_i X \sum_j \vec{V} \cdot \vec{P}$$

In their most general form, the sales volume functions and product price functions can be functions of market rates. For example, expected sales volumes may be expressed as a function of exchange rates. Even if a company has only domestic revenue, sales could fluctuate with exchange rates due to competitive exposures (e.g., if the Japanese yen weakens against the U.S. dollar, U.S. consumers may buy more imported goods since their effective prices are lowered). If product or service prices P_j are adjusted to account for changes in exchange rates or commodity prices, the adjustments should also be specified in the pricing function.

C.2 Cost of goods sold

The cost of goods sold (C) is equal to the input volume function (\vec{V}) multiplied by the price per input (K) for all the products (j) the company sells and for all the currencies (X) in all the countries (i) in which the company sources inputs:

$$[C.3] \quad C = \sum_i X \sum_j \vec{V} \cdot K$$

In a manner similar to exposure mapping for revenue, the sensitivity of the cost function to currency, interest rate, and commodity price movements should be specified and expressed in the exposure map's entries relating to the cost of goods sold.

C.3 Net interest expense

The net interest expense for levered companies can be expressed as the amount of debt on the balance sheet (B) multiplied by the period's interest rate per debt instrument (r) for all instruments (k), in all the countries (i), and currencies (X) in which debt has been assumed:

$$[C.4] \quad I = \sum_i X \sum_k B \cdot r$$

Thus interest expense gives rise to currency and interest rate exposures that need to be captured in an exposure map. A detailed corporate plan may also include debt rollover assumptions to accurately project interest expenses over time. For companies with net interest earnings, such as financial institutions and low- or zero-debt companies, a similar analysis is performed on interest-bearing assets net of debt.

C.4 Other expenses, depreciation, and amortization

These components are typically fixed-nominal value cash flows projected by the user. However, to the extent that the nominal values of these flows are sensitive to market rate changes, the relationships should be incorporated into exposure maps.

For example, other expenses may include:

- Pension-related expenses—Expenses related to pension fund contribution may be related to market movements in interest rates, equity prices, or foreign exchange.
- Compensation in the form of stock and stock options—Depending on the level of future stock or stock option awards and treasury stock available that can be used to meet obligations, companies may forecast stock purchasing expenses that take into account equity price risk.

C.5 Gains and losses

Anticipated gains and losses for transactions denominated in foreign currencies or other positions that need to be accounted for on a fair-value basis can be a component of earnings. These are not cash flows, but rather end-of-period accounting adjustments. Hence, a comprehensive inventory of items that need to be valued must be maintained and the formulas for pricing the items need to be included in the exposure map.

Example C.1 Revaluation of accounts receivable

A German company agrees to buy DM 100,000 of equipment from ABC, a U.S. company, in month one. The revenue is booked at an exchange rate of 1.75 deutsche marks per dollar, resulting in recorded revenue of \$57,142.86. At the same time, ABC's accounts receivable are debited with \$57,142.86. ABC expects to collect DM 100,000 in cash to settle the account in month three.

In month two, the end-of-month exchange rate is 1.80 deutsche marks per dollar. As a result, ABC records a loss on foreign exchange translation of its account receivable in the amount of:

$$\text{DM}100,000 \times [(1/1.80) - (1/1.75)] = -\$1,587.30.$$

C.6 Provision for income taxes

Typically, the allowance for income taxes (T) for each country in which earnings are booked is a function of net income before taxes ($NIBT$) adjusted for book/tax differences, the tax rate (τ), the amount of interest expense ($I = f(B, r, X)$) assuming interest deductibility, any Tax Loss Carry-forwards (TL), and the condition that ($NIBT$) is positive (otherwise $T = 0$). Tax can be expressed as follows:

$$[C.5] \quad T = f(\tau, B, r, X, TL, NIBT > 0).$$

Tax policies can be extremely complicated and need to be properly modeled in the pro forma income statement or other exposure map in order to obtain accurate after-tax earnings estimates. Issues such as book/tax differences, credits for foreign taxes paid and incremental taxes due on remitted income from foreign operations should be accounted for with the appropriate external accountants and internal tax specialists.

C.7 The impact of account collection periods on earnings

When constructing exposure maps for foreign currency-denominated revenues or expenses that are not immediately cash-settled and that first result in the booking of an account receivable or payable, both the booking date and the average settlement period for the account are generally needed to fully determine the potential impact of market risk on earnings. The date on which an account is booked will determine the period in which an expense or revenue is recognized. The settlement date will determine the period in which a transaction gain or loss may need to be recognized. The combined effect of revenue/expense and transaction gain/loss is needed to deduce potential earnings impacts.

C.8 Policies for dividends and remittance of profits

To permit accurate calculation of earnings and other results, the anticipated timing of any dividends from foreign operations needs to be specified and modeled in the pro forma financial statements or other exposure maps. For example, if foreign currency profits are dividended to the parent company, the timing of the event and the anticipated prevailing exchange rates need to be specified. If foreign earnings remain abroad, assumptions regarding how profits are to be managed (e.g., kept in cash or reinvested) need to be specified. Identification of the exposure implications inherent in corporate policies permits a comprehensive and accurate forecast of earnings and its potential volatility.

Glossary of terms

absolute risk. A forecast of the worst case result, for a specified confidence level and time horizon, for a financial result or other performance metric.

accrual accounting. An accounting approach emphasizing the recognition of a transaction on the financial statements when it occurs.

anticipated transaction. Exposures associated with cash flows which are not firm commitments, but are likely to occur.

balance sheet. A financial statement that shows the assets, liabilities, and shareholder's equity of a business entity at a particular instant in time.

budget rates. Market rates based on spot rates, forward rates, consensus estimates by internal economists or analysts, or whatever rates are deemed appropriate by the company for use in the planning process to calculate budgeted earnings.

business risk. The uncertainty of future financial results related to the business decisions and investments that companies make, such as investing in productive capabilities, product development choices, market strategies, and business development strategies.

cash flow. 1. In the context of corporate performance measurement, cash flow refers to the net change in cash balances for a specified reporting period. 2. In the context of a transaction or in reference to a financial instrument, a cash flow refers to a payment of currency for a specific payment date.

Cash-Flow-at-Risk (CFaR). The maximum shortfall of net cash generated, relative to a specified target, that could be experienced due to the impact of market risk on a specified set of exposures, for a specified reporting period and confidence level.

competitive risk. See *economic risk*.

cost of capital. The opportunity cost of funds employed as a result of an investment decision with respect to investments of comparable risk.

cumulative translation adjustments (CTA) account. A balance sheet item within shareholder's equity which shows the cumulative balance of translation adjustments for a company.

derivative instrument. A financial instrument whose value is based on another instrument, security, or index.

earnings (net income). The excess of all revenues and gains for a period over all expenses and losses for the same period, as calculated in accordance with GAAP.

Earnings-at-Risk (EaR). The maximum shortfall of earnings, relative to a specified target, that could be experienced due to the impact of market risk on a specified set of exposures, for a specified reporting period and confidence level.

economic (competitive) risk. Market risks that includes both the direct price effect of market price changes and the indirect effect on volumetric or quantity risks.

EPS. Earnings per share. Basic EPS is calculated by dividing earnings available to common stockholders divided by the weighted-average number of common shares outstanding for a given report-

ing period. Diluted EPS includes the determinants of basic EPS and, in addition, gives effect to dilutive potential common shares that are outstanding for the period, such as options and convertible securities. For more detail on EPS, see FASB's *Statement of Financial Accounting Standards No. 128*.

EPSaR. Earnings-per-Share-at-Risk.

exposure mapping. The process of translating market risk exposures into cash flows or market risk sensitive mathematical functions to be used as input in scenario simulation. In the corporate context, pro forma financial statements may be used for collecting and organizing mapped exposures to be valued for a particular market rate scenario.

fair value. Defined by U.S. GAAP as the amount at which an asset (liability) could be bought (incurred) or sold (settled) in a current transaction between willing parties, that is, other than in a forced liquidation or sale.

fair value accounting. See *mark-to-market (accounting)*.

FASB. Financial Accounting Standards Board.

financial statements. Refers to a company's income statement, balance sheet, statement of cash flows, statement of changes in shareholder's equity, and statement of comprehensive income.

forecasted transaction. See *anticipated transaction*

GAAP. Generally Accepted Accounting Principles.

hedge. A financial instrument or position that reduces the variance of the expected value of an underlying exposure.

hedge accounting. In general, the practice of matching the recognition of gains or losses of derivative contracts in conjunction with losses and gains on underlying exposures intended to be hedged.

income statement. A report of all revenues, expenses, gains, and losses pertaining to a specified reporting period.

liquidity risk. Used here in reference to the risk of not having sufficient funds on hand to honor financial obligations such as supplier or debt payments. In other contexts, liquidity risk refers to the potential loss upon sales of financial instruments or positions due to insufficient demand in the market, leading to depressed sale prices.

mark to market (accounting). The process of adjusting the valuation of a security, financial instrument, or portfolio to reflect fair values.

market rate scenario. A collection of data points describing one possible path of market rates and prices for the period, starting from the initial analysis date to the forecast horizon.

market risk (financial risk). The uncertainty of future financial results due to changes in market rates and prices,

path dependency. A characteristic of certain financial performance measures or contract prices which result in their value being a function of the path of market rates.

PDF. Probability distribution function.

pro forma. (adj.) Projected estimates. (n.) Also commonly used as an abbreviation for *pro forma financial statements*, which project a company's future earnings, cash flows, and balance sheet.

relative risk. The risk that future financial results fall short or underperform a specified target value. Risk measured relative to a specific target.

SEC. Securities and Exchange Commission of the United States.

standard deviation. Indication of the width of a distribution around its mean.

$$\sigma_x = \sqrt{\frac{1}{N-1} \cdot \sum_{i=1}^N (X_i - \bar{x})^2}$$

statement of cash flows. A statement that reports the cash receipts and cash payments of an entity during a particular reporting period.

stress-scenario. A specific user-defined market rate scenario which usually specifies large changes for a specific variables of interest in order to test a company's level of exposure to these markets. Sample stress-scenarios might specify a 20% drop of Thai baht against U.S. dollars or 100 basis point increase in interest rates across all maturities of the U.S. yield curve.

translation adjustment. A periodic adjustment to shareholder's equity reflecting the change in the translated value of consolidated foreign assets net of liabilities.

volatility. The standard deviation of market rate **return** distributions.

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