
Financial Risk Management by Insurers:
An Analysis of the Process
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ABSTRACT
On-site visits to financial service firms were conducted to review and evaluate their risk management systems. In the insurance sector, this evaluation covered prominent life/health and property-liability insurers, both in the United States and abroad. The information obtained covered both the philosophy and the practice of financial risk management. This article outlines the results of this investigation. It reports the state of risk management techniques in the industry. It reports the standard of practice and evaluates how and why it is conducted in the particular way chosen. In addition, critiques are offered where appropriate. We discuss the problems which the industry finds most difficult to address, shortcomings of the current methodology used to analyze risk, and the elements that are missing in the current procedures of risk management.

INTRODUCTION
The past decade has seen a dramatic rise in the number of insolvent insurers. The ostensible causes of these insolvencies were myriad. Some of the insolvencies were precipitated by rapidly rising or declining interest rates. Others resulted from losses on assets such as junk bonds, commercial mortgages, collateralized mortgage obligations, real estate, and derivatives. Mispricing of insurance policies, natural catastrophes, and changes in legal interpretations of liability and the limits of coverage hurt still others. The "churning" of policies by unscrupulous sales agents, insolvencies among the reinsurers backing the policies issued, noncompliance with insurance regulation, and malfeasance on the part of officers and directors of the insurance companies affected some as well. But despite the numerous and disparate apparent causes of these insolvencies, the underlying factor in all of them was the same: inadequate risk management practices. In response to this, insurers almost universally have embarked upon an upgrading of their financial risk

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management and control systems to reduce their exposure to risk and better manage the amount they accept. In short, the industry has turned to financial risk management techniques as a way to improve performance.

Coincidental to this activity, and, in part, because of our recognition of the industry's vulnerability to financial risk, the Wharton Financial Institutions Center, with the support of the Sloan Foundation, has been involved in an analysis of financial risk management processes in the financial sector. During 1995 and 1996, on-site visits were conducted to review and evaluate the risk management systems and the process of risk evaluation that are in place.

In the insurance sector, system evaluation was conducted covering a number of prominent life/health and property-liability insurers, both in the United States and abroad. The information obtained on the philosophy and practice of risk management comes primarily through intensive interviews of these insurance firms, conducted by a team of researchers from the Wharton Financial Institutions Center.1 Measured in terms of admitted assets, these firms range in size from $7 trillion to well over $100 billion. They are organized as stock, reciprocal, or mutual insurers. Some firms restrict their activities to life insurance and pensions, whereas multiline insurers, selling the full range of property-liability and life/health products. These visits were augmented by interviews conducted with additional large insurance firms domiciled in Japan and Europe as well as North America. As was the case above, these firms include life insurers, property-liability insurers, and a multiline company.

Our information was then supplemented by five published surveys. Three of these were the 1994, 1995, and 1996 "Insurer CIO Surveys," conducted by Goldman, Sachs & Co. (see Alexander et al., 1994; Siegel et al., 1995; and Millette et al., 1996). These surveys were based on responses from between 58 and 79 companies, depending on the survey, with approximately two-thirds from the life lines and one-third from the property-liability lines. The response rate in these surveys was roughly 40 percent. Over 90 percent of the responding companies had assets in excess of $1 billion. Another pair of surveys conducted by Lamm-Tennant & Co. (1994) and Lamm-Tennant and Gattis (1996) covered a much more extensive set of insurers, ranging in assets from $75 million to over $100 billion. There were 9 and 144 respondents to these 1995 and 1996 surveys, respectively, representing a response rate between 11 and 20 percent of the firms surveyed. The business of these firms was split about equally between life/health and property-liability insurers.

This article outlines the results of our investigation. It reports the state of risk management techniques in the industry—questions asked, questions answered, and issues left unaddressed by respondents. This report cannot recite the litany of approaches used within the industry, nor can it offer an evaluation of each and every approach. Rather, it reports the standard of practice and evaluates how and why it is conducted in the particular way chosen. But even the best practice employed within the industry is not good enough in some areas. Accordingly, critiques will also be offered where appropriate. Our conclusion discusses the problems which the industry finds most difficult to address, shortcomings of the current methodology used to analyze risk, and the elements that are missing in the current procedures of risk management.

**Why Manage Risk—Some Generic Answers**

It seems appropriate to begin our analysis of risk management techniques with a brief review of the reasons given for firm-level concern over the volatility of financial performance. The finance literature on why firms manage risk at all is usually traced back to 1984. In that year, Stulz (1984) first suggested a viable reason for objective function concavity, and his contribution is widely cited as the starting point of this burgeoning literature. Doherty (1985) provides the first comprehensive treatment of this topic for insurers in a finance framework. Since that time, several alternative theories and explanations have been offered. Santomero (1995) presents a useful review of these explanations. The reader is referred to that study for a thorough review and extensive citations to the economic literature.

The goal, as noted above, is to offer viable economic reasons for firm managers, who are presumed to be working on behalf of firm owners, to concern themselves with both expected profit and the distribution of firm returns around their expected value. The rationales for risk aversion can usefully be segmented into four categories.

*Managerial Self-Interest*

Firm managers have limited ability to diversify their own personal wealth position, associated with stock holdings and the capitalization of their career earnings from their own employment position. Therefore, managers prefer stability to volatility because, other things equal, such stability improves their own utility, at little or no expense to other stakeholders.

*The Nonlinearity of Taxes*

With a nonproportional tax structure, income smoothing reduces the effective tax rate and, therefore, the tax burden shouldered by the firm. By reducing the effective long-term average tax rate, activities that reduce the volatility in reported earnings will enhance shareholder value.2

*The Cost of Financial Distress*

To the extent that the bankruptcy state—or any set of specific states—is associated with a discrete increase in costs, the firm will be forced to recognize this fact in its

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1 Members of the team included Anthony Santomero (leader), David Babbel, Yuval Bar-On, Joel Herring, Paul Hoffman, Susan Ken, Spencer Martin, Steve Piloff, Jeffrey Trester, and Sri Neer.

2 Evidence on this point for the insurance industry is provided by Cummins and Grace (1994) and Lamm-Tennant and Rollins (1994).
choice calculus. In such cases, the firm behaves as if it had a concave objective function, because its payoff structure is nonlinear across states.  

**The Existence of Capital Market Imperfections**

The existence of the cost imperfections results in underinvestment in some states, where internally-generated funds fall short of the amount of new investment that would be profitable in the absence of these capital market imperfections. The cost of volatility is the forgone investment in each period that the firm is forced to seek external funds. Recognizing this outcome, the firm embarks upon volatility reducing strategies, which have the effect of reducing the variability of earnings.

In each case, the economic decision-maker is shown to face a nonlinear optimization because of the reason offered, and this leads the decision-maker to be concerned with the variability of returns. In the first case, the objective function itself is concave, while in the others the effect of some feature of the economic environment is to lead firm managers to behave in a risk-averse manner.

Together, the stories work fairly well. Firm managers are interested both in expected profitability and the risk, or variability, or reported earnings or market value. The latter can be rationalized by the existence of nonlinear costs across the range of profit states associated with any given expected value. The nonlinearity stems from managerial incentive effects, the tax structure, the costs of crisis, and/or forgone investment opportunities. In any or all of these cases, the firm is led to treat the variability of earnings as a choice variable that it selects, subject to the usual constraints of optimization. How it proceeds to manage the risk position of its activity is the area to which we now turn.

**Risk as a Central Ingredient in the Industry's Franchise**

**What Risks Are Being Managed?**

Insurers are in the risk business. In the process of providing insurance and other financial services, they assume various kinds of actuarial and financial risks. The risks contained in the insurer’s product sales—that is, those embedded in the products offered to customers to protect against actuarial risk—are not all borne directly by the firm itself. In many instances, the institution will eliminate or mitigate the actuarial and financial risk associated with a transaction by proper business practices, in others, it will shift the risk to other parties through a combination of reinsurance, pricing, and product design. Only those risks that are not eliminated or transferred to others are left to be managed by the firm for its own account. This is the case because the insurance industry recognizes that it should not engage in business in a manner that unnecessarily imposes risk upon it, nor

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3 Staking and Babbel (1995) provide some empirical support for the application of this argument to the insurance industry. The National Association of Insurance Commissioner’s risk-based capital requirements have the effect of creating nonlinear costs of financial distress, and insurers are very much aware of this effect (see Cummins, Harrington, and Niehaus, 1994).

4 For a review of the use of derivatives by insurers, see Cummins, Phillips, and Smith (1997).
However, there are two classes of activities where the risk inherent in the activity must and should be absorbed at the insurance firm level. In these cases, risk management must be aggressive, and good reasons exist for using firm resources to manage insurance-level risk. The first of these includes actuarial exposures where the nature of the embedded risk may be complex and difficult to communicate and transfer to third parties. For example, Progressive Insurance Co. has a definite niche in the high-risk auto insurance business owing to its concentration of underwriting activities, and Lutheran Brotherhood has a natural advantage for writing life insurance to its clientele. A similar situation may arise on the asset side of the business where the insurer holds private placements and other complex, proprietary assets that have thin, or even nonexistent, secondary markets. Communication in such cases may be more difficult or expensive than hedging the underlying risk. Moreover, revealing information about the customer may give competitors an undue advantage. The second case includes risk positions that are central to the insurer’s business purpose and are absorbed because they are the raison d’être of the firm. Actuarial risk inherent in key insurance lines where the insurer may enjoy a competitive advantage or a market niche is a clear case in point. In all such circumstances, risk is absorbed and must be monitored and managed efficiently by the institution. Only then will the firm systematically achieve its financial performance goal.

How Are These Risks Managed?

What are the necessary procedures that must be in place to carry out adequate risk management for those risks that are essential ingredients to the insurer’s franchise? What techniques are employed to both limit and manage the different types of risk, and how are they implemented in each area of risk management?

In general, the management of an insurance firm relies on a variety of techniques in their risk management systems. However, it appears that common practice has evolved such that four elements have become key steps to implementing a broad-based risk management system. These include standards and reports, underwriting authority and limits, investment guidelines or strategies, and incentive compensation. These tools are established to measure risk exposure, define procedures to manage these exposures, limit exposures to acceptable levels, and encourage decision-makers to manage risk in a manner consistent with the firm’s goals and objectives. To see these four parts of basic risk management achieve these ends, we elaborate on each part of the process. Then, we illustrate how these techniques are applied to control each of the specific risks facing the insurance community.

Standards and reports. Underwriting standards, risk classification, and standards of review are all traditional tools of risk control. Consistent valuation and rating of exposures of various types are essential for management to understand the risks on both sides of the balance sheet, and the extent to which these risks must be mitigated or absorbed.

The standardization of financial reporting is the next ingredient. Statutory accounting reports have long been standardized, for better or worse. However, the need here goes beyond public reports and audited statements to the need for management information on actuarial risk, asset quality, and overall risk posture. Such internal and external reports need similar standardization but much more frequent reporting intervals, with daily, weekly, and monthly reports substituting for the quarterly statutory accounting periodicity.

Underwriting authority and limits. A second technique for internal control of active management is the use of position limits and/or minimum underwriting and asset quality standards. In terms of the latter, the domain of risk taking is restricted to only those customers or assets that pass some prespecified quality standard. Then, even for those that are eligible, limits are imposed to cover exposures to counterparties, credits, and overall position concentrations relative to various types of risks. In large organizations, with thousands of positions maintained, accurate and timely reporting is difficult, but even more essential.

Investment guidelines or strategies. Investment strategies are outlined in terms of concentration and commitments to particular areas of the market, the extent of desired asset/liability mismatching or exposure to interest rate risk, and the need to hedge against systematic risks of a particular type. These limits lead to passive risk avoidance and/or diversification, because managers generally operate within position limits and prescribed rules. In addition, securitization and even derivative activity are rapidly growing techniques of position management open to participants looking to reduce their exposure to be in line with management’s guidelines.

Incentive schemes. To the extent that the firm can enter incentive-compatible contracts with senior management, line managers, and sales agents, and make compensation related to the risks borne by these individuals, the need for elaborate and costly controls is lessened. Well designed systems align the goals of managers with other stakeholders in a most desirable way. Most financial debacles can be traced to the absence of incentive compatibility.

Risks in Providing Insurance Services

How are these techniques of risk management employed by the insurance sector? To explain this, we must begin by enumerating the risks that the insurance industry has chosen to manage and illustrate how the four-step procedures outlined are applied to risk control in each area.

The Actuarial View of Risks

As a starting point, most of the insurers interviewed classified their risks by adapting a framework that was proposed years ago by the Society of Actuaries’ Committee on Valuation and Related Problems. Even though the Society of Actuaries is focused on life insurance and pensions, the property-liability insurers interviewed also had adapted the same risk classification paradigm. The various categories of risks are dubbed C-1, C-2, C-3, and C-4, deriving these names from
the committee assigned to make recommendations on these issues. We begin our review of the perceived risks with an explanation of the industry's own definitions.

C-1 risks are asset risks, which arise from the possibility that borrowers of insurer funds may default on their obligations to the company, or that the market value of an insurer's investment assets may decline. They include interest rate risk, credit risk, market risk, and currency risk.

C-2 risk is pricing risk, which stems from uncertainty about future operating results relating to items such as investment income, mortality and morbidity, frequency and severity of claims and losses, administrative expenses, sales, and lapses. If an insurer's pricing is based on assumptions that prove inadequate, it may not be able to meet its obligations to policyholders.

C-3 risk is asset/liability matching risk, which springs from the impact of fluctuating interest and inflation rates on the values of assets and liabilities. If the impact of fluctuating rates is different on assets than on liabilities, the values of assets and liabilities will change by different amounts, and could expose the insurer to insolvency.

C-4 risks are miscellaneous risks, generally thought to be beyond the ability of insurers to predict and manage, but they nevertheless represent real risk to the company. These risks include tax and regulatory changes, product obsolescence, poor training of employees and sales agents, and malfeasance, malversation, or misconduct of managers or other employees. Also included is the risk that laws or legal interpretations will change in a way that will alter the firm's obligations extrinsically. Another manifestation of C-4 risk is that there will be an unforeseen downgrade of acquisitions that could lead to a "run" on the insurer's assets. One firm referred to C-4 risk as "stupidity risk"—failure to employ and retain good people.

Two firms wryly refer to a new category of risk, dubbed C-5 risk, which is the havoc that arises when a person who has strong political ambitions or is running for higher political office is appointed to be state insurance commissioner.

The use of the Society of Actuaries' risk classification taxonomy is viewed as a useful point of departure by some of the insurance firms we interviewed, while others view it as satisfactory for their purposes. In our view, none of the risk assessment schemas we saw was completely satisfactory. However, most of the conceivable risks that would impact insurers are included somewhere on the lists we saw. In most cases, however, the industry is straining to define the inherent financial risks as part of the C-1 through C-4 paradigm that had been developed years ago. In addition, it appears that most schemas have undue focus on risks in isolation, rather than on their contribution to overall firm risk.

**Financial View of Risks**

An alternative to the actuarial decomposition of risk which is unique to the insurance industry, standard financial risk definitions are increasingly being pursued in the industry. For the sector as a whole, these risks can be broken into six generic types: actuarial, systematic, credit, liquidity, operational, and legal risks. Briefly, we discuss each of these risks facing the insurance institution, and we indicate how they are managed. Our focus will be on the financial risks, which include the first four of the risks listed below. Of course, the risks associated with the provision of insurance services differ by the type of service rendered.

Actuarial risk is the risk that arises from raising funds via the issuance of insurance policies and other liabilities. It is the risk that the firm is paying too much for the funds it receives or, alternatively, the risk that the firm has received too little for the risks it has agreed to absorb. If an insurer invests these funds in efficiently traded securities, it should expect to have, on average, a zero net economic profit on those securities. Therefore, if the insurer pays too much for its assets, it cannot expect to earn a satisfactory profit in the long run. Another aspect of actuarial risk is that, during any given time period, the underwriting losses will be in excess of those projected. This could happen for two reasons. First, the expectations themselves may be based on an inadequate knowledge of the loss distribution. Second, the losses may exceed their expectations in the normal course of business simply because losses fluctuate around their mean. The degree to which they deviate from the mean will depend, of course, on the characteristics of the loss distribution, which depend on the nature of the risks insured.

Systematic risk is the risk of asset and liability value changes associated with systematic factors. It is sometimes referred to as market risk. As such, it can be hedged but cannot be diversified completely away. In fact, systematic risk can be thought of as undiversifiable risk. All investors assume this type of risk whenever assets owned or claims issued can change in value as a result of broad economic factors. Systematic risk comes in many different forms. For the insurance sector, however, three are of greatest concern: variations in the general level of interest rates, basis risk, and (especially for property-liability insurers) inflation.

Because of the insurers' dependence on these systematic factors, most try to estimate the impact of these particular systematic risks on performance, attempt to hedge against them, and thus limit the sensitivity of their financial performance to variation in these undiversifiable factors. To do so, most will both track and manage each of the major systematic risks individually. The first of these is undoubtedly interest rate risk. Here, they measure and manage the firm's vulnerability to interest rate variation, even though they cannot do so perfectly. At the same time, insurers with large corporate bond, mortgage, and common stock holdings closely monitor their basis risk. Here the concern is that yields on instruments of varying credit quality, liquidity, and maturity do not move together, exposing the insurer to market value variation that is independent of fluctuating liability values. In this case, too, they try to manage, as well as limit, their exposure to it. Finally, to the extent that the frequency and severity of claims are influenced by inflation risk, expected losses will also be affected. This is particularly the case where insurance policies are written on a replacement cost basis. The inflation of concern can be general inflation affecting repair costs, medical costs, and the like or specific and localized inflation—like the quadrupling of certain building materials costs in
Liquidity risk is the risk that a borrower will not perform in accordance with its obligations. Credit risk may arise from either an inability or an unwillingness on the part of the borrower to perform in the precommitted contracted manner. This can affect the investor holding the bond or lender of a loan contract, as well as other investors and lenders to the creditor. Therefore, the financial condition of the borrower, as well as the current value of any underlying collateral, are of considerable interest to an insurer who has invested in the bonds or participated in a direct loan.

The real risk from credit is the deviation of portfolio performance from its expected value. Accordingly, credit risk is diversifiable but difficult to eliminate completely, as general default rates themselves exhibit much fluctuation. This is because a portion of the default risk may, in fact, result from the systematic risk outlined above. In addition, the idiosyncratic nature of some portion of these losses remains a problem for creditors in spite of the beneficial effect of diversification on total uncertainty. This is particularly true for insurers who take on highly illiquid assets. In such cases, the credit risk is not easily transferred, and accurate estimates of loss are difficult to estimate.

Liquidity risk can best be described as the risk of a funding crisis. While some would include the need to plan for growth, the risk here is more correctly seen as the potential for a funding crisis. Such a situation would inevitably be associated with an unexpected event, such as a large claim or a writedown of assets, a loss of confidence, or a legal crisis. Because insurers operate in markets where they may receive clustered claims due to natural catastrophes, or massive requests for policy withdrawals and surrenders due to changing interest rates, their liabilities can be said to be somewhat liquid. Their assets, however, are sometimes less liquid, particularly where they invest in private placements and real estate. Given this situation, it is important for an insurer to maintain sufficient liquidity to handle easily any demands for cash. Otherwise, an insurer that would be solvent without a sudden demand for cash may have to sell off illiquid assets at concessionary prices, leading to large losses, further demands for cash, and potential insolvency.

Operational risk is associated with the problems of accurately processing claims and accurately processing, settling, and taking or making delivery on trades in exchange for cash. It also arises in record keeping, processing system failures, and compliance with various regulations. As such, individual operating problems are small probability events for well-run organizations, but they expose a firm to outcomes that may be quite costly.

Legal risks are endemic in financial contracting and are separate from the legal ramifications of credit and operational risks. New statutes, court opinions, and regulations can put formerly well-established transactions into contention even when all parties have previously performed adequately and are fully able to perform in the future. For example, changes in the application of statutes of limitations for filing suits have affected the losses arising from property-liability poli-
cies. Similarly, the change to joint and several liability rules has also altered the distribution of risks that may be covered by insurance policies (see Huber, 1988).

Another type of legal risk arises from the activities of an institution’s management, employees, and agents. Fraud, violations of regulations or laws, and other actions can lead to catastrophic loss. Even a situation where the insurer legally fulfills all of its contract obligations can result in massive litigation if some policyholders had different expectations or understandings about the performance of their policies than what was specified in the contracts.

Every insurer faces a different exposure to each of these risks, depending on its business mix. In all its activities, an insurer must decide how much business to originate, how much to finance, how much to reinsure, and how much to contract to agents. In so doing, it must weigh both the return and the risk embedded in its asset and liability portfolios. Management must measure the expected profit and evaluate the prudence of the various risks enumerated above to be sure that the result achieves the stated goal of maximizing shareholder value (in the case of a stock insurer) or maximizing ownership interests (in the case of a mutual or reciprocal insurer). If the product’s expected profit warrants the risk, then the activity is added to the insurer’s balance sheet, and the risk must be managed. This risk management is achieved through the four-step process outlined above. How this is implemented for each of the key financial risks enumerated above is the focus of the next section.

In concluding this section, we observe that the actuarial versus the financial views of risk are worlds apart. This difference is a critical barrier impeding the progress toward effective financial risk management. Although both views encompass most of the same risks, the contexts in which they are measured and weighed give rise to different treatments of risk. The actuarial view, with its focus on risks in isolation and their impact on the statutory accounting statements, tends to foster risk measures that do not aggregate well at the firm level and leads to a piecemeal approach toward risk management. In contrast, the financial view looks at risk only insofar as it impacts firm economic value. Risk aggregation and covariance are the focus. Until the actuarial and financial views of risk converge and a unified view of risk is accepted, there will continue to be some disarray in how financial risk is managed by insurers.

**INSURANCE RISK MANAGEMENT SYSTEMS**

**Actuarial Risk**

The risk of paying too high a price to raise funds is an important risk, particularly in light of the fact that insurers raise few funds in the competitive capital market. Most of their debt is raised in the form of issuing insurance policies. Policies are written today in exchange for lump sum or periodic premiums, but the amounts and timing of the repayment of these funds are often unknown and may occur within a month or more than 80 years later. Because the pricing of the policies reflects not only expected losses but also the yields an insurer can earn on the funds between the inception of a policy and its termination or the payment of benefits,
the interest assumption used in developing insurance prices is of critical importance. Two things complicate this process. Forward interest rates cannot be synthesized to lock in a spread, for the insurer has no way of knowing if future periodic premium payments will be forthcoming. Also, the loss distributions can undergo substantial evolution over time, as more information is revealed and as the economic environment changes.

Insurers typically are quite skilled in managing actuarial risk. The manner in which this is done is described in insurance and actuarial textbooks (see Black and Skipper, 1994; Beard, Pentikainen, and Pesonen, 1984; Gerber, 1979; and Cummins and Derrig, 1989). Therefore, here we will focus on what developments have occurred during the past decade that improve an insurer’s ability to price and manage this risk.

Life insurers. Until recently, life insurance prices were developed using conservative static assumptions regarding loss distributions and interest rates. Although this approach was satisfactory for much of the past century, it was ill-equipped to accommodate the interest rate volatility that began during the late 1970s. Life insurance policies are replete with options—settlement options, policy loan options, over-depositing privileges, and surrender or renewal privileges on the part of the insured, and discretionary dividend and crediting rate options on the part of the insurer. Indeed, some have even viewed a life insurance policy as little more than a package of options (see Smith, 1982). In stable interest rate environments, policyholder utilization of these options is often predicated on individual or family circumstances. Hence, in the aggregate, utilization rates are fairly steady and amenable to forecasting.

However, when interest rates are volatile, the options gain in value and their utilization rates can fluctuate wildly. Traditional actuarial methods, which depend upon stability, were incapable of correctly valuing these options; hence, many policies were woefully underpriced. Today, the standard valuation methods that have been adopted by most of the sophisticated life insurers explicitly value these embedded options. Thus, insurers now can estimate the cost of the various option-like provisions of all kinds of life insurance policies. Most life insurers we interviewed were using the PTS software of Chalke, Inc. (now SS&C, Inc.). This software, and competing software offered by Tillinghast and others, uses modern stochastic valuation techniques, familiar in the pricing of fixed income and mortgage-backed securities, to estimate the values of insurance policies in a manner consistent with that used to value the assets. Needless to say, this represents a big advance in the tools with which insurers can practice risk management.

Lest our enthusiasm for this advance be misconstrued as euphoria, we hasten to add that all is not well here. First, the stochastic valuation methodology most commonly used relies on a single stochastic factor. Most fixed income and mortgage-backed security valuation models are based on at least two stochastic factors. Without two factors, one tends to produce model values that are too highly correlated and whose movements in value are perfectly correlated. Also, the speed of the software is sufficiently slow that it is difficult to implement more than a handful of path simulations in arriving at “option-adjusted” values. Moreover, it is unrealistic to attempt to model a prepayment feature or a call feature, which may be triggered by changes in long-term yields, while using the short-term rate paths to value the instrument. The second drawback is perhaps even more serious. Most insurers have inadequate data collected and assembled with which to reliably model the interest sensitivity of policy option utilization. Accordingly, the valuation models really allow an insurer only to quantify better the impact of guesses about what those utilization functions might look like. We encountered much frustration among life insurers that, even though the valuation software had taken a long time to develop, the data requirements of the valuation software have still not been met. The third drawback is in how insurers interpret the data analyses provided by “black boxes.” We found that, in some companies, there is neither an understanding of nor an appreciation for the risk measures produced. There is often such shallow understanding of the underpinnings of the methodologies employed to measure risk that the computer output is either disregarded or uncritically accepted. Over time, as insurer personnel receive more training in stochastic methods and the meaning of the risk measures, they will be able to use the software to greater advantage in measuring and managing their risks.

Nonetheless, the availability of valuation software that is consistent with modern valuation principles is an important step forward, and software that is currently under development will remedy the shortcomings of being based on a single stochastic factor and producing value estimates, dare we say, at a relaxed pace. With this software, actuaries currently produce pricing estimates based on a dozen or so scenarios. However, they typically also test their prices using hundreds and thousands of additional scenarios, albeit not in an option-adjusted framework.

Property-liability insurers. Financial risk management is closely related to the issue of financial pricing, especially for property-liability insurers. In the property-liability insurance sector, there is no counterpart to the modern valuation software for pricing liabilities. However, option-adjusted arbitrage-free valuation tools may be overly powerful given the imprecision associated with many of the risks that are insured. There are few options that compare with those available in life policies, and nominal values are often not guaranteed; guarantees are sometimes in terms of covering repair costs, replacement costs, medical costs, and so forth. Even when there are nominal maximum amounts of coverage, the losses below the maximum are subject to additional uncertainty because of inflation.

The use of reports and standards for underwriting life/health and property-liability risks is routine. It is common to have dozens, and sometimes over a hun-

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6 The value of the policy loan option by itself could account for 20 to 45 percent of the present value of all future insurance premiums, if the option were used optimally. When factoring in the suboptimal utilization of this option, the estimated cost to an insurer of providing this option was in the 8 to 12 percent range. Yet insurers had historically charged nothing for this option. Indeed, it was simply mandated that insurers begin to offer this option.

7 See Cummins and Harrington (1987), Taylor (1994), and Derrig (1994) for a discussion of this important related issue.
dred, "cells" in which to classify the risks. Base rates can be related to a number of factors, such as age, gender, occupation, schooling, health status and history, property characteristics, nature of business, and so forth. These base rates are then adjusted to reflect experience factors (e.g., past claims, driving behavior). While the fair premiums will be a function of interest rates, in practice the premiums charged will not adjust to reflect current interest rates very often. This is because it is administratively cumbersome to alter insurance premium schedules every time the interest rates change.

Underwriting limits are commonly established. Authority is limited to a certain amount. While insurance agents may have temporary binding authority, it is a common practice to have a party who is not involved in the policy sale to review he underwriting and make a determination whether the risk will be ultimately accepted and insured. Insurers are typically better at keeping track of sales commissions than at tracking losses to a particular sales agent or underwriter. However, many of the leading life/health and property-liability insurers are carefully tracking the experience of their sales and underwriting personnel. If the experience falls outside the norm, it is common to place restrictions on further sales or more severe limitations on underwriting; alternatively, the activities of these sales agents and underwriters could be subject to greater oversight.

Perhaps the area of greatest concern in the area of actuarial risk is the misalignment of incentives between owners of the insurance firm and its sales and marketing staff. Much can be done to improve it. The typical arrangement is to say commissions for sales of new policies, with the commissions on a multiperiod contract heavily front-loaded, particularly for life/health products. This creates a tremendous incentive for agents to sell as much business as possible, whether it is profitable for the company or not. It also creates strong incentives to replace existing policies, whose commission rates have dwindled to the low single digit percentage range, with new policies that pay commissions ranging from 20 to 100 percent of first-year premiums. Sales managers and marketing personnel are also often rewarded based on volume of sales. Even senior management may sometimes have their compensation tied to sales growth.

Experience has shown that rapid growth is one of the factors most commonly associated with insolvency. It is useful to remember here that what is growing most rapidly is the accumulation of liabilities, not assets. One way to foster rapid growth is to underprice liabilities. Employees and agents whose compensation is tied to sales growth are therefore strong proponents of more "competitively-priced" insurance policies. Senior management often comes from a sales background and is sympathetic with the notion that what is good for the insurance agents is good for the company. Pricing actuaries, who are supposed to be the watchdogs and gatekeepers in this area, are often placed under tremendous pressure to alter their assumptions so that the company's products can be priced more competitively. Of course, over time it will become apparent if the insurance policies are mispriced, but that is weighed against the immediate benefits of higher commission earnings and growth.

The sales side has one powerful club in this battle for determining policy prices. Sales agents often work for a number of insurers and can shift new business toward them. Worse, they can take existing business away from the firm, before it breaks even from heavy initial policy costs, and direct it elsewhere if they can demonstrate satisfactorily that policy illustrations or prices appear to be more favorable elsewhere. Many firms in the insurance industry are well aware of this misalignment of interests, yet feel thwarted by regulations about commission schedules.

In the long run, of course, insurers offering noneconomic policies will go bankrupt. But the long run can take a long time to arrive; hence, the insurer who is trying to rationally price its policies faces a quandary. Does it succumb to the un-economic pricing temporarily and hope to survive beyond the irrational players, and then restore sensible pricing, or does it choose to write very little current business and lose its distribution force? Neither choice is an attractive alternative.

Systematic Risk

Systematic risk of liabilities. No area in financial risk management of insurance has evolved as much as the analysis of systematic risk of liabilities during the past decade. This is, in large measure, due to the fact that insurers feel an increased sense of urgency in applying the tools of asset/liability management to measure and manage interest rate risk. We note that the two most recent Goldman Sachs surveys of life insurance chief investment officers ranked asset/liability management at the top of the list of their concerns, whereas the topic did not surface in the top four rankings in their earlier surveys. Property-liability insurers are also giving greater attention to the area.

The increased importance given to asset/liability management is echoed in the 1995 and 1996 surveys of Lamm-Tennant and Lamm-Tennant and Gattis, who found it near the top of the factors that influence investment policy. These findings are notable because they combine the results of both life/health and property-liability insurers, and cover companies that are much smaller than those in the Goldman Sachs surveys. When contrasted with the earlier surveys of Babbel and Lamm-Tennant (1987), Babbel and Klock (1988), Lamm-Tennant (1989), and Bouyoucos and Siegel (1992), the increased importance of interest rate risk and asset/liability management during the past few years is remarkable. All of the life/health and property-liability insurers we interviewed perceive this source of risk to be crucial to understand, measure, and manage. However, the insurers we interviewed run the gamut from naive to very sophisticated when it comes to measuring interest rate risk.

On the liability side of the balance sheet, most of the life insurers were using PTS software developed by Chalke, Inc. to measure the effective duration and convexity of their liabilities. The others were using TAS from Tillinghast or some

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¹ Measures of interest rate sensitivity that take into account the interest-sensitive cash flows of an asset or liability stream are referred to as "effective duration and convexity" or, alternatively, "option-adjusted duration and convexity." Measures of interest rate sensitivity which assume all cash flows
commercially-available software did not even produce convexity estimates for life insurance liabilities. Instead, firms relied almost entirely on simulations. Many firms used only the seven highly artificial scenarios required of New York’s Regulation 126. Prior to its passage, some insurers did not use the simulation method at all. Rather, they relied simply on their “best point estimates” and static lapse assumptions. Even today, there are insurers who use nothing more than the seven scenarios required under Regulation 126 to assess their exposure to interest rate risk.

The property-liability insurers with whom we spoke have less concern about interest rate risk than their life/health counterparts. Nonetheless, they manifest greater understanding of the problem than they had a few years earlier. All of them are well aware of the importance of measuring duration of assets, producing in-house estimates of duration, or acquiring them from outside vendors, for most of their fixed income assets. More problematic is the estimation of duration of their real estate and equity portfolios. However, an analysis of the duration of their liabilities is generally missing. They have a notion that the duration is relatively short—perhaps a couple of years or so—but no more specific information (see Babbel and Klock, 1993). Convexity is even less of a concern for these property-liability insurers. Nonetheless, there appears to be at least some interest rate sensitivity in the payments made to satisfy property-liability claims. For example, it is well known that workers’ compensation claims tend to increase during periods of unemployment, as fraudulent claims are tied with greater frequency. Similarly, fires and arson tend to occur with greater frequency when insured values exceed market values. To the extent that these and other situations are linked to interest rate levels, it can be supposed that some property-liability liabilities are interest sensitive. Available evidence on this front is scant, however (see Choi, 1992). Where the sensitivity is measurable, it tends to be more closely linked to inflation than to nominal interest rates. Therefore, the influence of inflation on their liabilities is deemed more important.

It is fair to say that most property-liability insurers pay little attention to the duration of their liabilities. It is generally thought that interest rate risk accounts for only a small portion of the change in the value of liabilities over time and that other risks, such as actuarial risk, price regulation, legal risk, underwriting risk, inflation risk, and event or catastrophe risk, swamp the influence of interest rate movements on the pricing and valuation of property-liability insurance liabilities.

Systematic risk of assets. Insurers are concerned with interest rate risk more than other systematic risk factors, and rightly so. Over the past two decades, it has been the source of much of the fluctuation in the value of fixed income assets, which constitute the majority of their assets. However, while it is the crucial systematic risk on the life insurance liability side, and of some importance for property-liability liabilities as well, it is prominent but less dominating on the asset side of the balance sheet. This is because asset values are perceived to be affected not only by general interest rate levels, but also by basic risk, default risk, liquidity risk, call risk, prepayment risk, extension risk, sinking fund options, convertibility, real estate, and equity risk. Yet, several of these risks are simply different manifest-
tions of interest rate risk, making accurate measurement of paramount importance.

The measurement of interest rate risk on the asset side of the balance sheet is generally well done, although some insurers have a long way to go. Many insurers use the actuarial software mentioned above to estimate the durations and convexities of their investments. Some use software and pricing services like GAT and Bloomberg that are oriented strictly toward the asset side of the balance sheet. Several have developed their own, more sophisticated in-house programs for estimating values of both sides of the balance sheet. It is common to use more than a single source to assess the duration and convexity of assets. One stated reason for this is the divergence of opinion between the various programs and pricing services.

We did not encounter any property-liability insurers who carefully measure the interest rate risk of both sides of their balance sheet. It is more common for the focus to be on the interest rate risk of only the assets. Here the tools of duration and convexity measurement are applied, and insurers take steps to manage the overall exposure of their assets to interest rate risk and keep it within some targeted range. It is common for property-liability insurers to use interest rate futures, swaps, and options to moderate this risk to acceptable levels. Options and futures are also used to hedge equity market risks, where the insurer maintains a large position in common stocks. The hedges are put in place, and then removed, as market conditions change and the insurers' appetites for equity risk wax and wane.

Asset/liability management. Asset/liability management typically does not go far beyond an assessment of the impact of interest rate movements on the value of the firm. Other systematic risks are usually dealt with in a more piecemeal fashion. The standard practice is to produce estimates of liability durations and convexities for each line of business, as well as for each asset class. These estimates are then weighted by the fair value of liabilities, or market value of assets, to arrive at overall asset and liability duration and convexity estimates. After factoring in leverage, the insurers are able to obtain measures of surplus duration and convexity. Examples of product level and firm level analyses are given in Tables 1 and 2.

The frequency for providing analysis of interest rate risk varies widely. Some firms provide weekly summaries of their asset durations and convexities, and monthly or quarterly summaries of their liabilities. In the case of interest rate futures and options, reports are more frequent, owing to their tremendous impact on overall interest rate risk. Some firms assess their liability interest rate risks on only an annual basis, and among the property-liability companies, liability durations are often not measured at all, nor is the interest rate sensitivity taken into account in liability simulations.
Although many firms use the same general frameworks for analysis, when it comes to implementation we begin to see divergence in the quality of inputs and practice. By relying on a number of outside sources to provide the estimates of interest rate sensitivity for assets and liabilities, a number of insurers have injected another risk into the mix: divergent technologies and assumptions. We believe that, for the purposes of asset/liability management, it is a misdirected effort to obtain the most credible measures of interest sensitivity of certain assets or liabilities. It is far more important to get measures of interest rate sensitivity that are calibrated similarly. After all, the precise values are of less importance here than their relative values and the implication these have for the volatility of equity.

We saw a number of practices that invite problems. One prominent insurer uses effective duration and convexity estimates for the liability side of the balance sheet and modified Macaulay duration measures for the asset side. Another insurer does exactly the opposite. Some insurers base their aggregate duration and convexity numbers on book value weights, rather than market value weights. More than one insurer is frustrated that its actuarial department relies entirely on simulation models, or simulating through lattices. Only one insurer we know of is attempting to correct the duration measures on corporate bonds for the basis risk between corporate and government bonds.\textsuperscript{10} Some insurers take into account the basis risk between movements in long-term vs. short-term interest rates, but many do not. Some take into account all kinds of potential twists in the yield curve, while others allow only for parallel shifts. In setting limits on the amount of systematic risk the company desires to retain, a common approach is the one used by a leading multiline insurer. The company places limits on its desired portfolio structure to reflect the variety of risks to which it is exposed. Limits are set on individual asset holdings, on industry concentration, and on asset type—including mortgage-backed securities and collateralized mortgage obligations—all in a risk-based capital context. However, nowhere did we observe a methodology to derive such limits, or even a standardized approach across business lines.

For the balance sheet as a whole, limits are employed in two different ways. One approach is to impose a limit on the amount of duration mismatch allowed, either for particular product lines or for aggregating across all assets and liabilities. For instance, one company applies these restrictions on a product segmentation basis, allowing up to a year duration mismatch on participating whole life products, but only one-tenth of a year on GICs. Another company does not place restrictions on duration mismatches on a product-by-product basis, but on an aggregate portfolio basis. In our view, although most companies we interviewed used some sort of product segmentation approach, it is not necessary to do so. The advantage of a segmentation approach is the discipline it imposes on the pricing process, so that long-term yields are not used for pricing short-term liabilities, and so forth. However, if this same discipline can be achieved in the pricing of insurance policies without a segmentation of assets into various product groupings, it seems that advantage would disappear. On the other hand, valuable resources would not be consumed in notionally dividing up the general account into the various segments, and it could be managed on an aggregate basis. This would avoid the costly duplication of efforts, where one product manager is selling an asset and another is buying the same or a similar asset, incurring transaction costs. Some firms simply transfer the assets between portfolio segments and use some sort of internal transfer pricing mechanism. Assets are acquired by the firm and then allocated to each product group according to perceived needs. This is done to foster a better sense of accountability and used in performance evaluation. But to reward a product group for producing net profits between liability costs and rates of return on assets which they had no responsibility in acquiring or divesting seems to be rewarding them for risks over which they had no control. While we appreciate the

\textsuperscript{10} See Babbel, Merrill, and Panning (1987) for an explanation of the correction procedure.
need for pricing discipline and control, we feel this could be achieved more simply and that the asset portfolios can be managed better on an aggregate basis.

The other limit is a restriction on the amount of scenarios that are allowed to reveal losses due to asset/liability mismatches. These limits typically are placed not only on the distribution of final simulated results, but also on the evolution of solvency over time associated with the simulations. One leading firm has almost no tolerance for scenarios showing negative profitability due to interest rate risk exposure. Because it is persuaded that interest rates are virtually impossible to forecast, and over which it has no control, it has decided to avoid interest rate risk of any kind, to the extent possible.

At the firm that decided to avoid as completely as possible interest rate risk, portfolio managers are not rewarded in any way for taking interest rate risk and rates of return above some benchmark level. By measuring only periodically the investment department personnel if they achieve investment income or total rate of return, these firms purport to eschew interest rate risk, yet reward their investment position out of performance bonuses and commission awards. Some firms have duration targets but ignore convexity, leading portfolio managers to try barbell, ladder, or bullet maturity approaches to achieve higher investment income, depending on the shape of the term structure.

But by in large, the major difference between investment practices that we saw during this study, compared to what was occurring less than a decade ago, is that there is far less emphasis on yield and more on total rate of return. As recently as five years ago a survey of the American Council of Life Insurance revealed that two-thirds of chief investment officers did not even consider total rate of return as an investment objective. Yield was the primary focus. This was an impediment to effective asset/liability management but is beginning to dwindle. Nonetheless, we observed more concern with book yield than we feel is appropriate, given its lack of importance to the true economic performance of the firm.

Credit Risk
In addition to the credit risk that reveals itself as basis risk in the systematic risk factors listed above, there is also the risk of default on significant firm investments. Although it may be idiosyncratic risk to the market as a whole, it is not idiosyncratic risk to the insurer maintaining a significant position in an asset that goes into default.

Insurance firms are generally very focused on credit risk, as are rating agencies and regulatory authorities. They produce weekly and monthly reports that monitor the credit risk of their assets. They rely on outside rating agencies, such as Moody’s, Standard and Poor’s, Duff and Phelps, and Dunn and Bradstreet. In addition, virtually all of their investments are assigned credit ratings by the Securities Valuation Office of the National Association of Insurance Commissioners, which are used for statutory reporting purposes. These ratings are not always viewed as sufficient measures of credit risk for those insurers who feel that absorbing credit risk is an important part of their franchise. Many insurers have their own due diligence requirements to meet before they will take on an investment that has credit risk. They undertake internal credit risk assessments, in some ways quite similar to those of Moody’s or Standard and Poor’s, although with different weightings on the risk factors. Moreover, they are prone to update their internal credit risk ratings promptly as important information bearing on the creditworthiness of a major investment position is revealed.

Insurers produce “watch lists” of firms they feel are in financial jeopardy, likely to be downgraded or become insolvent. They often have a dual track credit risk assessment, one for the asset itself, and another for the underlying collateral. They place limits on the portfolio exposure by industry, geographic region, business (e.g., real estate prohibited), and company. They also have lists of approved counterparties for brokerage, settlement, and swaps.

Tables 3 and 4 provide an example of one set of investment guidelines, with general and specific authorizations and limits that we feel are representative of the industry. However, we have seen substantial variation in the practices. Perhaps the poorest approach we saw was a firm that uses Moody’s ratings and assigns numerical values to each rating class. For instance, 1 is assigned to a rating of Aaa, 2 is assigned to Aa, 3 to A, 4 to Baa, 5 to Ba, 6 to B, 7 to Caa, 8 to C, 9 to B, and 10 to D. Adjustments are made to accommodate the modifiers of 1, 2, and 3 that Moody’s often uses to designate relative quality within a rating class. The company then has a target number of 3 to achieve in its overall credit risk plan. One problem with this approach, which they recognize, is that default rates and volatility of default rates do not grow linearly as rating is decreased step by step. Coupled with an incentive structure that rewards portfolio managers for the investment yields they book, this system leads to a credit barbell approach, as shown in Figure 2, because the portfolio manager can achieve superior yields by doing so.

The best approach we saw included a more refined ranking of credit risk, not by letter but by default probability coupled with standard deviation of defaults for each ranking. Covariance of asset returns is also taken into account, and the entire credit risk problem is cast in a surplus-oriented mean-variance model. Diversification guidelines are incorporated through constraints on the optimization. Liquidity risk is reflected by reducing the expected returns by a number of basis points deemed appropriate from historical experience.
### Table 3

#### Investment Guidelines

**General Authorizations**

These general authorizations are to remain in effect until January 1997 unless modified or canceled.

The total investment in any one credit (total of bonds, preferred stock, convertible securities and common stock) is limited to 1 percent of net admitted assets, with the exception of direct U.S. Treasury and full faith and credit obligations and U.S. government-sponsored enterprise obligations, as further specified below.

The following authorizations specify which transactions the investment officers of the company are authorized to conduct at their discretion.

#### Fixed Income Securities—Nonconvertible

A. Purchase U.S. Treasury and full faith and credit obligations in unlimited amounts.

B. Purchase U.S. government-sponsored enterprise obligations. Such purchases to be limited to 3 percent of net admitted assets per enterprise and an aggregate limitation of 10 percent.

C. Purchase corporate, municipal, or foreign bonds denominated in U.S. dollars which are rated in the Baa category or better; purchase private placement issues rated in the Baa category or better, or its equivalent.

D. Purchase mortgage-backed securities and collateralized mortgage obligations consistent with investment committee limitations and the specific authorizations.

E. Purchase asset-backed securities consistent with investment committee limitations and specific authorizations.

F. Purchase preferred stocks of companies whose bonds or preferred stocks are rated in the Baa category or better, or its equivalent.

#### Short-Term Fixed Income

H. Purchase commercial paper (with maturities not exceeding 270 days), certificates of deposit, or bankers acceptances which are rated either A-1 or better by Standard & Poor’s or P-1 by Moody’s. Such purchases to be limited to 1 percent of net admitted assets per credit.

#### Repurchase Agreements

J. Repurchase agreements may be transacted with banks or security dealers by specific authorization. Total amount outstanding to be limited to 5 percent of net admitted assets and per counterparty to 2 percent.

#### Dollar Rolls

K. Enter into dollar roll transactions with banks or security dealers designated in the specific authorizations. Total amount outstanding to be limited to 5 percent of net admitted assets and per counterparty to 2 percent.

### Convertible Securities

O. Under the limits specified for nonconvertible bonds, purchase convertible bonds of companies with issues rated in the Baa category or better or of companies with lower or nonrated issues according to the following schedule:

<table>
<thead>
<tr>
<th>Moody’s (or S&amp;P) Rating</th>
<th>Authorized Limit per Issuer as Percentage of the Convertible Portfolio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ba1 (BB+) to Ba3 (BB-)</td>
<td>2.0</td>
</tr>
<tr>
<td>B1 (B+) to B3 (B-)</td>
<td>1.0</td>
</tr>
<tr>
<td>No Rating</td>
<td>1.0</td>
</tr>
<tr>
<td>Caa (CCC+) to C (D)</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Purchases must not cause the aggregate statement value of convertible debt rated less than 2 by the NAIC to exceed the following percentages of the convertible debt portfolio:

<table>
<thead>
<tr>
<th>NAIC Rating</th>
<th>Restrictions (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 3Z.6 6Z</td>
<td>60.0</td>
</tr>
<tr>
<td>4 4Z.6 6Z</td>
<td>40.0</td>
</tr>
<tr>
<td>5 5Z.6 6Z</td>
<td>7.5</td>
</tr>
<tr>
<td>6 6Z</td>
<td>2.5</td>
</tr>
</tbody>
</table>

(Continued)
(Table 3, Continued)

P. Purchase of medium or lower grade bonds must not cause the aggregate statement value of bonds, including convertible debt, rated less than 2 by the NAIC to exceed the following percentages of net admitted assets:

<table>
<thead>
<tr>
<th>NAIC Rating</th>
<th>Restrictions (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 3Z 6 6Z</td>
<td>10.0</td>
</tr>
<tr>
<td>4 4Z 6 6Z</td>
<td>5.0</td>
</tr>
<tr>
<td>5 5Z 6 6Z</td>
<td>3.0</td>
</tr>
<tr>
<td>6 6Z</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Q. No more than 25 percent of the portfolio's bonds rated less than 2 by the NAIC can be companies within a single industry, nor should these issues in aggregate conduct business within one narrow geographic region. The duration of these issues as a group should be viewed in the context of the total bond portfolio.

R. Purchase convertible preferred stocks under the limits specified for nonconvertible with issues rated Baa or better or of companies with lower or nonrated issues according to the following schedule:

<table>
<thead>
<tr>
<th>Moody’s (or S&amp;P) Rating</th>
<th>Authorized Limit per Issuer as Percentage of the Convertible Portfolio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baa (BB+) to Ba3 (BB-)</td>
<td>2.0</td>
</tr>
<tr>
<td>B1 (B+) to B3 (B-)</td>
<td>1.0</td>
</tr>
<tr>
<td>No Rating</td>
<td>1.0</td>
</tr>
<tr>
<td>Caa (CCC+) to C (D)</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Common Stock

S. The investment officers are authorized to purchase common stocks of any U.S. or Canadian corporation or any foreign corporation whose shares are included in the S&P Common Stock Index in amounts consistent with the investment policy statements as approved by the committee subject to these additional restrictions. Specifically, the investment officers may not:

1. Invest in the equity securities of closed-end funds, investment companies, limited partnerships, or real estate investment trusts without specific authorizations.
2. Make any purchase of common stock which would result in more than 5 percent of the value of the common stock portfolio being invested in the securities of one issuer.
3. Purchase a common stock if, as a result, more than 25 percent of the assets of the common stock portfolio will be invested in a particular industry.

(Continued)
The following specific authorizations for the purchase of securities to be executed at the discretion of the officers of the company were renewed by the committee:

1. **Bonds, Short-Term Investments, Convertibles Subordinated Debentures**
   None

2. **Common Stocks**
   A. **Domestic**
   None

   B. **Foreign Companies**
   Authorization
   - DeBeers Consolidated Mines (ADR) 1.0%
   - Sea Containers Ltd. 1.0%

3. **Convertible Preferred Stock**
   Sea Containers Ltd. 1.0%

4. **Repurchase Agreements, Reverse Repurchase Agreements and Dollar Roll Transactions**
   There is a list of banks and security dealers authorized for repurchase agreements and reverse repurchase agreements and dollar roll transactions.

5. **Hedging Transactions**
   A. The following officers of the investment department are hereby authorized to execute hedging transactions in accordance with the guidelines:
      - Executive Vice President & Chief Investment Officer
      - Senior Vice President, Vice President, and Second Vice President, Equity Securities
      - Senior Vice President, Vice President, and Second Vice President, Fixed Income
      - Assistant Vice President, Equity Trader

   B. There is a list of banks and brokerage firms approved for the establishment of futures trading accounts.

   C. Maximum amount which may be hedged is 5 percent of admitted assets.

6. **Residual Commitments**
   The maximum amount of CMO Residual commitments is limited to $100 million.

7. **Mortgage-Backed Securities Commitments**
   In the aggregate, the maximum amount of FHLMC, FNMA, and whole loan commitments is limited to $750 million at book value.

8. **Asset-Backed Securities**
   In the aggregate, the maximum amount of ABS is limited to $250 million at book value.

9. **Short-Term Borrowing**
   Up to a maximum amount of $100 million, such maximum amount not to exceed $50 million with any one bank or financial institution.

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**Figure 2**

**Liquidity Risk**

Although insurance companies face liquidity risk, most of the insurers we interviewed have little concern for it. Only one is concerned about having too little liquidity, and one is concerned about having too much liquidity. The others do not seem to be concerned, believing their situation to be well managed.

**Life insurers.** Liquidity is not as big a concern with many insurance firms as it is in other financial institutions for one good reason: most of their policies are less liquid than their assets. Life insurers issue policies that commonly feature high surrender charges. These charges are either explicitly stated or implicit in the schedule of cash buildup. For example, a single premium deferred annuity, with annual crediting rate reset and a seven-year maturity, may feature surrender charges beginning at 7 to 10 percent during the first year, and declining in steps toward zero at maturity. Similarly, universal life and whole life products often have very low surrender values during the first year or two of a policy, and begin building up rapidly after that point. Other policies, such as variable universal life, have surrender provisions that act much like a mutual fund, where the amount received depends on the value of the underlying fund.

A decade or so ago, the problem of illiquidity was more pronounced. Policy surrenders for some companies approached a 60 percent rate, and massive amounts of policy loans were withdrawn. The industry has managed this problem...
in two ways. First, much of the new business written is sensitive to market rates of interest, so that there is not as wide a divergence between crediting rates on life policies and annuities vs. market rates of interest. Thus, the incentive to surrender a policy is lessened. Second, policy loans are now mostly offered at variable rates that track market rates of interest, rather than the fixed policy loan rates of yore. An alternative to the variable rates charged on loans is a process known as “direct recognition,” whereby the schedule of cash value buildup is altered if policy loans are incurred. The tax environment has also changed, and interest paid on policy loans is now no longer a deductible expense for tax purposes. Thus, the interest rate arbitrage incentive has virtually disappeared.

Not long ago, however, several well known life insurance companies, such as First Capital Life, Fidelity Bankers Life, Executive Life of California, Executive Life of New York, and Mutual Benefit, experienced severe liquidity problems. But in each of these cases, there were other factors that precipitated a “run on the bank” phenomenon. The run in each case was caused, in part, by well publicized investment performance problems. In the case of the first four of the above mentioned companies, there were vast sums of policies in force with minimal, and even zero, surrender charges. Some of the policies had been marketed through Wall Street brokerages and were therefore of the “hot money” variety. Although the first four of these companies had large amounts of liquid assets, the withdrawal rates were so high that even these liquid resources were strained. Generally, however, life insurers are managed in such a way as to avoid these runs on the bank, either through policy design, sales channel, investment policy, or level of surplus.

Another problem that was more prevalent a decade ago was that all bonds were essentially reported at amortized book values. If a bond was sold prior to maturity, any capital gain or loss would need to be recognized. Many insurers, particularly during the early 1980s, could not afford to have the large capital losses appear on their books and impact their surplus. Today, however, a large portion of fixed income holdings are placed in accounts available for sale or trading, and are therefore already marked to market. Therefore, whether they are sold does not impact the reported values or the surplus as much.

Property-liability insurers. On the property-liability side of the business, the liquidity risk comes mostly from event risk or catastrophe risk. Most policies do not feature cash values that are easily accessible through surrender, although some policies will allow insureds to cancel prior to maturity and receive a portion of their premium. Moreover, the policies are typically very short term, renewable annually. With the relatively large surplus positions of most property-liability insurers, most policyholders are willing to ride out a storm, knowing that renewal time will approach in just a few months.

In terms of the accounting policies of property-liability companies, they tend to mark-to-market a larger portion of their fixed income securities than life insurers and also tend to hold more liquid, shorter-term securities on average. Thus, their liquidity concerns almost always stem from event risk or catastrophe risk. They can avoid some of these risks by reinsuring portions of their books of business and by broadly diversifying their risk portfolios geographically, by industry, and by type of risk. Alternatively, they can hold large amounts of liquid surplus assets. One leading property-liability insurer attempts to keep enough surplus on hand to accommodate a “once in 500 years” event.

We provide some tables that are representative of the practice of liquidity risk measurement and management. The company defines liquidity risk as the risk of having inadequate net cash flows to meet expenses, benefits, withdrawals, and loan payments. It views product liquidity risk as the fluctuations in cash flows outside of the ranges that are expected. It first ranks assets by relative liquidity. It then projects its cash flows over a multiple year horizon on both sides of the balance sheet using a form like Table 5. For those firms that maintain segmented accounts by product line, these liquidity reports are generated by product, as in the case of Table 6.

A company’s asset/liability committee is typically responsible for measuring and managing liquidity risk. Despite the lack of concern regarding this risk, there is still a large amount of analysis that is done to guard against illiquidity. In this regard, liquidity risk decisions are part of the analytics and scenario testing used by the company. In its investment plan, management of liquidity risk is two-fold. First, the company uses corporate and Regulation 126 modeling to measure net cash flow under various interest rate scenarios. Second, control is achieved by imposing constraints on investment. One such constraint includes ensuring that over 50 percent of the assets are held in “marketable securities.”

Many companies use PTS for most of their analysis and stress testing. The scenario testing includes about 50–100 scenarios which shift the yield curve, both parallel and slope changes. For each path created by the scenario, net cash flows must be positive. Solvency of the company is also determined along each path. Reports are used for each product, and cash flows are projected out for about 30 years under each of the scenarios. By aggregating across products for each scenario, the company has an idea of the distribution of liquidity at the firm level.

After all the scenario tests, the results have little impact on immediate decisions. For instance, if net cash flows were negative for a large portion of the stress tests, this would not imply that asset composition would change immediately. Suggestions would of course be made, but there is no guarantee that the portfolio would change immediately. Similarly, concentrations are not altered unless there are modifications to limits which would only occur quarterly or annually.
In addition to running these scenario tests, there is also a "worst case scenario." This includes cash outflows of over 300 percent over a 2 to 3 year period and a lapse rate of 45 percent. For comparison, the highest lapse rate the company has ever experienced is 18 percent, when it decided to decrease significantly dividends after a long history of either increasing or maintaining dividend payments.

There are no managers at the companies studied whose performance is based on the management of liquidity risk. Although it would be difficult to base everyday compensation on unlikely events, the company may benefit in the future from having a clearer line of responsibility with regard to liquidity management. The general procedure is that any ongoing problems with liquidity would be brought to the attention of the chief financial officer. Any changes to the company's credit ratings which could potentially affect liquidity demands are very much a concern of the auditing group.

Other Risks Considered But Not Modeled

Beyond the basic four financial risks—actuarial, systematic, credit, and liquidity—insurers have a host of other concerns, as indicated above. Some of these, like operating risk, are a natural outgrowth of their business, and insurers employ standard risk avoidance techniques to mitigate them. Standard business judgment is used in this area to measure the costs and benefits of both risk reduction expenditures and system designs, as well as operational redundancy. While generally referred to as risk management, this activity is substantially different than the management of financial risk addressed here.

Yet there are still other risks, somewhat more amorphous, but no less important. In this latter category are legal, regulatory, reputational, and environmental risk. In each of these risk areas substantial time and resources are devoted to protecting the firm's franchise value from erosion (see Babbel, 1994a). As these risks are less amenable to a priori financial measurement, they are generally not addressed in any formal, structured way. However, they are not ignored at the senior management level of the insurance firm.

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Table 5
Liquidity Report
Life Insurance Product XXX Projected Cash Flows

<table>
<thead>
<tr>
<th>Period</th>
<th>Asset Cash Flow</th>
<th>Liability Cash Flow</th>
<th>Net Cash Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Table 6
Relative Liquidity of Assets and Liabilities for Life Product XXX

<table>
<thead>
<tr>
<th>Liabilities</th>
<th>Current Quarter</th>
<th>Prior Quarter</th>
<th>Prior Quarter</th>
<th>Prior Quarter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Level 1 Liquidity</td>
<td>Level 2 Liquidity</td>
<td>Level 3 Liquidity</td>
<td>Level 4 Liquidity</td>
</tr>
<tr>
<td></td>
<td>Level 1 Liquidity</td>
<td>Level 2 Liquidity</td>
<td>Level 3 Liquidity</td>
<td>Level 4 Liquidity</td>
</tr>
<tr>
<td></td>
<td>(Levels 1 + 2) + Total</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assets</th>
<th>Current Quarter</th>
<th>Prior Quarter</th>
<th>Prior Quarter</th>
<th>Prior Quarter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1 Liquidity</td>
<td>Level 2 Liquidity</td>
<td>Level 3 Liquidity</td>
<td>Level 4 Liquidity</td>
<td></td>
</tr>
<tr>
<td>Level 1 Liquidity</td>
<td>Level 2 Liquidity</td>
<td>Level 3 Liquidity</td>
<td>Level 4 Liquidity</td>
<td></td>
</tr>
<tr>
<td>(Levels 1 + 2) + Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Summary

| Level 1 (Assets) + Level 1 (Liabilities) | Level 1–2 (Assets) + Level 1–2 (Liabilities) | Guideline |
| Guideline | Level 1–3 (Assets) + Level 1–3 (Liabilities) |

<table>
<thead>
<tr>
<th>Note: Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liabilities</td>
<td>Book</td>
<td>Int Gnty Expires</td>
<td>Market; Now Allowed</td>
</tr>
<tr>
<td>Surrender is at:</td>
<td>Surcharge &lt; 2 Percent</td>
<td>+ Scheduled Market and Surcharge;</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Annuity Payments,</td>
<td>Book,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Next 12 months</td>
<td>Surcharge &gt; 2 Percent</td>
</tr>
<tr>
<td>Assets</td>
<td>Cash, STI Inv Grade Bonds with aggregate market loss &lt; IMR; Other</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mtg amort NII over Nest 12 months</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inv Grade Bonds with aggregate market loss in excess of IMR</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mortgage;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Below Investment Grade Bonds;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Affiliates; VC;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Liabilities are net of policy loans.
In passing from this topic it is worthwhile and timely to pause to consider one of the legal risks now encroaching upon the life insurance industry. During the course of our interviews, a number of firms had been sued in the area of misrepresentation of insurance products by insurance agents. At the time of this writing, 64 class action lawsuits had been filed against firms for their so-called "vanishing premium" policies whose premiums did not vanish as illustrated, owing to a protracted decline in market interest rate levels. New class action lawsuits were being filed at the rate of one every three days. The damages claimed are staggering for some of the companies.

The manner in which insurers are responding to these lawsuits ranges from attempts to gain a quick and comprehensive settlement to attempts to have the arguments heard in court. Some insurers are merely biding their time to see how other firms fare in the struggle. But more interesting is how insurers are acting to avoid future problems stemming from alleged agent misrepresentation. One of the leading firms has established a large department of compliance to train and monitor the behavior of its sales agents. All of its sales and promotional literature is undergoing careful scrutiny by the legal department.

Another firm has created an auditing division to oversee compliance from a central location, computerizing each transaction. Management is concerned with five components of compliance: customer satisfaction, new products, stable earnings, expansion capabilities, and corporate miscellaneous. They are building controls into the centralized computer system. Should an agent exceed the allotted number of address changes, disbursements, lapses, or sales, the computer will not process the policy until the auditing department has had a chance to investigate further. These stop measures are not announced to either the customer or the sales agent. The director of auditing indicated that the system is intended to prevent problems rather than react to them.

A compliance division has been introduced to complement the role of the internal audit group. This division is responsible for insuring the field force and also providing training to sales agents so they will better be able to represent the company's products. This division is currently sending out surveys to its customers to find out if they really understand the products they now hold. It is hoped that these measures will mitigate any class action suits in the future.

Areas Where Further Work Will Improve Methodology

Thus far, the techniques used to measure, report, limit, and manage individual risks have been presented. In each of these cases, a process has been developed, or at least has evolved, to measure the risk considered, and techniques have been deployed to control each of them.

The insurance industry is clearly evolving to a higher level of risk management techniques and approaches than had been in place in the past. Yet, as this review indicates, there is significant room for improvement. Before the areas of potential value added are reviewed, however, it is worthwhile to reiterate an earlier point. The risk management techniques reviewed here are not the average, but the techniques used by firms at the higher end of the market. The risk management approaches at smaller institutions, as well as larger but relatively less sophisticated ones, are less precise and significantly less analytical. In some cases, they would need substantial upgrading to reach the level reported here. Accordingly, our review should be viewed as a glimpse at best practice, not average practices. Nonetheless, the techniques employed by those that define the industry standard could use some improvement. By category, recommended areas where additional analytic work would be desirable are listed below.

Actuarial Risk

There remains too much disagreement in the most fundamental area of actuarial science—namely, what discount rate or rates does one use to value insurance liabilities (see Altman and Vanderhoof, 1996). With such broad disagreement about what insurance is worth, or what it will cost the insurer, it is little wonder that we encounter difficulties when it comes to managing risk. On the bright side, it must be acknowledged that there is a flurry of activity taking place directed toward solving this conundrum. In our opinion, as the scope of what exactly is being valued is more carefully defined, there is a convergence in the estimates produced by the alternative valuation methods (see Babbel, 1997).

During the past decade, tools have been developed that can take into account the interest rate sensitivity of policy cash flows. However, many insurers have not employed these tools. Among those who have, there is a severe problem with the data inputs that are necessary to produce useful output. Insurers have not tracked or organized their lapse, surrender, and claims data in a manner that allows them to accurately model their interest rate sensitivity. Although the models are capable of accommodating virtually any functional form of this behavior including the effects of policy seasoning, channel of distribution, and so forth—little data exist to estimate the functional form. Of course, this was also the case with regard to the modeling of mortgage-backed securities prepayment a decade ago, but since that time data were collected and analyzed, allowing for the enlightened application of the valuation tools that we see today in that sector. We expect that the same will be true for insurers in a few more years.

Another area where we expect to see rapid improvement is in the versatility of the actuarial software and its speed. Currently, only single-factor stochastic models are being widely used. This results in output that is inconsistent with the other side of the balance sheet, where two or more factors are typically used. Moreover, the speed of processing is so slow that insurers make undesirable compromises when it comes to modeling their products fully. Emerging computer technology undoubtedly will remove this impediment to better policy pricing and risk analysis.

Systematic Risk

Tremendous progress has already been made over the past five years in managing systematic risk. Most of it has been directed toward interest rate risk management, which is appropriate given its importance to insurers. An important area for fur-
be linked better to operational details. In addition, the usefulness of such exercises will soon be evaluated in a framework consistent with other financial risks. Some insurers are already moving in this direction.

Credit Risk

The evaluation of credit rating continues to be an imprecise process. We note divergence between the NAIC ratings assigned in particular public and private placements vs. the ratings assigned by the Wall Street ratings agencies. We should never expect to see a complete convergence here, as there is no single set of weights to apply to the risk factors across all industries and firms. However, we do expect to see less divergence over time, as more becomes known about the factors that lead to default.

We also expect to see more enlightened practices when it comes to aggregating credit risks. A sensible aggregation scheme would take into account default rates, default losses, and the shape of the distribution of losses across all ratings categories. In time, we may even see a move toward market-based default measures, at least on publicly-traded debt instruments. We anticipate that credit risks will soon be evaluated in a framework consistent with other financial risks. Some insurers are already moving in this direction.

Liquidity Risk

For the life insurers, liquidity risk seems to be the least of their major financial risks. Most companies are doing a satisfactory job of managing this risk. With the advent of mark-to-market accounting, the problems for liquidity caused by the fiction of book accounting will gradually subside. Most life insurers model this risk well. In the property-liability sector, it remains a large risk. Crisis models need to be rather simplistic, and scenario testing is rather limited.

The quest for an estimate of aggregate firm risk has been a stumbling block for the insurance industry. The extent of the differences across risks of different types is quite striking. Actuarial risk is carefully modeled but reported at infrequent intervals. There is often a lack of follow-up to see whether, based on the insurer’s experience, the actuarial assumptions have been appropriate. Systematic risk, particularly interest rate risk, is typically measured by life insurers on both sides of the balance sheet and by property-liability insurers at least on the asset side. Interest rate risk exposure is discerned using measures of effective duration and convexity, scenario simulations, or a combination of the two. For assets it may be reported as often as weekly or monthly, but for liabilities it is generally reported only quarterly or annually. The credit risk process is a qualitative review of the performance potential of different bonds and borrowers. It results in a rating, periodic reevaluation at reasonable intervals through time, and ongoing monitoring of various types or measures of exposure. Liquidity risk, on the other hand, more often than not, is dealt with as a planning exercise, although some reasonable work is done to analyze the effect of adverse events that affect the firm.

CONCLUSION

The analytical approaches that are subsumed in each of these analyses are complex, difficult, and not easily communicated to non-specialists in the risk considered. The insurer, however, must select appropriate levels for each risk and select, or at least articulate, an appropriate level of risk for the organization as a whole. How can and is this achieved?

The simple answer is “not very well.” Senior management often is presented with myriad reports on individual exposures, such as specific credits, and complex summaries of the individual risks, outlined above. The risks are not dimensioned in similar ways, and management’s technical expertise to appreciate the true nature of both the risks themselves and the analyses conducted to illustrate the insurer’s exposure to them is limited. Accordingly, over time, the managers of specific risks have gained increased authority and autonomy. In light of recent losses, however, things are beginning to change.

At the organizational level, overall risk management is being centralized into a risk management committee, headed by someone designated as the senior risk manager. The purpose of this institutional response is to empower one individual, or group, with the responsibility to evaluate overall firm-level risk, and determine the best interest of the company as a whole. At the same time, this group is holding line officers more accountable for the risks under their control and the performance of the institution in that risk area. Activity and sales incentives are being replaced by performance compensation which is based not on business volume, but on overall profitability.

At the analytical level, aggregate risk exposure is receiving increased scrutiny. To do so, however, requires the summation of the different types of risks outlined above. This is accomplished in two distinct but related ways. In the first approach, risk is measured in terms of variability of outcome. Where possible, a frequency distribution of net returns is estimated from historical data, and the standard deviation of this distribution is estimated. Capital is allocated to activities as a function of this risk or volatility measure. Then, the risky position is required to carry an expected rate of return on allocated capital, which compensates the firm
for the associated incremental risk. By dimensioning all risk in terms of loss distributions, and allocating capital by the volatility of the proposed activity, risk is aggregated and priced in one and the same exercise.

The second approach is similar to the first, but depends less on a capital allocation scheme and more on cash flow or earnings effects of the implied risky position. This approach can be used to analyze total firm-level risk in a similar manner to the first approach. Again, a frequency distribution of net returns from any one type of risk can be estimated from historical data. Extreme outcomes can then be estimated from the tail of the distribution. Either a worst-case historical example is used for this purpose, or a three or four standard deviation deviation outcome is considered. Given the downside outcome associated with any risk position, the firm restricts its exposure so that, in the worst-case scenario, the insurer does not lose more than a certain percentage of its surplus or current income. Therefore, rather than moving from volatility of equity value through capital, this approach goes directly to the current earnings implications from a risky position. The approach, however, has two very obvious shortcomings. It is cash-flow based, rather than market value driven; and it does not necessarily directly measure the total variability of potential outcomes through a priori distribution specification. Rather, it depends upon a subjectively prespecified range of the risky environments to drive the worst-case scenario.

Both measures attempt to treat the issue of tradeoffs among risks using a common methodology to transform the specific risks to firm-level exposure. In addition, both can examine the correlation of different risks and the extent to which they can or should be viewed as offsetting. As a practical matter, however, only two of the insurers interviewed that were using these approaches viewed the array of risks as a standard portfolio problem. Rather, they separately evaluate each risk and aggregate total exposure by simple addition. As a result, much is lost in the aggregation. Perhaps over time this crucial issue will be addressed more widely.

The ability of insurance companies to estimate and manage firm-level risk is a long way off. To reach this goal requires much more precision in the estimation and management of the individual risks within the firm. Aggregation has meaning only to the extent that the individual elements can be aggregated. This presumes that they are measured correctly, dimensioned in a similar manner, and incorporated in a unified framework of risk. When this is accomplished, risks of different types will be contrasted and compared, and tradeoffs will become possible. However, to achieve this requires a significant amount of work on the individual risks within the industry before any reasonable aggregation can transpire.

REFERENCES


An Integrated Approach to the Hedging and Pricing of Eurodollar Derivatives

Robert A. Jarrow
Stuart M. Turnbull

ABSTRACT

Taking the term structure of Treasury securities and Eurodollar rates as exogenous, this article provides an integrated approach to the pricing and hedging of London Inter-bank Offer Rate (LIBOR) derivatives. Our approach allows the spread between Eurodollar and Treasury rates to reflect both the credit risk in holding Eurodollar deposits and a convenience yield from holding Treasury securities. This integrated approach includes the models of Babbs (1991), Grinblatt (1994), and Jarrow and Turnbull (1995) as special cases.

INTRODUCTION

Eurodollar futures contracts are some of the most actively traded contracts in the world. In the over-the-counter market, there is a large volume of trading in Eurodollar derivatives such as forward rate agreements, caps, and floors. All of these instruments can be used in hedging swap portfolios. At the short end of the maturity spectrum (approximately the first three years), because of liquidity considerations, Eurodollar futures contracts provide the easiest hedging vehicle for the derivatives product book. But, at the long end of the maturity spectrum, it is necessary to use both Treasury bonds and Treasury bond futures. This hedging practice implies that it is necessary to have a framework in which both LIBOR and dollar derivative contracts can be priced and hedged consistent with the absence of arbitrage.

The consideration of LIBOR and over-the-counter (OTC) derivative contracts also raises the question of credit risk, because for LIBOR there is the risk of default, and for OTC derivatives there is the additional risk that the writer of the derivative might default. Currently, there are three modeling approaches to pricing credit risky derivatives.

The first approach values these options as contingent claims on the assets of the firm (see Merton, 1974, Black and Cox, 1976, Ho and Singer, 1982, Chance,