EPRI

Portfolio Optimization: Concepts and Challenges

Technical Report

Portfolio Optimization: Concepts and Challenges

1001567

Final Report, December 2002

EPRI Project Manager
A. Altman

EPRI • 3412 Hillview Avenue, Palo Alto, California 94304 • PO Box 10412, Palo Alto, California 94303 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

DISCLAIMER OF WARRANTIES AND LIMITATION OF LIABILITIES

ORGANIZATION(S) THAT PREPARED THIS DOCUMENT

The Brattle Group

ORDERING INFORMATION

Requests for copies of this report should be directed to EPRI Orders and Conferences, 1355 Willow Way, Suite 278, Concord, CA 94520, (800) 313-3774, press 2 or internally x5379, (925) 609-9169, (925) 609-1310 (fax).

CITATIONS

This report was prepared by

The Brattle Group
44 Brattle Street
Cambridge, MA 02138

Principal Investigator
J. Read

This report describes research sponsored by EPRI.

The report is a corporate document that should be cited in the literature in the following manner:

Portfolio Optimization: Concepts and Challenges, EPRI, Palo Alto, CA: 2002. 1001567.

REPORT SUMMARY

The term "portfolio optimization"—the process of finding and exploiting opportunities to add value by changing the composition of a business portfolio—has been occurring with increasing frequency in the electric power industry. For example, portfolio optimization has appeared as a topic on agendas for numerous industry conferences. Vendors of commercial software for trading and risk management also are starting to promote portfolio optimization capabilities. Though portfolio optimization is a hot topic, discussions often fail to provide either a foundation in economic principles or a connection to traditional capital budgeting methods. This report supplies the missing conceptual foundations and connections to traditional practices.

Results & Findings

This document compares and contrasts the notion of capital in financial and non-financial businesses. In particular, it introduces the idea of risk capital, which differs from the cash capital that is more familiar to managers in the electric power industry. It discusses the implications for project and contract evaluation in modern electric power companies, which have aspects of both industrial and financial companies. The report then provides a definition of risk capital based on the analysis of corporate liabilities and credit risk. It compares and contrasts this notion of risk capital with value at risk ("VaR"), which has become the standard measure of portfolio risk in the financial services industry. It also discusses why a cash flow or liquidity-based measure of portfolio risk may be a useful supplement to value-based measures. Finally, it explains problems that arise when allocating risk capital to a firm's business units and activities.

Challenges & Objectives

Many electric power companies are really hybrid industrial-financial firms, with characteristics of both "asset heavy" industrial businesses and "asset light" financial services businesses. As a consequence, their portfolios of assets and liabilities can vary greatly in terms of duration, liquidity, and transparency. Portfolio optimization is particularly challenging in this setting.

In an era of wholesale market competition and industry restructuring, managers in the electric power industry frequently have to evaluate contracts and commitments. These include power purchase agreements, fuel supply contracts, retail service agreements, and ongoing regulatory obligations. These contracts and commitments usually entail little or no up-front investment of the traditional sort. On the other hand, they can entail a high degree of risk. This report explains that risky contracts and commitments do entail capital investment, but one of a different sort. Portfolio optimization is intended to help managers do a better job of evaluating and selecting investments, contracts, and commitments in this setting.

Applications, Values & Use

Portfolio optimization requires that managers measure and ration risk capital as well as cash capital. This leaves a number of problems for further research:

- **Measuring risk capital**. What measure of risk capital should managers in the electric power industry use? Are cash-flow measures of portfolio risk better suited to companies with physical assets and long-term contracts? Would a combination of value and cash-flow-based portfolio risk metrics be better?

- **Capital allocation**. How should risk capital be allocated to specific business units, products, investments, and commitments? Under what conditions are marginal capital allocations satisfactory for decision making?

- **Downstream effects**. Investments and commitments made today affect future cash flows and capital requirements as well as current ones. Are there practical ways to take these downstream effects into account in capital budgeting?

- **Multiple constraints**. How can constraints on other resources (for example, cash capital) be incorporated into portfolio optimization methods?

- **Computation**. What computational tools are required to implement an effective program of portfolio optimization for electric power companies?

EPRI Perspective

Incorporating portfolio analysis into project and contract evaluation is likely to have the greatest influence on decisions about commitments that require little if any cash capital but substantial risk exposure. Risk management transactions are the prime example, but other decisions, such as providing retail services, have the same characteristics and often much longer term exposures. Conventional valuation analyses of capital investments are prone to assume that the cost of capital and debt capacity of all capital investments in a given industry are the same. Portfolio analysis should help to identify differences in debt capacity and perhaps clarify the systematic risk of different types of investments.

Approach

The project team addressed the subject of portfolio optimization from the point of view of understanding and exploiting synergies with financial origins. Since many non-financial decisions have important financial consequences, the team's focus on the financial origins of portfolio effects also is relevant to decisions about topics such as choice of production technology, inventory policies, and vertical integration.

Keywords

Portfolio Optimization
Capital Budgeting
Risk management
Derivatives
Market Value
Value-at-risk

CONTENTS

1 **INTRODUCTION 1-1**

What Is Portfolio Optimization? 1-1

Why Is Portfolio Optimization Important? 1-2

2 **CAPITAL AND RISK 2-1**

The Traditional Capital Budgeting Rule 2-1

What About Risk Management? 2-2

Risk Capital 2-3

Corporate Liabilities and Default Risk 2-4

Illustrative Examples 2-6

Why Ration Capital? 2-8

Implications For Decision Making 2-9

Risk Management Revisited 2-10

Conclusions 2-10

3 **DEFINING AND ALLOCATING RISK CAPITAL 3-1**

Definition Of Risk Capital 3-1

Example 3-2

Value at Risk 3-3

Cash Flow Risk Metrics 3-4

Risk Capital Allocation 3-5

An Example 3-5

Marginal Capital Requirements 3-6

4 **CHALLENGES FOR ELECTRIC POWER COMPANIES 4-1**

5 **REFERENCES 5-1**

LIST OF TABLES

Table 2-1 Capital Structure and Default Values..... 2-7
Table 2-2 Default Values with "High Risk" Assets 2-8
Table 3-1 Default Ratios and Capital Structure 3-3
Table 3-2 Marginal Versus Stand-Alone Default Ratios..... 3-6

1
INTRODUCTION

The term "portfolio optimization" has been surfacing with increasing frequency in the electric power industry. Evidence for this assertion exists in at least two forms. First, portfolio optimization has now appeared as a topic on agendas for numerous industry conferences.[1] Second, vendors of commercial software for trading and risk management are starting to tout capabilities for portfolio optimization. Though portfolio optimization is a hot topic, discussions often fail to provide either a foundation in economic principles or a connection to traditional capital budgeting methods. The purpose of this report, therefore, is to supply the missing conceptual foundations and connections to traditional practices. We begin by explaining what portfolio optimization is and why it has become an important subject for managers in the electric power industry.

What Is Portfolio Optimization?

Portfolio optimization can be defined as the process of finding and exploiting opportunities to add value by changing the composition of a business portfolio. The key word here is "portfolio", because the focus is on how resources—real assets as well as financial and non-financial contracts—can be combined to enhance their collective value. Portfolio optimization therefore differs from asset optimization, the focus of which is extracting additional value from a single asset.

This definition of portfolio optimization brings to mind the notion of synergy—the idea that the whole can be more than the sum of the parts. In a business context it is the *value* of the whole that can be greater than the sum of the *values* of the parts. Synergies can be classified as having either real or financial origins. By distinguishing between real and financial sources of value, we do not intend to suggest that the latter are in any way imaginary or ephemeral. These terms are standard in the lexicon of economic theory. Real synergies are those that arise due to the nature of production technologies and/or consumer preferences. For example, managers in the electric power industry have long recognized that some combinations of baseload, cycling, and peaking generation (production technologies) are more efficient than others because customer loads (consumer preferences) exhibit systematic (e.g., time of day and seasonal) and random variation. Thus a generation fleet consisting of a mix of baseload, cycling, and peaking resources can satisfy consumer demand more effectively than a fleet consisting of, say, peaking resources only.

[1] For example, Infocast recently held a conference devoted entirely to portfolio optimization (Houston: November 14-16, 2001).

Financial synergies in business are those that arise due to the way capital markets and financial institutions work—or *don't* work. In contrast to the assumptions of many theoretical models in financial economics, real-world financial markets and institutions are characterized by a variety of "frictions", such as transactions costs, taxes, and regulatory constraints on holdings of certain types of securities. These frictions imply—also in contrast to classical financial economics—that in general businesses need to ration capital. Specifically, that managers need to identify the capital requirements associated with prospective investments and commitments (e.g. contracts) in order to decide whether those are worth pursuing. This may not sound any different from traditional capital budgeting analysis but in fact it is because the term "capital" as just used is not the same as the notion of capital with which most managers in non-financial businesses are familiar. We will see that activities have requirements for risk capital, which will be defined presently. The amount of risk capital an activity requires, in turn, is related to how much risk that activity entails. Exactly how risk is to be measured in this context is not entirely clear, however, and that is one of the key topics of this exposition.

In this report we will address the subject of portfolio optimization from the point of view of understanding and exploiting synergies with financial origins. We want to emphasize at the outset, however, that this does not limit the application of the ideas to financial decisions. Indeed many non-financial decisions have important financial consequences, so our focus on the financial origins of portfolio effects is relevant to decisions about, e.g., choice of production technology, inventory policies, vertical integration, and so on. Elsewhere we have made this point by saying that firms have access to many "real" instruments for risk management, not just financial instruments, like insurance, swaps, and options.[2] These real risk management tools include, for example, the design and pricing of wholesale power and fuel contracts, fuel inventory policies, and choice of production technologies, all of which can have important affects on the risk of corporate assets and liabilities.

Why Is Portfolio Optimization Important?

It is a commonplace that the primary objective of corporate managers is to add value for shareholders. They do this by acquiring resources and deploying them in such a way that they are worth more in the market than they cost. The difference is value added. In one sense, portfolio optimization is just the implementation of this idea.

Prior to the emergence of wholesale market competition and industry restructuring, most electric utilities were vertically integrated businesses, with generation, transmission, and distribution assets. Companies with obligations to deliver power also had the capability to generate it, transmit it, and distribute it. Risk management was, in effect, provided by public utility regulation, which served to transfer much of the risk, as well as the potential returns, to the business from investors to ratepayers.

[2] This has been a central theme of the *Value & Risk Management in Commodity Markets* training seminars sponsored by the EPRI Asset & Risk Management Target.

This meant that most resource allocation decisions in the electric utility industry involved capital investments. The problem for utility planners was to determine whether forecast returns justified required investments (or what prices the utility would have to charge to recover its costs). Now, in contrast, managers in the electric power industry frequently have to evaluate contracts and commitments. These include power purchase agreements, fuel supply contracts, retail service agreements, and ongoing regulatory obligations, to name a few of the key ones. What's different is that these contracts and commitments usually entail little or no up-front investment of the traditional sort. On the other hand, they can entail a high degree of risk. In this report we explain that risky contracts and commitments *do* require a capital investment, but one of a different sort. Portfolio optimization is intended to help managers do a better job of evaluating and selecting investments, contracts, and commitments in this setting.

2
CAPITAL AND RISK

This section compares and contrasts the notion of capital in financial and non-financial (industrial) businesses. In particular, we introduce the idea of *risk capital,* which differs from the *cash capital* that is more familiar to managers in the electric power industry. We conclude with a discussion of the implications for project and contract evaluation in modern electric power companies, which have aspects of both industrial and financial companies.

The Traditional Capital Budgeting Rule

Capital budgeting is the process by which corporations decide which investments to make. The traditional capital budgeting rule goes more or less as follows.[3] Calculate the net present value (NPV) of prospective investment projects by forecasting the cash flows they will generate and discounting them back to the present at the opportunity cost of capital. Accept projects only if NPV is greater than zero. If faced with a choice from among two (or more) mutually exclusive projects, both (or all) of which have positive NPVs, select the project with the maximum NPV. Properly applied, the net present value criterion serves to distinguish investments that will add value for shareholders from those that won't. An investment with a positive NPV is *worth* more than it *costs*.

In principle, determining capital requirements and the cost of capital are straightforward. Capital requirements are incremental cash (or cash equivalent) outlays required to pursue an investment opportunity. The cost of capital is defined as the expected rate of return in capital markets on alternative investments of equivalent risk. This means that investment opportunities *in the capital market* provide the hurdle rate for corporate investment decisions, not the *internal* investment opportunities of corporations. It reflects a tacit assumption that corporations could (1) raise additional cash if necessary to undertake an investment, so long as the returns are favorable in the light of the returns available in the securities market or (2) return cash to shareholders (by paying dividends or repurchasing shares) rather than pursuing internal investment opportunities. The assumption is crucial because it implies that the risk analysis that is germane for corporate decision making depends on the characteristics of the specific investment opportunity under consideration, not the characteristics of the corporation evaluating the investment.[4]

[3] See, for example, Brealey and Myers, *Principles of Corporate Finance*, or the EPRI *Utility Capital Budgeting Notebook*.

[4] See Brealey and Myers, *Principles of Corporate Finance*. They emphasize this idea by saying that "the cost of capital depends on the use of funds, not the source."

Capital market theory concludes that there is a linear tradeoff between risk and expected returns in securities markets. The risk that is priced is systematic risk, that is, risk that cannot be eliminated merely by holding a well-diversified portfolio of securities. The systematic risk of a security thus depends on its *contribution* to the risk of a reference portfolio of securities.[5] The traditional capital budgeting rule therefore implies that the required rate of return on a corporate investment is likewise a function of its systematic risk. That is, the required rate of return *is not* a function of its contribution to the risk of the corporate portfolio. The risk-return tradeoff in capital markets is linear, implying that the required return on a corporate investment is the same whether that investment is a small or large part of the corporate portfolio. To put all of this another way, the traditional capital budgeting rule implies that there are no relevant interactions between the risk of a corporate investment project and the risk of its other investments and commitments. This is an extremely convenient result, since it implies that corporate managers can adopt decentralized investment decision rules.

The assumption implicit in this decision rule is that capital is always available to fund value-adding investments at zero *economic* cost. In other words, if it's a good investment, then funds will be available to finance it at zero premium (or discount) to the market price of capital. This is a critical assumption, to which we will return presently.

What About Risk Management?

The traditional capital budgeting rule seems to imply that risk management is *per se* value-destroying. Consider the following example. The front-month futures contracts for delivery of natural gas to Henry Hub are very liquid, which means that substantial volumes of gas can be traded forward on short notice with negligible impact on the market price. As a result, one can view Henry Hub futures prices as "fair", in that they are established through the competitive interactions of many buyers and sellers. This in turn implies that if we consider a futures contract as a stand-alone commitment and ignore any associated transaction costs, the net present value of entering into the futures contract is zero (i.e., is a fair forward trade of cash for commodity).

If we extend the analysis to take account of transactions costs (which are small but not zero), it implies that entering into a futures contract is a negative-NPV commitment. For example, suppose the transactions costs associated with putting on a 100,000 MMBtu natural gas futures position (ten contracts) is equal to one percent of the notional value of the contracts. If the futures price is $3/MMBtu, the notional value of the contracts is $300,000 and the associated transaction costs are $3,000. Since the NPV of the contracts before taking transactions costs into consideration is zero, the NPV with transactions costs factored in is –$3,000. On this basis, the hedge transaction would appear to be unattractive.

[5] The simplest model of this sort is widely known as "the" capital asset pricing model. In fact, there are many models of capital market equilibrium, some of which are extensions of the original Sharpe-Lintner-Mossin model and others of which differ in more fundamental ways. Nevertheless, these models share the properties that (1) tradeoffs between risk and return in securities markets are linear, and (2) risk that can be eliminated through diversification by investors is not "priced" in the sense of commanding a premium rate of return over and above the returns available on riskless securities.

Absent a speculative motive for trading futures, how, then, can one justify taking a futures position? The answer is that the preceding analysis must have left something out. Some of the participants in the futures market must realize benefits from hedging, which, when taken into account, change a negative-NPV transaction into a positive NPV.

What are the benefits to hedging? They can take many forms. The basic idea, though, is that risk has to be managed if a corporation is to remain a going concern. Firms that are too risky will not have access to capital markets, bank loans, or trade credit. Firms that are too safe may be "leaving money on the table". The benefits of risk management are generally difficult to quantify, but portfolio analysis can provide insights into when it pays to take on or lay off risk.

Risk Capital

Managers in non-financial businesses usually think about capital requirements in terms of the amount of cash needed to undertake an investment. In contrast, managers in financial businesses think of capital in terms of the equity required to achieve or maintain a target credit quality. Merton and Perold (1993) refer to the former as "cash capital" and the latter as "risk capital". Why the two notions of capital?[6] Many financial services entail little or no cash capital. Indeed, some financial services, such as property and casualty insurance, actually entail *negative* cash capital.[7] That is, the customer makes a payment (e.g., pays an insurance premium) in return for which the financial firm promises to deliver services in the future. Although many financial services require minimal cash capital, they typically require substantial risk capital.

As Merton and Perold emphasize, the customers of financial service firms are *liability holders*. They are therefore justifiably concerned about the ability of a company that sells them financial services to meet its obligations. If (potential) customers are not confident that the obligations will be fulfilled, they will decline to purchase such services. Credit quality is therefore crucial to the viability of a financial services firm. Financial firms are sometimes referred to as "credit-sensitive" to emphasize this point.

Credit sensitivity is a matter of degree, not whether a business is or is not "financial". Any forward service obligation, such as the warranty on an automobile, entails the risk that the contract will not be honored. More to the point, companies and their counterparts that enter into forward contracts for delivery of oil, natural gas, electricity, and other energy commodities are exposed to credit risk, which is the risk that one or the other will fail to perform on the obligations created by the contract. Any business that entails substantial forward rights and/or obligations is to some degree "credit sensitive". The same observation, therefore, is germane to retail as well as wholesale energy businesses.

To assure customers of their ability to meet their obligations, financial services firms need to provide collateral. Sometimes this collateral is explicit, as when firms post margin in connection

[6] Managers in the banking and insurance industries are also concerned with a third type of capital: regulatory capital.

[7] Other examples include financial guarantees and bank letters of credit.

with futures transactions. Usually, however, the collateral is implicit, meaning that it is embedded in the company's balance sheet in the form of aggregate assets that exceed aggregate liabilities by a substantial margin. This implicit collateral is one way to think of what is meant by the term "risk capital".

Corporate Liabilities and Default Risk

The customers of financial service companies are in an analogous position to the trade creditors, lenders, and bondholders of non-financial companies. As Black and Scholes (1973) observed in their seminal paper on option pricing, corporate liabilities are options. Their insight is crucial because, among other things, it implies that liability values depend on the total risk (as distinct from the systematic risk) of the corporation that has "issued" them. How much risk capital does a company need? The Black-Scholes insight suggests that risk capital requirements will depend on the total risk of a company's net assets—its aggregate assets net of its aggregate liabilities.

Consider a hypothetical corporation with a single issue of debt outstanding which is due one year from today. The fundamental accounting identity that assets equal liabilities implies that the market value of the corporation's assets V in this case is equal to the sum of the market value of its debt B and the market value of its equity S. What are the debt and equity worth today? To find out, we need to understand the structure of the debt and equity payoffs. One year from now, if the market value of assets V_1 is greater than face value of the debt F plus interest at promised rate R (compounding continuously), the debt will be worth its face value plus interest and the equity will be worth the residual value of the assets after the debt is paid off:

$$\text{If } V_1 \geq Fe^R, \text{ then } B_1 = Fe^R \text{ and } S_1 = V_1 - B_1$$

If the assets are worth less than the face value of the debt plus interest one year from now, then bondholders will realize the entire value of the assets and the shareholders claim will be worth nothing. The shareholders claim will never be worth less than zero due to the limited liability provisions of corporation law:

$$\text{If } V_1 < Fe^R, \text{ then } B_1 = V_1 \text{ and } S_1 = 0$$

We can summarize the end-of-year debt and equity payoffs using the following two formulas:

$$B_1 = Min\left\{V_1, Fe^R\right\}$$

$$S_1 = Max\left\{0, \left(V_1 - Fe^R\right)\right\}$$

Inspection of the equity payoff formula reveals that the equity in a corporation with debt outstanding is analogous to a call option on the corporation's assets. In this simple example, with a single issue of debt outstanding, the "strike price" of the call is equal to the promised principal plus interest on the debt. Inspection of the payoff formula for the debt leads (after some additional algebra) to the conclusion that it, too, is like an option. Specifically, the debt is

equivalent to the combination of a "default-free" bond and a put option on the corporation's assets. The default-free bond in this case is identical to the one issued by the corporation, except that it is assumed to be protected from the risk of default. In other words, the payoff to the default-free bond $\hat{B}_1$ is equal to the promised payment regardless of the value of the assets:

$$\hat{B}_1 = Fe^R$$

The "strike price" of the put option, like the strike price of the call, is equal to the face value of the debt plus interest, i.e., it is equal to $\hat{B}_1$. The put, which is written by the bondholders, can be viewed as a *default option*, with value D:

$$B_1 = \hat{B}_1 - D_1$$

$$D_1 = Max\left\{0, \left(\hat{B}_1 - V_1\right)\right\}$$

The value of the equity in the corporation is equal to the value of the assets minus the value of the outstanding debt, assuming that there is no right to default, plus the value of the default put:

$$S_1 = V_1 - \hat{B}_1 + D_1$$

These observations about payoffs imply that the current market values of the debt and equity in this case will be determined by (1) the current value V_0 of corporate assets, (2) the current value $\hat{B}_0$ of a bond that will repay the principal plus interest for sure one year from today, and (3) the standard deviation σ of the rate of return on corporate assets over a one-year time horizon. If the distribution of the future value of assets is log-normal, the value of the implicit default option is given by the following formula:

$$D_0 = \hat{B}_0 N\{z\} - V_0 N\{z - \sigma\}$$

Here $N\{\bullet\}$ is the cumulative normal probability function and the argument z is given by the following formula:

$$z = \frac{\ln\left\{\hat{B}_0 / V_0\right\}}{\sigma} + \tfrac{1}{2}\sigma$$

If the default-free rate of interest (compounding continuously) over a one-year time horizon is r, the current value of a default-free bond that will pay principal F plus interest at the promised rate R is given by:

$$\hat{B}_0 = e^{-r}\left(Fe^R\right) = Fe^{(R-r)}$$

We can use this framework to explore how investment and financial policies affect the value of liabilities issued by the corporation. Keep in mind that the single issue of debt can serve as a proxy for liabilities generally.

Illustrative Examples

Consider a firm with $10,000 worth of assets. Suppose the standard deviation of the rate of return on its assets over a one-year time horizon is 20 percent. The interest rate on default-free bonds is 5 percent. We will use the preceding framework to examine how the amount of liabilities a firm has outstanding affects its credit risk.

Compare the five cases in Table 2-1, which include debt-to-asset ratios ranging from 60 to 95 percent (i.e., debt worth $6,000 to $9,500). In each case the promised interest rate on the bonds has been set so that the market value of the bonds is equal to the face value. The market value of the bonds is always less than the default-free value, due to the possibility of default. The greater the debt, the higher the value of the option to default. This option value, remember, is an asset to the shareholders and a liability to the bondholders. At a debt ratio of 60 percent, the default value is only $3. This means the bonds would be worth an extra $3 if protected from default by a financial guarantee. At 80 percent debt, the default value is $142. At 95 percent debt, the default value is $1,265. Clearly the net assets of the firm—the value of its assets minus the value of the default-protected bonds—is critical to credit quality.

Table 2-1
Capital Structure and Default Values

Debt Ratio	60%	70%	80%	90%	95%
Market value of assets	10,000	10,000	10,000	10,000	10,000
Face value of bonds	6,000	7,000	8,000	9,000	9,500
Promised interest rate	5.04%	5.37%	6.76%	11.39%	17.50%
Value of default-free bonds	6,003	7,026	8,142	9,594	10,765
Default value	3	26	142	594	1,265
Market value of debt	6,000	7,000	8,000	9,000	9,500
Market value of equity	4,000	3,000	2,000	1,000	500
Net assets	3,997	2,974	1,858	406	-765

Source: Calculations by The Brattle Group.

Suppose that investors buy bonds anticipating that the firm will have a total of $8,000 of debt outstanding, and then the firm surprises them by immediately issuing an additional $1,000 of bonds. The promised interest rate required to compensate for the higher level of debt and credit risk will be 11.39% instead of 6.76%. The bonds will then be worth only $7,638, so the original purchasers will have lost $361.[8]

The default values and credit quality also depend on the risk of the firm's assets. Table 2-2 shows default values and promised interest rates for the same five cases if the standard deviation of the firm's assets is 25 percent rather than 20 percent. Default values are higher in all cases, with the largest changes being in the high-debt cases.

[8] The value of the bonds will be $Fe^{(R-R^*)}$, where R^* is the promised rate required under the new level of debt.

Table 2-2
Default Values with "High Risk" Assets

Debt Ratio	60%	70%	80%	90%	95%
Market value of assets	10,000	10,000	10,000	10,000	10,000
Face value of bonds	6,000	7,000	8,000	9,000	9,500
Promised interest rate	5.29%	6.18%	8.72%	15.46%	23.49%
Value of default-free bonds	6,015	7,080	8,300	9,988	11,425
Default value	15	80	300	988	1,925
Market value of debt	6,000	7,000	8,000	9,000	9,500
Market value of equity	4,000	3,000	2,000	1,000	500
Net assets	3,985	2,920	1,700	12	-1,425

Source: Calculations by The Brattle Group.

Suppose investors purchased $8,000 of bonds with the understanding that the standard deviation of the rate of return on the firm's assets was 20 percent, as in Table 1, but that they learned immediately thereafter that the firm had changed its business so that the true standard deviation of returns was actually 25 percent. By comparing the 80 percent debt cases in Tables 1 and 2, we can calculate that the value of the bonds would fall from $8,000 to $7,845, and thus that the bondholders would suffer a loss of $155. No value is created or destroyed, so the loss to bondholders would be a gain to shareholders.

These simple examples demonstrate why liability holders of a corporation have a strong interest in understanding the amounts and risks of the corporation's assets and liabilities. They also demonstrate why liability holders have an interest in the consistency of the firm's investment and financing policies, since unanticipated changes in policy imply transfers of wealth from bondholders to shareholders or vice versa.

Why Ration Capital?

Capital rationing implies that there is a "wedge" between the all-in cost of capital for corporate investments and the cost of capital prevailing in securities markets. There are several possible components of this wedge. Perhaps the most obvious is transactions costs: it is costly to negotiate loans and to issue securities, for example. Another reason is the income tax code: the United States tax code allows corporations to deduct interest expense in the calculation of tax liabilities, and it taxes interest income. This seems to imply that there is a tax benefit to debt financing and a tax cost to holding interest bearing securities. But there are other, less tangible costs too. In economic theory these are referred to as "agency" and "information" costs. Agency costs refer to the dissipation of value that occurs due to conflicts of interests between managers,

shareholders, creditors, and other liability holders of a corporation.[9] Information costs are costs associated with asymmetries between what corporate insiders know and what outside investors and creditors know.[10] Unfortunately, agency and information costs are difficult to quantify.

Implications For Decision Making

Corporations need risk capital to function as going concerns. The greater the risk of the corporation, the greater its requirements for risk capital. We have already observed that the Black-Scholes insight that liabilities are options implies that risk capital requirements are a function of total risk, not systematic risk. This means that risk capital requirements are a function of risk evaluated in a corporate portfolio, not market portfolio context. Thus, when a corporation contemplates making a change to its business, managers need to consider how that change will affect the corporation's requirements for capital. If a corporation does not infuse additional capital when it expands its business, for example, then it is in effect drawing down capital from the balance sheet—from the existing capital of the corporation.

The constrained capital budgeting problem implied by the forgoing discussion can be stated as follows: maximize value added subject to a constraint on aggregate risk capital. That is, managers should seek to maximize the sum of NPVs subject to the condition that total risk capital requirements are equal to or less than the available risk capital.

This suggests that companies need to use an *adjusted present value* (APV) criterion for decision making, where the adjusted present value is equal to the net present value (NPV) less a charge for use of risk capital. The charge for risk capital should equal the product of the capital requirement K and the shadow price of capital ϕ:

$$APV = NPV - \phi K$$

The shadow price of risk capital is equal to the net present value of the next-best investment or contract opportunity NPV^* the corporation faces, where the NPV is normalized by the amount of risk capital required by that investment K^*:

$$\phi = \frac{NPV^*}{K^*}$$

Some financial corporations attempt to incorporate the cost of risk capital in evaluations of individual business units by computing a "risk-adjusted return on capital" or RAROC. The RAROC for a business unit is equal to its earnings as conventionally calculated less a charge for capital, where the capital charge is equal to the product of a risk capital allocation and an

[9] The classic paper on agency costs in corporate finance is by Jensen and Meckling, "Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure".

[10] See Myers and Majluf, "Corporate Financing and Investment Decisions When Firms Have Information that Investors Do Not Have".

imputed cost of capital.[11] This practice is broadly consistent with the APV methodology outlined above.

Risk Management Revisited

In light of this augmented capital budgeting problem, the potential merits of a hedging transaction are clear: Hedging can reduce the risk of a corporate portfolio and release risk capital for investment and contract opportunities that add value. If the value added by the available opportunities exceeds the costs associated with hedging, then hedging adds value for the firm.

In the natural gas hedging example we calculated transactions costs of $3,000, and thus a stand-alone NPV of –$3,000. On that basis the transaction appeared to be unattractive. But suppose that the transaction had an incremental risk capital requirement of –$45,000 due to the reduction in portfolio risk that would result. If the marginal return on risk capital in the corporate portfolio was 10%, then the hedge transaction would free up capital with an opportunity cost of $4,500. Therefore, the APV of the transaction is +$1,500, indicating that it adds value when all costs and benefits are taken into account.

The costs of risk management transactions (e.g., commissions, bid-offer spreads, etc.) are generally easier to determine than are the benefits. Benefits are firm-specific. They depend on the composition of the corporate portfolio as well as the opportunities the corporation faces.

Conclusions

The upshot of this analysis is that firms need to measure both the market ("systematic") risk of their investments and commitments and the contribution those investments and commitments make to the risk of the corporate portfolio. Systematic risk determines the cost of capital in securities markets and hence the market value of future cash flows. Portfolio risk determines the credit quality of the corporation and hence its requirements for risk capital. To calculate the net present value of an investment or commitment, we need to estimate its systematic risk. To calculate the adjusted present value of an investment or commitment, which takes into account other components of capital costs, we need to analyze it as part of the corporate portfolio to understand how it will affect corporate requirements for risk capital.

Incorporating portfolio analysis into project and contract evaluation is likely to have the greatest influence on decisions about commitments that require little if any cash capital but have a substantial effect on risk. Risk management transactions are the prime example, but other commitments, such as providing retail services, have the same characteristics and often much longer term exposures. This is not to suggest that analysis of portfolio risk will be irrelevant to more traditional investments. Conventional valuation analyses of capital investments are prone to assume that the cost of capital and debt capacity of all capital investments in a given industry are

[11] See, for example, E. Zaik *et al*, "RAROC at Bank of America: From Theory to Practice", *Journal of Applied Corporate Finance*.

the same. Portfolio analysis should help to identify differences in debt capacity, and perhaps clarify the systematic risk of different types of investments.

3
DEFINING AND ALLOCATING RISK CAPITAL

The preceding section of this report explained why corporate managers need to measure risk capital and ration it as part of an overall program of portfolio optimization. Thus far, however, it has dodged two questions that arise immediately in any effort to implement these ideas:

- How should risk capital be defined? Managers need to be able to define risk capital in order to measure it.
- How can risk capital be allocated to business units, investments, and contracts? Managers need to be able to allocate risk capital to evaluate the merits of prospective commitments.

This section provides a definition of risk capital based on the analysis of corporate liabilities and credit risk in the previous section. It compares and contrasts this notion of risk capital with value at risk ("VaR"), which has become the standard measure of portfolio risk in the financial services industry. It also discusses why a cash flow or liquidity-based measure of portfolio risk may be a useful supplement to value-based measures. Finally, it explains the problems that arise when allocating risk capital to the business units and activities of the firm.

Definition Of Risk Capital

Risk capital was defined loosely in Section 2 as "the equity that a corporation needs to achieve or maintain a target credit quality". A more formal definition of risk capital is suggested by our analysis of corporate liabilities and credit risk.

First define the *default ratio*, which is the ratio d of the default value D to the present value of default-free liabilities $\hat{L}$:

$$d \equiv D_0 / \hat{L}_0$$

The default value is the present value of possible losses to liability holders in the event the corporation defaults. It is the amount the corporation would have to pay in a well-functioning market to purchase financial guarantees for its liabilities. The default ratio, therefore, is the present value of possible losses normalized by the value of default-free liabilities. It can be thought of as the fraction of the potential value of corporate liabilities dissipated due to credit risk. The default ratio is a measure of the credit quality of corporate liabilities, which the corporation needs to control to remain a financially viable counterparty.

Now a definition of risk capital. Risk capital K is the minimum investment required to keep the default ratio at or below a specified level d^* :

$$K = N_{\text{minimum}} \text{ such that } D_0 \leq \hat{L}_0 d^*$$

Net assets N is defined as the market value of assets less the present value of default-free liabilities: $N \equiv V_0 - \hat{L}_0$. It is not the same thing as equity. The market value of equity cannot be less than zero because shareholders have the option to default. The market value of net assets, on the other hand, can be positive or negative, since it is defined in terms of default-free liabilities.

Default-free liabilities are equivalent to risky liabilities that have been packaged with a financial guarantee. Risk capital is defined in terms of default-free liabilities rather than risky liabilities because corporate liability values depend not only on the characteristics of the liabilities themselves, but also on the amount and risk of the net corporate assets that implicitly back them. Thus the value of a risky liability will change when either the value or the risk of corporate net assets changes. The value of a default-free liability, in contrast, is independent of these variables.

Notice that this generalizes somewhat from the earlier analysis. Rather than casting the results in terms of a corporation with a single issue of debt outstanding (the value of which was denoted B), this allows for a portfolio of liabilities L all of which are assumed to have the same priority in bankruptcy. Remember, too, that corporate liabilities include not only financial contracts like bank loans and bonds but also commitments like wholesale supply contracts and retail service agreements.

How would managers choose a target default ratio? Most corporations try to maintain a certain credit rating (e.g., BBB). The default ratio that corresponds to a selected credit rating can be inferred by comparing the market prices of publicly traded bonds that have that rating with the prices of otherwise comparable bonds of very high credit quality. If, for example, the current interest rate on BBB-rated bonds with T years to maturity is R and the rate on default-free bonds with T years to maturity is r (R and r compounding continuously), then the implied default ratio on BBB-rated credits over a T-year time horizon is $d = 1 - e^{-(R-r)T}$.

Example

Table 3-1 is a version of Table 2-1 that has been augmented to report the default ratios corresponding to each of the five cases. Suppose management wished to maintain an A credit rating. Suppose further that management has analyzed bond prices and concluded that the default ratio over a one-year time horizon for A-rated credits is approximately 1 percent. Table 3 suggests that the firm could achieve its objective by keeping the liability component of its balance sheet somewhere in the range of $7,000 to $8,000.

Table 3-1
Default Ratios and Capital Structure

Debt Ratio	60%	70%	80%	90%	95%
Market value of assets	10,000	10,000	10,000	10,000	10,000
Face value of bonds	6,000	7,000	8,000	9,000	9,500
Promised interest rate	5.04%	5.37%	6.76%	11.39%	17.50%
Value of default-free bonds	6,003	7,026	8,142	9,594	10,765
Default value	3	26	142	594	1,265
Market value of debt	6,000	7,000	8,000	9,000	9,500
Market value of equity	4,000	3,000	2,000	1,000	500
Net assets	3,997	2,974	1,858	406	-765
Default ratio	0.04%	0.37%	1.75%	6.19%	11.75%

Source: Calculations by The Brattle Group.

Calculating the default ratio in this example was straightforward because we assumed the underlying assets had a log-normal distribution. Unless the credit quality of a company is poor, the "default put" will be a deep out-of-the-money option. This means the default value for a portfolio will be very sensitive to assumptions about the left-hand tail of the probability distribution of net asset values. Since corporations typically have complex portfolios, modeling the components of the portfolio and the underlying risks and then simulating the portfolio under a wide range of possible outcomes is likely to be required to obtain reasonable estimates of default values.

Value at Risk

The measure of risk capital that has dominated risk management and capital allocation practices in the financial services industry is "value at risk" or VaR. VaR is defined as the maximum loss that will be realized over a specified holding period with a specified degree of confidence. In principle, calculating the VaR for a portfolio allows one to make statements such as, "the probability that the losses on our portfolio will exceed $10 million over a five-day period is 5 percent." An estimate of the "maximum loss" serves as a measure of capital requirements. Many financial services firms use VaR to manage the overall risk of the corporation as well as the risk of business units and risk limits on traders.

A variety of methodologies are used to calculate VaR. Common approaches include constructing frequency distributions from the historical profit and loss experience of a given portfolio or type of portfolio; parametric "delta-normal" methods, which involve making simplifying assumptions about the form of the probability distribution of future portfolio values;

simplifying assumptions about the form of the probability distribution of future portfolio values; and simulation, which typically involves a much richer specification of both the components of a portfolio and its underlying risks. VaR calculations are usually supplemented by "stress tests" designed to estimate losses in possible but very unlikely events. Stress tests are, in effect, sensitivity analyses of parametric assumptions made either about the probability distribution of portfolio values or the distributions of the underlying risks (in simulation analyses).

Note that VaR is calculated by finding a point on the probability distribution of net asset values. In contrast, the measure of risk capital defined earlier reflects both the probability of default and the recovery rate (i.e., the fraction of liabilities recovered) in the event of default. Thus, two portfolios with the same VaR (calculated based on the same holding period and confidence level) could have materially different capital requirements when figured using the first notion of capital. This suggests that VaR is not an ideal measure of risk capital. On the other hand, it may be satisfactory in many situations, especially given the inherent estimation problems, and it has the virtue that there is an extensive literature on methods for calculating VaR.

Cash Flow Risk Metrics

Both VaR and the risk capital definition introduced above are value-based measures of credit quality. That is, they are based on estimates of uncertainty about the future value of the net assets of the firm. Now we will consider arguments for measuring liquidity or cash flow risk as a supplement for valued-based risk metrics.

Bankruptcy decisions are usually triggered by insolvency, which is the inability of a corporation to meet its obligations to pay. Insolvency does not necessarily coincide with the decline of net asset values to zero. If assets could be readily converted into cash, either by sale or by borrowing against those assets, the distinction between value and cash flow measures of risk would be inconsequential. In practice, however, it is likely to be both time consuming and costly to convert assets into cash. This is especially true of intangible and firm-specific assets. Thus, a company could be bankrupt and yet have net assets worth more than zero.

Financial services firms are sometimes described as "opaque" because it is difficult for creditors and "outside" investors to discern the composition of portfolios of financial assets. If the composition of a portfolio is difficult to discern, then presumably it is also difficult to assess the value and risk of the portfolio. This means that it will be difficult for outsiders to appraise the credit quality of the company. As a result, outsiders' perceptions of credit quality could be very different from insiders' understanding.

There are deadweight costs to bankruptcy, whether it results in the reorganization or liquidation of corporate assets. The mere prospect of bankruptcy is therefore a value sink. Furthermore, when there is an appreciable chance of default and bankruptcy, management actions are likely to be constrained by lack of financial flexibility. Absent sufficient financing, managers may be unable to execute profitable transactions and make value-adding investments. This condition is referred to as "financial distress" in the academic literature on corporate finance.

These considerations suggest that a measure of portfolio cash flow or liquidity risk may be a useful criterion for capital budgeting. Not only does liquidity itself have merit as a measure of capital, but the net cash flow to an opaque business may be easier to monitor than its net asset value. Corporate financial statements, which are released on annual and quarterly cycles, provide outsiders with information from which they can infer historical cash flow. Both of these considerations suggest that a measure of cash flow risk would be useful to support the management of credit quality and risk capital.

Risk Capital Allocation

How can the capital requirement for a corporation be allocated to the business units and transactions that comprise the firm? And how can capital requirements for prospective investments and commitments be estimated? The answers to these questions are not obvious because the portfolio default ratio is not equal to the average of the stand-alone default ratios of the component businesses. Therefore, the stand-alone risk capital requirements for the components of a portfolio do not add up to the portfolio risk capital requirements.

We know from portfolio theory that the contribution of a security to the risk of a portfolio is not the same as the risk of the security held in isolation. Since the returns to securities are imperfectly correlated—when the price of one security goes up, the price of another may go down or remain unchanged—some of the risk of a security effectively "vanishes" when it is held in a portfolio. The same is true of the components of the "portfolio" of assets and liabilities held by a corporation. For example, a long futures position in natural gas could reduce risk at one company and increase risk at another. As a consequence, the capital requirements associated with taking a futures position on gas would differ at those companies.

An Example

Here is a simple example. Consider a hypothetical corporation with a total of $1,500 of net assets. The total net assets represent the sum of the net assets of three business units, each of which has net assets of $500. The risks of the business units (measured by the standard deviation of net asset values) are 20, 30, and 40 percent respectively. Net asset values are assumed to be uncorrelated across the three businesses.

Table 3-2 reports default ratios on both a stand-alone and a combined basis. The fourth column shows the stand-alone default ratios—the default ratios the businesses would entail if operated in isolation. The fifth column shows the marginal default ratios, which are calculated assuming the three business units are part of a single company. The risk and default ratios for the combined businesses are clearly lower than risk and default ratios for any of the businesses operated as separate companies.

Table 3-2
Marginal Versus Stand-Alone Default Ratios

	Liabilities	Net Assets	Standard Deviation	Stand-Alone Default Ratio	Marginal Default Ratio
Line 1	1,500	500	20%	0.77%	-0.86%
Line 2	1,500	500	30%	3.10%	0.32%
Line 3	1,500	500	40%	6.32%	1.97%
Portfolio	4,500	1,500	18%	0.48%	0.48%

Source: Calculations by The Brattle Group.

Marginal Capital Requirements

The fact that the capital requirements for a portfolio are less than the sum of the stand-alone capital requirements of the components is a consequence of the diversification or "co-insurance" that results when two or more lines of business are conducted by a single firm. Multi-business firms need to allocate capital both for pricing and for performance evaluation purposes. Merton and Perold (1994) flag the pitfalls in capital allocation:

> [F]ull allocation of risk capital across the individual businesses of the firm is generally not feasible and attempts at such full allocation can significantly distort the true profitability of individual businesses.

Myers and Read (2001) show that *marginal* capital allocations add up to total capital requirements for a firm:

> [If] a company operates in two or more lines of business, then the line's marginal [capital] allocations are unique and do add up.

Marginal capital allocations will depend both on the own risks of the component lines of business (risks the lines would entail if operated as stand-alone businesses) and the correlations of the lines. Myers and Read conclude that marginal capital allocations are likely to be satisfactory for applications in the insurance industry, where the composition of business tends to be relatively stable from year to year:

> [F]or companies with even a modest degree of diversification, marginal [capital] requirements for existing lines of business are reasonably robust to the introduction of a new line of business….

The Myers-Read findings suggest that marginal capital allocations may be satisfactory for decision making in many other business settings as well. In particular, electric power companies are more like insurance companies than they are like the financial services companies that were the principal concern of Merton and Perold. (Financial services firms mostly hold financial assets, and so can alter the type and scale of their activities over relatively short periods of time).

It would seem reasonable to anticipate that an electric power company could identify a core set of activities which it would treat as “fixed” for purposes of calculating capital requirements.

4
CHALLENGES FOR ELECTRIC POWER COMPANIES

We have laid out the case on conceptual grounds that portfolio optimization—that is, maximizing value added for owners or shareholders—requires that managers measure and ration risk capital as well as cash capital. Our analysis suggested a formal definition of risk capital, but one that is not the same as the standard measure employed in financial services, where the issues of risk capital allocation were first addressed and where they are dealt with routinely. This leaves a number of problems for the research agenda.

1. Measuring Risk Capital. What measure of risk capital should managers in the electric power industry use? Are cash-flow measures of portfolio risk better suited to companies with physical assets and long-term contracts? Would a combination of value and cash-flow-based portfolio risk metrics be better still?

2. Capital Allocation. How should risk capital be allocated to specific business units, products, investments, commitments? Under what conditions are marginal capital allocations satisfactory for decision making? What is to be done when marginal allocations are not satisfactory?

3. Downstream Effects. Investments and commitments made today affect future cash flows and capital requirements as well as current ones. Are there practical ways to take these downstream effects into account in capital budgeting?[12]

4. Multiple Constraints. How can constraints on other resources (e.g., cash capital) be incorporated into portfolio optimization methods?

5. Computation. Given answers to the preceding questions, what computational tools are required to implement an effective program of portfolio optimization for electric power companies?

The research agenda reflects the fact that many electric power companies are really hybrid industrial-financial firms, with characteristics of both "asset heavy" industrial businesses and "asset light" financial services businesses. As a consequence, their portfolios of assets and liabilities can vary greatly in terms of duration, liquidity, and transparency. The demands of portfolio optimization are particularly challenging in this setting.

[12] This problem is partially addressed by the framework of Froot, Scharfstein and Stein, "Risk Management: Coordinating Corporate Investment and Financing Policies".

5
REFERENCES

F. Black and M. Scholes, "The Pricing of Options and Corporate Liabilities", *Journal of Political Economy* 81, May-June 1973.

R. A. Brealey and S. C. Myers, *Principle of Corporate Finance* (7th ed.), New York: McGraw-Hill/Irwin, 2003.

Utility Capital Budgeting Notebook, EPRI TR 104369, Palo Alto: EPRI, September 1994.

K. A. Froot, D. S. Scharfstein and J. C. Stein, "Risk Management: Coordinating Corporate Investment and Financing Policies", *Journal of Finance* 48, December 1993.

M. C. Jensen and W. H. Meckling, "Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure", *Journal of Financial Economics* 3, October 1976.

R. C. Merton and A. F. Perold, "Risk Capital in Financial Firms", *Journal of Applied Corporate Finance* 6, Fall 1993.

S. C. Myers and N. Majluf, "Corporate Financing and Investment Decisions When Firms Have Information that Investors Do Not Have", *Journal of Financial Economics* 13, June 1984.

S. C. Myers and J. A. Read, Jr., "Capital Requirements for Insurance Companies", *Journal of Risk and Insurance* 68, December 2001.

E. Zaik, J. Walter, G. Kelling and C. James, "RAROC at Bank of America: From Theory to Practice", *Journal of Applied Corporate Finance* 9, Summer 1993.

Target:
Asset and Risk Management

About EPRI

EPRI creates science and technology solutions for the global energy and energy services industry. U.S. electric utilities established the Electric Power Research Institute in 1973 as a nonprofit research consortium for the benefit of utility members, their customers, and society. Now known simply as EPRI, the company provides a wide range of innovative products and services to more than 1000 energy-related organizations in 40 countries. EPRI's multidisciplinary team of scientists and engineers draws on a worldwide network of technical and business expertise to help solve today's toughest energy and environmental problems.

EPRI. Electrify the World

Printed on recycled paper in the United States of America

1001567

EPRI • 3412 Hillview Avenue, Palo Alto, California 94304 • PO Box 10412, Palo Alto, California 94303 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com