Modelling and Managing Risk

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ABSTRACT

This paper looks at the risks faced by financial institutions, and how they can be modelled and managed. I compare the way in which each of the risks affects different types of financial institution and look for similarities (and differences) across industries. Finally, I consider what makes a good risk management system.

KEYWORDS

Financial Risk; Operational Risk; Modelling; Pension Fund; Insurance Company; Bank

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1. Introduction

1.1 *Overview*

1.1.1 The purpose of this paper is to assess the techniques currently available for financial risk management and to discuss the use of these methods by different financial entities. This analysis shows where different types of organisation are making the best use of the approaches available and where there is room for improvement.

1.1.2 The layout of the paper is as follows. First, I give an overview of the various types of financial institution and their relationships with various interested parties. I next look at how these parties might view risk. I then go on to consider the ways in which different types of risk can affect different types of financial institution, before looking at how these risks can be modelled. Next, I look at ways in which risk and return can be assessed and, for market risk in particular, how investment strategies can be compared. I then go on to look at ways of managing risk, before commenting on some of the characteristics of good risk management systems.

1.1.3 There is, of course, an enormous range of types of financial firm.

However, in carrying out my analysis I consider only three types of organisation:

— banks;
— insurance companies; and
— defined benefit pension schemes.

1.1.4 Defined benefit pension schemes fall into two categories: public sector and private sector. Whilst much of the analysis below applies to both, some aspects, such as the reliance of the pension scheme on the solvency of the sponsor, are more applicable to private sector pension schemes.

1.1.5 I must also limit the level of detail in my analysis. It is possible to produce lengthy research on many of the individual areas which I cover in this paper; however, a compromise between breadth and depth must be struck in order to make this analysis useful. The references which I give should, I hope, provide guidance as to where further information on individual areas can be explored more fully. Finally, it is worth noting that, although the discussions in this paper revolve around risk in financial institutions, it is invariably individuals who ultimately pay the price of any shortcomings.

2. Financial Institutions

2.1 *Relationships with Capital*

2.1.1 All financial institutions need and use capital (as do many non-financial institutions). There are two broad types of relationship which these institutions have. The first type is with the providers of capital. Such providers can also be categorised, broadly, into those who expect a fixed return on their capital (providers of debt capital) and those who expect whatever is left (providers of equity capital). The aim is to make as much profit as possible in order to make fixed payments to debt holders and to maximise the payments to equity shareholders. On the other side, institutions also have relationships with their customers.

2.1.2 These relationships have an impact on the way in which capital will be used. In particular, equity shareholders will wish to maximise the return on the capital which they supply, whereas debt holders and customers will wish to minimise the risk to capital. The former group is concerned with investing aggressively enough and with the model used for pricing; the latter group is concerned with matching assets to liabilities and with the model used for reserving.

2.1.3 There is a significant volume of literature on the conflicts between equity and bond holders. For example: Jensen & Meckling (1976) discuss this in the context of the principal-agent problem, looking at the agency cost of debt; Harris & Raviv (1990) develop a theory of capital structure based

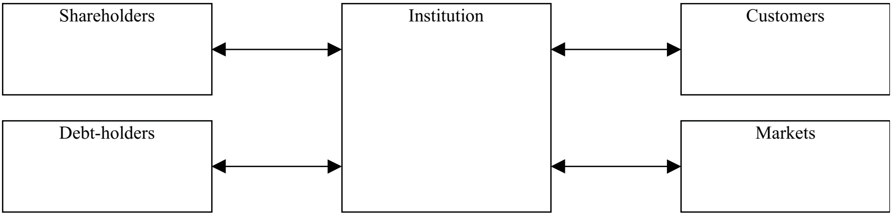

Figure 1. Dynamics of a financial institution

on the effect of debt on the investors' information about a firm and their ability to oversee management; and Myers (1977) argues that the present value of a firm's option to make future investments will tend to be financed by equity share capital, since profit from the investment will otherwise be captured by debtholders. He also argues that the higher the proportion of debt which is used to capitalise the firm, the weaker the firm's incentive to invest in risky projects, so the lower the value of the firm. Myers (1984) and Myers & Majluf (1984) explore these themes further.

2.1.4 The relationship between the various parties is shown in Figure 1. Whilst this model can be applied broadly to financial institutions, the names used for each party will differ from type to type. For a bank, the shareholders are clearly those investors who provide equity share capital to banks, and investors in banks' debt instruments (bonds, bills and so on) are the debt holders. Those institutions trading derivative instruments with banks are customers, but what about account holders whose deposits are with a bank — are they customers or providers of debt capital? A comparable issue arises for insurance companies. Non-profit and non-life policyholders are unambiguously customers, whilst the debt holders are those who hold debt instruments issued by the insurance company, or provide bank lending. However, for a mutual insurance company, the shareholders are also customers, being with-profits policyholders; and, even for a proprietary insurance company, part of the equity capital is provided by with-profits policyholders (if they exist) in addition to that provided by more traditional shareholders.

2.1.5 When looking at defined benefit pension schemes, a change in perspective is needed. Pension scheme liabilities can be regarded as collateralised borrowing against scheme members' future benefit payments. This being the case, pension scheme members might be regarded as debt holders more than customers, whilst the sponsoring employer can be thought of as the provider of equity capital, being the party which must make up any shortfall and which receives the benefit of any surplus of assets over liabilities (usually through a reduction in contributions payable). It is worth noting that, unlike most equity capital, that provided by the sponsor is unlimited, since the Section 75 liability (the debt on the employer in the event of a pension scheme wind-up) has no explicit limits.

2.1.6 One way of looking at the way in which the various parties should be regarded is to consider who is looking after each party's interests. This does not necessarily refer to a legal obligation; rather it refers to the party or the individual which can exert a significant influence on the way in which the institution is run.

2.1.7 The interests of the debt holders of most institutions are looked after primarily by the Financial Reporting Council (FRC), whose role is to ensure high standards of corporate governance and to set, monitor and enforce accounting and auditing standards. By so doing, sufficient information is available to debt holders to assess the security of their investments. It could be argued that market forces also play a role, since the market, as a whole, will assess the information available and will arrive at an appropriate price for the investments (although the extent to which this is true depends on the extent to which market efficiency is accepted).

2.1.8 Debt holders are also protected by the way in which an issue is constructed, for example: by any covenants attached to debt issues; by the extent to which the issue is explicitly linked to any collateral (and the nature of that collateral); and by the seniority of the issue.

2.1.9 It could also be argued that credit rating agencies, which (for large issues of traded debt at least) monitor the creditworthiness of the issuer, have a role to play. The purpose of a credit rating is to allow a firm to borrow funds at a more competitive rate of interest, and it is the firms themselves which pay for the credit ratings; however, in order to maintain credibility with debt investors — so that a credit rating is seen as reflective of the creditworthiness of the borrower, and therefore worth paying for — a degree of accuracy in the rating process is required, and thus rating agencies are also acting on behalf of debt holders (whether the debt holders want this or not). Clearly, investors in most rated firms will also carry out their own analysis rather than rely on the credit rating. Also, holders of unquoted debt or smaller quoted issues do not have the benefit of rating agency analysis, and so must rely on their own calculations. Credit rating methodologies are discussed later.

2.1.10 The interests of banks' deposit holders are partly served by rating agencies. The assessments of rating agencies are also a key source of information for institutions choosing between banks as counterparties for derivative transactions. However, individuals with bank deposits are more obviously served by the Financial Services Authority (FSA). Insurance company debt holders again use credit rating agencies, but both non-profit and with-profits policyholders rely on the FSA, regardless of the extent to which they may be regarded as providers of equity capital. Pension scheme members are also limited users of credit rating agencies, despite the fact that, to a greater or lesser extent, they are often subject to the creditworthiness of the sponsor; rather, pension scheme members rely on the Pensions Regulator, and, at a more practical level, on their Scheme Actuary for security.

2.1.11 The FRC is also primarily responsible for the interests of bank and insurance company equity shareholders. These interests are also supplemented by additional listing requirements imposed by many stock exchanges. As with bonds, it could be argued that market forces play a role, with the market assessing the information available and arriving at an appropriate price. Clearly, the earlier point about market efficiency still holds here.

2.1.12 The extent to which equity holders obtain value for money is also influenced by the pricing models for both banks and insurance companies: for the former in pricing complex instruments; and for the latter in pricing insurance products. If incentives are in place to align the interests of shareholders and those pricing the products, then the pricing teams will also be acting in the interests of equity shareholders.

2.1.13 In the context of a pension scheme, the interests of the equity holder — also known as the scheme sponsor — are less well guarded. Sponsors rely on independent actuarial advice to ensure that they are getting value for money from their investment in the pension scheme.

2.1.14 The final link which financial institutions have is with the markets. In all cases this will involve marketable investments for return purposes, but also the use of market-based solutions for managing risk, such as the purchase of matching bonds by pension schemes and life assurance companies, and the securitisation of risk by banks and general insurers.

2.1.15 The views of the parties discussed and their assessments of financial institutions' capital are the topic of the next section.

3. Some Views of Risk

3.1 *Introduction*

In this section I look at some views of what risk means (or should mean) to some parties. To summarise, the parties whose views are of interest are:
— the FRC;
— the FSA;
— credit rating agencies;
— pricing teams;
— the Pensions Regulator; and
— corporate actuarial advisers.

3.2 *The FRC*

3.2.1 The views of the FRC can be covered very quickly or in great detail; I choose the former route. This is not to say that the input of the FRC into risk control is unimportant — indeed, ensuring that sufficient information is produced by firms in a timely manner is key to ensuring transparency, and thus to protecting investors.

3.2.2 Whilst there are differences of opinion as to what is the correct detail to include in the accounts (for example in relation to pension costs or employee share options), the general view taken by the FRC is that more information is better.

3.3 *The FSA*

3.3.1 The role of the FSA is broadly determined by two international agreements: that relating to banks (the Basel Accord and, shortly, Basel II), and that relating to insurance companies (Solvency II, which is still being implemented). It has two broad aims: to protect policyholders; and to limit the risk of systemic failure.

3.3.2 The FSA's regulation of banks is in line with the 1988 Basel Accord and its amendments. This concentrates on the Cooke ratio, the ratio of capital to risk-weighted assets, which must be greater than 8%. The Basel Accord concentrates on two risks: credit risk and market risk. The former is dealt with by assigning lending to one of four risk buckets, each with its own risk weight. Market risk is allowed for through the bank's own model. This approach has the advantage of simplicity, but has led to regulatory arbitrage, discussed later.

3.3.3 Still in development is the successor to this accord, known as Basel II. This consists of three pillars:

— Pillar 1 sets out the minimum capital requirements;
— Pillar 2 is a supervisory review process, whereby the FSA may require a firm to hold additional capital against risks not covered in Pillar 1; and
— Pillar 3 is the requirement for firms to publish details of their risks, their capital and the ways in which they manage risk.

3.3.4 Of particular note is the fact that Pillar 1 also considers operational risk, not allowed for under the first Basel Accord.

3.3.5 The FSA has a comparable reference for insurance companies, although insurers also have to face Solvency II, which is also still in development. This consists of the same three pillars as Basel II, although some types of risk for insurers find themselves under different pillars than for banks. Pillar 3 is yet to be implemented, but Pillars 1 and 2 are already with us.

3.3.6 Under the Pillar 1 approach, required reserves are calculated according to a specified deterministic basis, although stochastic methodology is often required, particularly in the valuation of with-profits guarantees. Market risk is dealt with by limiting the assets which are admissible and, for firms writing long-term business, by requiring stress testing in response to a small number of deterministic scenario tests; credit risk is dealt with by limiting exposure to reinsurance and other counterparties. An additional solvency margin is calculated which differs by business: for general insurance business, the margin is the greater of various amounts determined from premiums written or earned, claims incurred and the previous year's reserves on a deterministic, formulaic basis; and for firms writing long-term business, proportions of the liabilities, assets and sums assured are calculated, again in a deterministic and formulaic manner.

3.3.7 For 'realistic basis life firms' — broadly speaking, those having with-profits liabilities of at least £500m — an additional reserve may be required. Such firms are required to calculate their liabilities on two bases, and the larger figure from the two methods (the higher of two 'peaks') is effectively the reserve. The calculation described above gives the first measure of the liabilities, known as the 'regulatory' peak. The second, 'realistic' peak is calculated using the realistic value of assets (the admissible assets plus some inadmissible ones), the realistic value of liabilities (a deterministic calculation using realistic assumptions) and the risk capital margin (a deterministic scenario analysis to determine the additional reserves which would be needed in particular market conditions). The methodologies for calculating each of the twin peaks are very similar — deterministic projections and scenario analysis; only the bases are different.

3.3.8 The Pillar 2 calculation is somewhat different. In the United Kingdom, this is the Individual Capital Assessment (ICA) required for the Individual Capital Adequacy Standards (ICAS) regime. This is a risk-based capital approach, with the criterion that the probability of ruin for a one-year time horizon must be less than 0.5%, although a lower level of confidence over a longer time frame can be used instead. The Pillar 2 reserve is not reported to the FSA, but the FSA can come to review the model and request *ad hoc* assessments, effectively meaning that the reserve must be calculable on a daily basis. The reserve which must be held is the higher of that calculated under Pillar 1 and that under Pillar 2.

3.3.9 Pillar 2 is the 'sensible' assessment, in that it allows the inclusion of all relevant risks in a coherent approach, rather than relying on rules of thumb; however, given that those carrying out these assessments are remunerated by the insurance company, which is also (it is hoped) looking out for its shareholders, the FSA needs to ensure that sufficient account is being taken of all the risks.

3.4 *Credit Rating Agencies*

3.4.1 A conflict of interest also exists with credit rating agencies, to the extent that such agencies are hired and paid by firms in order to allow firms to borrow more cheaply. One would hope that competition between rating agencies would be for credibility rather than for favourable ratings.

3.4.2 Credit rating agencies provide ratings on debt issues and issuers, which are intended to give a broad view on the creditworthiness of the entity being assessed or the debt issued by that entity. The assessment also takes into account the terms of each debt issuance and its location within a corporate structure, allowing for collateralisation and subordination. The agencies generally use a combination of 'hard' accounting data and 'soft' assessments of factors such as management quality and market position to arrive at forward-looking assessments of creditworthiness, although some use methods based on leverage and the volatility of quoted equity. An overview of the approaches of major rating agencies is given in Christiansen *et al.* (2004), and I cover some aspects of the approach in more detail later. Credit ratings are long-term assessments, considering the position of an entity over an economic cycle. This means that, whilst the risk for each firm will change over the economic cycle, the credit rating will not.

3.4.3 An issuer may, in fact, have a number of different credit ratings. Short-term and long-term ratings may differ, and varying levels and types of collateralisation invite different credit ratings.

3.5 *Pricing Teams*

3.5.1 Pricing teams within banks are concerned with pricing complex instruments, such as collateralised debt obligations (CDOs), financial options and other derivative instruments. The models used to price these instruments are used in a variety of ways. For example, they might be used to determine the levels of exposure in CDO tranches, or points at which option trades should be made. The models can also feed back into the regulatory valuation models discussed above.

3.5.2 Pricing for a general insurance company — more commonly known as premium rating — covers a wide range of insurance classes, from short-tail business, such as household contents and motor insurance, to long-tail business, such as employer liability. The key here is to arrive at a premium, which will not only be profitable, but which makes the best use of the insurer's capital. This means that the opportunity cost of the business must be modelled — what business cannot be written if this business is? This modelling involves employing a model office. This is not to say that additional capital cannot be raised. Indeed, capital issuance is desirable if particularly profitable opportunities arise. However, frequent issuance and repayment of capital can be costly.

3.5.3 Pricing for a life assurance company involves similar considerations — although practically all business is long term — with the additional complication that pricing of payments out for with-profits policies must also be included. With-profits policies do deserve additional consideration. Such policies provide (generally) low guaranteed rates of return, with the potential for higher (but smoothed) returns, subject to investment returns. For policyholders, this means good upside potential with limited downside risk. However, it also means that some investors will receive a return higher than that on the underlying investments, whilst the return for other investors will be lower — there is inter-generational cross-subsidy. For mutual insurance companies these are usually the only cross-subsidies (although, in extreme circumstances, bond holders can suffer if the creditworthiness of the insurer is damaged); however, for shareholders there is limited upside, but potential for significant downside. This is because with-profits policyholders would (ultimately) be expected to receive the bulk of any strong investment returns, whilst, if investment returns were poor, shareholders' funds would be needed to support guaranteed rates of return or previously awarded bonuses.

3.6 *The Pensions Regulator*

3.6.1 The Pensions Regulator, set up by the Pensions Act 2004, has substantial powers to protect the benefits of members of occupational pension schemes. These include the ability to appoint trustees and to freeze or wind up a pension scheme. The Pensions Regulator can also take action if there are problems with the Statutory Funding Objective or the Statement of Funding Principles. The methodology in the Occupational Pension Schemes (Scheme Funding) Regulations 2005 is general enough that it is up to the pension scheme trustees to ensure that pension scheme members are truly protected. However, in practice the trustees will generally rely on the advice of the Scheme Actuary when considering funding.

3.6.2 Whilst the funding valuation is important, the first area with which the trustees (and therefore, in practice, the Scheme Actuary) should be concerned is the buyout valuation — given that the Pension Protection Fund covers only a proportion of the benefits accrued, the cost of securing accrued benefits with an insurance company is paramount. The Scheme Actuary should ensure that the projected contributions will be sufficient to maintain solvency on a buyout basis, with an adequate degree of confidence over the projection period, given the proposed investment strategy. The funding valuation can then be assessed with reference to the minimum contribution rate acceptable for each asset allocation on the buyout basis.

3.6.3 The purpose of the funding valuation is to calculate the level of contributions required to maintain or achieve an acceptable level of funding with an adequate degree of confidence over a specified time horizon. As alluded to above, the funding valuation should also be considered together with the asset allocation. Provided that the contribution rates arrived at are at least as great as those calculated for the buyout valuation, then there is much more freedom in relation to the appropriate range of assumptions.

3.7 *Corporate Actuarial Advisers*

3.7.1 On the other side of the equation, the sponsor has to be aware of the impact which the pension scheme might have on the firm's core business. An important development in this regard comes with Bagehot, aka Treynor, (1972), who introduces the idea of the pensions-augmented balance sheet.

This is a concept where the values of pension assets and liabilities are added to the value of the firm's assets and liabilities, with the value of corporate equity being the balancing item. Following on from this, Sharpe (1976) introduces the ideas of a pensions deficit being a put option and of a surplus being a call option for the employer. The deficit as a put option is a particularly important concept. It comes about by recognising that a pension scheme deficit is money owed by the company. The firm has the option to default on the deficit in the same way in which it has the option to default on debt, and this option has value to the firm. The firm will only default on the deficit when it is insolvent (so the value of its liabilities exceeds that of its assets) and when a deficit exists (so the value of the pension scheme's liabilities exceeds that of its assets). The greater the deficit and the less financially secure the sponsoring employer, the greater the value of this put option.

3.7.2 In addition to the economic impact of pension schemes on their sponsors, there are the accounting impacts. For example, increasing pensions costs (in the accounting sense) affect the retained profits of firms. It is possible that losses could be so large as to reduce the free reserves to such a level that the ability to pay dividends is affected. Even if the situation does not reach this level, the pension scheme might adversely affect profitability or other key financial indicators.

3.7.3 The sponsor's actuarial advisers can help by analysing and mitigating the risks faced, both accounting and economic.

4. Risks Faced by Institutions

4.1 *Market and Economic Risk*

4.1.1 I define market risk as the risk inherent from exposure to capital markets. This can relate directly to the financial instruments held on the assets side (equities, bonds and so on), and also to the effect of these changes on the valuation of liabilities (long-term interest rates and their effect on life assurance and pensions liabilities being an obvious example). I include in this section related economic factors, such as price and salary inflation. Whilst these risks often affect different aspects of financial institutions — market risk tends to affect the assets and financial risk the liabilities — there is some overlap (for example, the use of bond yields to value long-term liabilities), and both can be modelled in a similar way.

4.1.2 Banks face market risk in particular in two main areas. The first is in relation to the marketable securities held by a bank, where a relatively straightforward asset model will suffice. However, this risk must be assessed in conjunction with market risk relating to positions in various complex instruments to which many banks are counterparties. It is important, both to include all of the positions, but also to ensure that any offsetting positions between different risks (for example, long and short positions in similar instruments) are allowed for.

4.1.3 Market risk for general insurance companies again relates to the portfolios of marketable assets held, but is also closely related to the assumptions used for claims inflation. Similarly, for life assurance companies and pension schemes, the market risk in the asset portfolios is linked to the various economic assumptions used to value the liabilities, in particular the rate at which these liabilities are discounted. For these two types of institution, market risk is arguably the most significant risk faced.

4.2 *Demographic Risk*

4.2.1 Demographic risk can be interpreted as covering a wide range of risks. I take it to include proportions married or with partners, age differences of partners, numbers of children (all for dependent benefits), lapses (for insurance products) or withdrawals (for pension schemes), pension scheme new entrant and retirement patterns, but, most importantly, mortality or longevity.

4.2.2 Mortality risk (the risk that a portfolio will suffer from mortality being heavier than expected) and longevity risk (the risk that a portfolio will suffer from mortality being lighter than expected) are significant factors for both pension schemes and life assurance companies. The former suffer only from longevity risk, but both risks are present for life assurance companies: term and whole-life assurances carry mortality risk, whereas general and pension annuity business carry longevity risk. Under certain conditions these risks can offset each other, although not perfectly, as discussed in Sweeting (2006b).

4.2.3 The International Actuarial Association (IAA) defines four types of mortality or longevity risk:

— level (uncertainty around the current average rate of mortality);
— trend (uncertainty around the future average rate of mortality);
— volatility (the risk that average rates will be different from the central expectation); and
— catastrophe (the risk of mortality being significantly different from the average because of a concentration of risk).

4.2.4 For practical purposes, these risks can be classified into two types: the risk of getting the average wrong; and the risk of getting the average right, but being unlucky. I discuss the modelling and mitigation of both later in this paper.

4.2.5 Lapses, withdrawals and pension scheme new entrants and early retirements are also of particular interest, because they are not necessarily independent, either from each other (for the pension scheme items) or from market and economic variables. For example, early withdrawals from a pension scheme are likely to be higher if a sponsor has to make employees redundant in the face of difficult economic conditions. This suggests that some demographic variables should be considered together with market and economic conditions.

4.2.6 However, it is worth noting that, whilst salary increases might be allowed for in funding valuations and for other planning purposes, the firm's obligation only extends as far as accrued benefits, which are not affected by these decrements.

4.3 *Non-Life Insurance Risk*

4.3.1 This is generally the main risk faced by firms writing non-life insurance business, the shorter time horizon for most general insurers meaning that market and economic risks are less relevant. It is the key factor in arriving at a correct premium rate for the business to be written and in arriving at the correct reserves for the business which has already been taken on. Two aspects need to be considered: the incidence of claims; and their intensity. In a way, incidence is not dissimilar to mortality risk, except that it can be assessed over a shorter time horizon, is often at a higher rate (for some classes of insurance), and can be much less stable from year to year. Unlike most mortality risks, the intensity of each claim is not necessarily the same from one claim to another. In some cases the maximum possible claim is known (for example, buildings insurance), whereas for others the maximum potential claim amount is unlimited (for example, employer liability insurance). Because the risks differ significantly from class to class, a variety of approaches is needed to model them correctly.

4.3.2 Another similarity with mortality risk is the fact that there are risks of getting both the average claim incidence and intensity wrong, and the risks of catastrophic loss. In non-life insurance, catastrophe risk occurs when a high intensity low probability event occurs, but can also occur if an insurer has an undue concentration of risks by some risk factor.

4.3.3 Although this risk is greater than market or economic risk for an insurer, in many cases it should be considered together with these risks. In common with some of the demographic risks, non-life insurance risk changes over the economic cycle, with claims in certain classes being higher in economic downturns. Considering claim levels together with economic and market variables would seem to be sensible here as well.

4.4 *Credit Risk*

4.4.1 When looking at credit risk, I am really considering only default risk. The other main aspect of credit risk — that is, spread risk or the risk of a change in value due to a change in the spread — is covered by market risk, and I do not consider it in this section. It is also worth noting that there is an element of default risk inherent in traded securities, and this, too, can be covered by market risk.

4.4.2 For banks, credit risk is often the largest risk, in the form of a large number of loans to individuals and to small businesses. Another major source of credit risk for many banks is counterparty risk for derivative trades. This is the risk that the opposite side to a derivative transaction will be unable to make a payment if it suffers a loss on that transaction.

4.4.3 Banks also model credit risk for many of the credit-based structured products which they offer, such as CDOs. These are portfolios of credits split into risk-based tranches and sold to investors. The tranche with the lowest rating (the equity tranche) suffers the effects of any defaults in the portfolio, and can have its value reduced to nil if defaults rise above a certain level; however, in return it provides the highest expected return. The expected returns fall and the certainties of repayment rise with each tranche until the highest tranche (AAA or similar), which pays out in full unless all other tranches have been exhausted by defaults. Complex credit models are needed to model the risk in these products accurately and to divide the tranches correctly.

4.4.4 Whilst credit risk in this context is separate from market risk, it is clear that these risks will be linked, together with economic risk. An economic downturn is likely to increase the risk of default, and, for particular quoted credits, an increased risk of default will be higher when the value of the equity stock is lower. It is important to consider these interactions together.

4.4.5 For general and life insurance companies, the main credit risk faced is the risk of reinsurer failure. This credit risk is clearly linked to longevity or, more likely, mortality risk for firms writing life assurance business, and to non-life insurance risk for those writing non-life business — when experience is worse, then claims from reinsurers are more likely to be made.

4.4.6 The greatest credit risk for most pension schemes is the risk of sponsor insolvency. This is potentially a significant risk, given that the sponsor's covenant can often be in respect of a significant portion of the pension scheme liabilities, and that the creditworthiness of many sponsors leaves much to be desired. An additional credit risk which many pension schemes now face relates to the financial strength of buyout firms. This is an important issue, and should be borne in mind by any Scheme Actuaries considering the buyout firm route.

4.4.7 An important point which actuaries should note is that credit risk is very similar to non-life insurance risk, in that there is both incidence (the probability of default) and intensity (the recovery rate). This suggests that many members of the actuarial profession are already working on problems similar to those faced by banks, insurers and pensions actuaries. Whilst some of the credit modelling approaches which I discuss later would be difficult to implement on an *ad hoc* basis, actuarial consultancies should be well able to develop consistent approaches to apply to all clients.

4.5 *Liquidity Risk*

4.5.1 Liquidity risk is a risk faced by all financial institutions. Illiquidity can manifest itself through high trading costs, a necessity to accept a substantially reduced 'fire sale' price for a quick sale, or the inability to sell at all in a short timescale.

4.5.2 When assessing the level of liquidity needed, the timing and the amount of payments, together with the uncertainty relating to these factors, are key. However, some illiquidity can actually be desirable — if an institution can cope with a lack of marketability in a proportion of its assets, then it might be able to benefit from any premium payable for that illiquidity. However, it must be borne in mind that some illiquid assets also have other issues, such as higher transaction costs or greater heterogeneity (real estate and private equity being key examples). Illiquid assets are also less likely to be eligible to count (or at least to count fully) towards the regulatory capital of a bank or an insurance company.

4.5.3 Assets can provide liquidity in three ways: through sale for cash; through use as collateral; and through maturity or periodic payments (such as dividends or coupons).

4.5.4 Banks are generally short-term institutions, but, whilst the direction of net cash flow is not clear, it is only in exceptional circumstances that the excess of outflows over inflows will amount to a large proportion of the bank's assets (a 'run on the bank'). This suggests that a degree of illiquidity is acceptable.

4.5.5 Life assurance firms, generally, have long-term liabilities and greater cash flow predictability than banks, so that a higher degree of illiquidity is appropriate. General insurance liabilities fall somewhere between bank and life assurance liabilities, in terms of both term and predictability, depending on the class of business, so that the appropriate level of liability is similarly variable.

4.5.6 Pension schemes are generally long-term institutions; however, a pension scheme which is cash flow positive (where benefits are still being accrued at a higher rate than they are being paid out) can afford to invest a higher proportion of its assets in illiquid investments than can a cash flow negative scheme (a closed, or even just a very mature, scheme). Having said this, even mature pension schemes or those in wind up can afford illiquidity in some of their assets: the extent depends on whether those assets match the liability cash flows and, in the case of a wind up, the extent to which the insurance company is willing to take on illiquid assets.

4.6 *Operational, Project and Strategic Risks*

4.6.1 If they are not correctly managed, these risks can be the biggest risks faced by any organisation. Operational failures have led to the ultimate demise of more than one firm. This is because poor control of operational risk allows other types of risk, such as market or credit risk, to be excessive.

On a less extreme level, operational failures or inadequacies can result in mistakes and inefficiencies which result in fines or lost business. Similarly, poor project implementation has been a source of shareholder value destruction in many firms across many industries, as has strategic mismanagement.

4.6.2 Many operational risks are risks to all firms, not just to financial institutions. Fire, fraud, loss of data, computer viruses, adverse publicity, terrorism, human error are just a few examples. However, there are also some groups of risk which are worthy of particular consideration.

4.6.3 Agency risk forms one group within operational risks. Broadly speaking, this covers the risk that one party appointed to act on behalf of another will, instead, act on its own behalf. Company managers acting for themselves rather than for the shareholders whose interests they are supposed to protect are the prime example. In banks, a key agency risk occurs if bonus systems create perverse incentives for traders — for example, if good results can give unlimited bonus potential, but the downside from poor results is limited, then this can create an incentive for traders to take too much risk. Within insurance companies, the fact that the actuaries responsible for regulatory reporting are remunerated by the firms, which might be more focussed on shareholder value than on policyholder security, gives another example of agency risk. For pension schemes, conflicts of interest are the main sources of agency risk, examples being company appointed trustees and actuaries acting on behalf of both the employer and the trustees. However, another key agency risk for pension schemes relates to the views of company management on investment policy. There is a risk that managers will aim to increase pension scheme equity weightings in order to improve apparent profitability (through the effect of the impact on the expected return on assets) and to reduce transparency (through the opportunity to use opaque actuarial techniques), as discussed by Exley *et al*. (1999).

4.6.4 Behavioural finance also gives a number of insights into potential operational risks. Taylor (2000) gives a good overview of the risks as they apply to the actuarial profession, and Nofsinger (2004) a good concise overview of the main behavioural biases. A particular bias to which those working in finance are susceptible is overconfidence. In particular, Jones *et al*. (2006) quote research which states that overconfidence is greatest for difficult tasks with low predictability which lack fast clear feedback — so this covers most actuarial work. Other aspects of overconfidence, such as the illusion of knowledge (the belief that more information improves forecast accuracy) or the illusion of control (the belief that greater control improves results), both have wide ranging implications for all areas of finance, particularly as the volume of information which is readily available is growing rapidly all the time.

4.6.5 Anchoring is another behavioural bias with clear actuarial implications. This occurs when decisions are made relative to an existing position rather than based solely on the relevant facts — the question asked is: “Given where we are, where should we be?”; but it should be: “Given the relevant facts, where should we be?” Jones *et al.* (2006) cite anecdotal evidence of under-reaction in the face of rapidly changing reserving information for general insurance. I can add anecdotal evidence of: a reluctance to change a pension scheme asset allocation too far from the existing position; a reluctance to update promptly a mortality basis in the light of revised mortality tables; and the time taken to adapt pension scheme valuation bases in the light of changing financial conditions in the 1990s. The rarity with which credit rating agencies downgrade a name by more than one notch suggests a similar inertia, as does the incremental way in which investment bank analysts change their ratings. In fact, the latter effect has been used to build trading models to exploit this anchoring effect.

4.6.6 Representativeness (making the assumption that things with similar properties are alike) and heuristic simplification (using rules-of-thumb) can also be a source of problems in all financial organisations, where the eventual level of risk might turn out to be very different to an initial estimation or approximation.

4.6.7 It is also worth considering the operational risks present in the systems themselves. For example, if the systems used for monitoring trading or credit risks in banks are inadequate, then this itself poses greater risks. If an insurer’s administration systems are not easily scalable, then a large change in premium rates relative to other insurers can result either in redundancies (if volumes fall) or in poor turnaround times and subsequent loss of business (if volumes rise). Generally, poor administration can similarly result in lost business for an insurer, and can even result in fines being levied for pension schemes if benefits are not paid correctly or enquiries are not dealt with in a timely manner.

4.6.8 Project risk encompasses all the risks inherent in a project. In the case of financial institutions, such projects may include the creation of physical assets, such as property development for investment purposes, or a new head-office building or computer system for the institution itself, but they may also include projects of a less tangible nature associated with the launch of a new product, expansion overseas, winding up or downsizing.

4.6.9 Strategic risk consists of the most important risks which an organisation faces; the possible future scenarios which would make a material difference (for better or worse) to its ability to achieve its main objectives or even to survive. Strategic risks are strongly influenced by people’s perceptions and their behaviour. Many strategic risks are related to forces which are dynamic, uncertain and interconnected, and therefore such risks often need to be managed as complex processes. There are often significant uncertainties which prevent complete definition of the risks in some areas, but there may still be scope for such risks to be managed to some extent.

5. Measuring and Modelling Risks

5.1 *Market and Economic Risk*

5.1.1 There are two broad types of model which can be used to assess market risk: deterministic and stochastic. At its most basic, deterministic modelling involves agreeing a single assumption for each variable for projection, and discounting to a single capital value. The single assumption might even be limited to the data history, for example monthly market returns over the last 20 years.

5.1.2 With deterministic approaches, prudence can be added only through margins in the assumptions used, or through scenario analysis. Scenario analysis is an extension of the deterministic approach, where a small number of scenarios is evaluated using different pre-specified assumptions. If historical data are being used, then this might involve adjusting the volatilities or the correlations of those data, or the length of history used. A criterion for success is determined and a scenario test is passed only if the criterion is met under each of the scenarios.

5.1.3 Stochastic modelling is a far broader category. It differs from scenario testing, because each run is drawn randomly from a distribution. In stochastic modelling, the first distinction is between bootstrapping and forward-looking approaches. For bootstrapping, all that is needed is a set of historical data for the asset classes being modelled. For example, monthly market returns for the last 20 years could be used. However, rather than simply using this as a single 'run' of data, modelling is carried out by selecting a slice of data randomly, in this case the results from a particular month. This forms the first observation. This observation is then 'replaced' and another month is chosen randomly. This means that a relatively small data set can be used to generate a large number of random observations.

5.1.4 The main advantage of bootstrapping is that the underlying characteristics of the data and linkages between data series are captured without having to resort to parameterisation. However, any inter-temporal links in the data, such as serial correlation, are lost, and there is an implicit assumption that the future will be like the past. This assumption is not necessarily valid, particularly for bond asset classes — if bonds have performed well because of falling yields, they are unlikely to perform as well going forward. Bootstrapping is also difficult if there is a limited history for a particular asset class.

5.1.5 When using a forward-looking approach, it is preferable to model a range of outcomes around a central 'best estimate' for each variable. Having said this, as Jones *et al.* (2006) point out, it is not necessarily clear what is meant by the phrase 'best estimate', and it is probably helpful to define this term in work using forward-looking stochastic analysis.

5.1.6 Forward looking approaches also require another decision to be made, and that is whether to use a factor-based or a returns-based approach. The former looks at the factors which determine the returns in a particular asset class and adopts an econometric view of returns, whereas the latter looks only at the returns themselves, and can be described as a statistical approach. For example, a factor-based approach to modelling corporate bonds would start by recognising that the returns on this asset class can be explained by movements in the risk free yield, movements in the credit spread, coupon payments and defaults. These can each be modelled and combined to give the return for the asset class. The interactions of these four factors and other financial variables would also need to be modelled. For example, defaults could be linked to equity market returns, in a way similar to that given by Merton (1974) with his contingent claims approach, where insolvency occurs if the value of the firm falls below the value of the outstanding obligations. With a factor-based approach, complex relationships between asset class returns arise because of the linkages between the underlying factors. Lee & Wilkie (2000) give an overview of a number of U.K. factor-based models.

5.1.7 The returns-based approach would start from the premise that understanding the drivers of an asset class does not improve the understanding of the returns structure, and modelling the returns directly gives superior results when compared with a factor-based approach (or comparable results with less effort). With a returns-based approach, the nature of the returns on each asset class must be modelled, as must the linkages between returns. A basic approach would be to assume that asset class returns are lognormal and that correlations adequately measure the linkages between them. However, there are particular issues with such an approach, particularly if the tails of the aggregate returns distribution are being analysed; however, if confidence in the underlying data is low, or the measure of central tendency is of more interest than the extreme results, then correlated normal distributions may suffice.

5.1.8 If the tails of a distribution are the focus of the analysis, then skew and kurtosis in the distributions of the individual asset classes (the marginal distributions) are relevant. Leptokurtosis (fat tails) is a particular issue in financial data, and can result in an underestimation of risk if ignored. Leptokurtosis can be modelled by using distributions other than normal distributions, such as Student's t-distribution, Lévy processes, combinations of other distributions, or other approaches, as discussed by Lee & Wilkie (2000) and Dowd (2005); through the use of an autoregressive conditional heteroskedastic (ARCH) model, as used by Wilkie (1995); through allowing for returns to be randomly drawn from different regimes, each with its own distribution, as described by Harris (1999); or through assuming random large moves in returns (jump-diffusion processes), as described by Merton (1976). However, parameterisation of skew and kurtosis is not straightforward. The problem is that there are, by definition, fewer observations in the tail of the distribution, so that skew and kurtosis are difficult to assess and can be unstable over time — much more so than the variance.

5.1.9 The marginal distributions are clearly important, but so are the links between them. Correlation gives one measure of the linkages, but assumes that the relationships between the marginal distributions are constant, whatever the levels of those distributions. It is only appropriate if the marginal distributions are jointly elliptical. Other measures of association, such as Kendall's tau and Spearman's rho, which do not depend on the marginal distribution, might be more appropriate. These are known as rank correlation coefficients.

5.1.10 However, all of these measures assume the same degree of association whatever the levels of the marginal distributions. If the degree of association is greater at extreme values of the marginal distributions (as it often is), then the above approaches understate the tail risk in the aggregate distribution. One solution is to use copulas. These functions describe the dependence of a number of uniform distributions; the level of dependence being allowed to change depending on the value of the uniform distribution. Copulas also allow the separation of the level of dependence from the marginal distributions of the various factors, since copulas describe the relationship between (0,1) uniform distributions. Dorey & Joubert (2005) give an overview of copula usage, whilst Cherubini *et al*. (2004) give more detail on modelling a wide range of copula functions. However, although there have been a number of papers on the subject of copulas, their use still appears to be limited. This is not least because assessing the dependency structure is not straightforward. Since the dependency structure is largely defined by what happens in the tails, and, as always, the tail of the distribution contains only few observations, the form of the copula function is not always clear. At one end of the scale visual inspection of normalised data is a possibility. This involves transforming the marginal distributions of pairs of variables to (0,1) distributions, plotting the results, and attempting to assess the relationship visually. Cherubini *et al*. (2004), on the other hand, suggest a maximum likelihood function approach. A compromise might be to map the pairwise data, as for the visual inspection approach, but then to grid the data into (say) 100 squares, and to compare the number of observations in each square with the number of observations in a reference distribution, perhaps using a chi-square test to determine the level of statistical significance.

5.1.11 Even if a returns-based approach is used, there may be some assets for which a factor-based approach remains appropriate. Derivatives, particularly options, where the relationship between the price of the instrument and that of the underlying is complex, provide a prime example.

5.1.12 Despite being simpler than a factor-based approach, even returns-based modelling might be computationally demanding if a large number of assets or asset classes are required. One way of reducing the computational intensity, if normally distributed returns are assumed, is to use the principal components approach. This is particularly useful if trying to model the returns on, say, a number of bonds, where a small number of factors explain most of the movement in all of the bonds. The principal components approach describes the historical return difference from the mean for each asset class as a weighted average of a number of independent volatility factors. Whilst the total possible number of factors is equal to the total number of variables, the principal components approach offers the opportunity to use only the factors which together explain an acceptably high proportion (say 95%) of the historical volatility. Rebonato (1996) describes principal components in more detail, whilst Willmott (2000) gives a simple approach to calculating the factors.

5.1.13 For any forward looking approach, it is interesting to consider the extent to which the projections are market consistent. At the most basic level, this involves comparing the interest rate assumptions with those implied by the appropriate yield curve; however, it is also possible to derive implied volatility expectations and even implied correlations from option prices. This is not to say that these market consistent figures are perfect — the impact of institutional demand and supply on long-dated fixed-interest securities is well known, and implied volatility 'smiles' demonstrate the care which must be taken when using this parameter — however, if any parameters differ from their market consistent counterparts, then it is important to recognise that there is a difference, and to have sound reasons for any deviation.

5.2 *Interest Rate Risk*

5.2.1 One particular economic or financial variable which is of specific interest to pension schemes and life assurance companies is the interest rate, since it is used to discount long-term liabilities. The rate may be a risk-free rate or a swap or bond-based rate. This means that it is important to be able to model the interest rate consistently with other financial and economic returns. If a factor-based model is being used, then the interest rate may well be modelled already as part of the projection process, the projected interest rate curve frequently being used as a basis for the projection of other variables; however, this will not be necessarily the case for a returns-based model.

5.2.2 One approach is to calculate the interest rate by calculating the duration and the convexity of bonds whose returns are modelled, and by calculating the change in interest rate implied by the simulated return on the bonds. A similar approach can be used for credit spreads if required.

5.2.3 It is also possible to bypass the modelling of interest rates completely by calculating the value which the liabilities would have had with historical rates of interest, by calculating the correlation of the liabilities with the assets, and then by projecting the liabilities like another asset class.

5.2.4 If the interest rate maturity structure is important — which it often is for the discounting of liabilities — then a number of interest rate models are available. A relatively straightforward approach is to treat interest rates as being normally distributed, and modelling the various spot rates as correlated normal distributions. In this instance, the effort required can be reduced by using the principal components approach detailed above.

5.3 *Demographic Risk*

5.3.1 Mortality/longevity is almost always dealt with on a deterministic basis. However, the risks posed by mortality are such that a stochastic approach is beneficial. As mentioned earlier, there are two types of risk: the risk of getting the average wrong; and the risk of getting the average right, but being unlucky.

5.3.2 The risk of getting the average wrong can be modelled using a model such as that described by Lee & Carter (1992), the *p*-spline model described by Eilers & Marx (1996) or the two-factor model described by Cairns *et al.* (2006). An even more straightforward (though less robust) approach is possible if deviations from trend mortality are assumed to be normal, correlations between the deviations across ages and business classes are calculated, and correlated normal distributions of future mortality are projected stochastically. This approach is used in Sweeting (2006a) to assess basis risk in survivor swaps between different reference ages and populations. Having said this, the uncertainty surrounding future mortality patterns is such that these mortality projections are particularly sensitive to model risk.

5.3.3 Cohort effects in mortality projection appear to be significant — Willets (2004) shows that allowing for the year of birth is crucial in understanding mortality. This suggests that such effects should also be allowed for in stochastic mortality modelling, although models which allow for this additional complication are relatively young.

5.3.4 The risk of being unlucky is partly a binomial-type risk. Given a number of individuals with associated mortality probabilities, the range of outcomes either side of that expected is relatively straightforward to calculate, albeit with a normal approximation to the binomial distribution. It can also be shown that this risk diminishes quickly as the number of lives under analysis increases. However, the key assumption in this analysis is that the risks are independent, and this is not necessarily the case. For example, concentrations of risk by geography, lifestyle or even occupation may lead to the 'bad luck' risk being higher than allowed for in simplistic calculations. On the life assurance side, this can be modelled as a catastrophe risk, looking at worst case scenarios for particular types of concentration, and attaching probabilities to these events; pensions-based analogies are less obvious, though lifestyle related or occupation related concentration risks may still occur. However, in the FSA's 2005 review of ICAS it notes that catastrophe risk for firms writing long-term business is often approximated due to limited good data.

5.3.5 Assumptions on the age and the number of dependants rarely features highly in a set of valuation assumptions, and changes to these assumptions are unlikely to be the largest cause of a change in the valuation results. However, for pension schemes in particular, changes in this assumption can make a noticeable difference in the valuation results, and it is worth reviewing the appropriateness of the assumption used, with particular reference to the dependants' benefits set out in the pension scheme rules. Given the likely stability of this assumption, though, it is doubtful that it justifies stochastic modelling.

5.3.6 Pension scheme withdrawals — the transition of individuals from active member to deferred pensioner — are less likely to be stable. In particular, a link between financial conditions (and especially the financial strength of the employer) and withdrawal rates is likely. One issue here, as far as stochastic modelling goes, is that of data volume. Most pension schemes will not have sufficient membership to build a statistically useful model of withdrawals; however, actuarial consultancies should have access to these data for a large number of schemes, and should be in a position to arrive at a suitable model. Another issue, though, is that of materiality. Given the rules on the preservation of pensions, profit to the pension scheme arising from early withdrawals will generally be small. Finally, it is worth remembering that withdrawals will not affect the buyout value of the liabilities, only valuations where salary increases are actually allowed for.

5.3.7 Early retirements, ill-health retirements and new entrants suffer from the same issues, including the link with economic factors, although these decrements are much more influenced by pension scheme rules and employer and/or trustee discretion.

5.3.8 Insurance policy lapses are also linked to economic and financial conditions. At a most basic level, policies offering a smoothed investment return might be more prone to lapses if market returns have been poor (subject to market value adjustments). However, lapses from investment policies might also increase in times when the economy is weak, when investors need money which has been invested previously. Modelling of the link between these types of lapses and economic variables would be helpful. Similarly, banks find that fixed rate mortgages are more likely to be repaid early if interest rates fall. This type of lapse should also be modelled consistently with financial and economic assumptions.

5.4 *Non-Life Insurance Risk*

5.4.1 As discussed above, general insurance claims contain two aspects: incidence and intensity. There are two broad groups into which insurance classes can be placed. The first group is those classes where there is a relatively high frequency of claims, such as motor or household contents insurance. This produces a significant volume of data, which is relatively straightforward to analyse and model. The most common way to model the incidence of claims in these classes of insurance for rating purposes is to construct multi-way tables covering all of the risk factors, so that the proportion of claims for any given combination of risk factors can be calculated. For example, the risk factors for motor insurance would include items such as post code, vehicle make, and whether the vehicle is garaged overnight.

5.4.2 Intensity for premium rating in these classes of insurance is generally modelled through multiple regression approaches. Clearly, if the distribution of claim amounts is not normal (and for many classes it will not be), ordinary least squares regression is inappropriate and an alternative approach must be used.

5.4.3 An alternative rating approach could use a stochastic projection approach, assuming a binomial or Poisson distribution for the incidence and an appropriate statistical distribution for the intensity, in order to arrive at a premium rate which would give an acceptable return on capital. However, given that one of the main drivers of premium rates is the rate charged by the rest of the market, the premium calculated by such an approach would probably not be charged. It might, though, be useful in helping to determine the areas where business might be written to best maximise the return on capital. It would also allow the link between claim levels and investment strategy to be modelled.

5.4.4 When looking at reserving approaches, the chain ladder method is still the dominant approach. This considers the claims which have already been reported, and uses the historical pattern of claim development to project reported claims forward. One augmentation to this approach is to treat the development as stochastic, as demonstrated by Zehnwirth (1997). A potential advantage of this approach is that is allows the linkage of claim levels to economic, market and other variables. However, it does involve additional complexity and computational intensity, and, given the large number of assumptions required, the degree to which the results any more accurate or useful than deterministic approaches is arguable.

5.4.5 Another way of assessing the ultimate claim level on any unearned premium is to consider the aggregate historical loss ratio on premium earned. The efficiency of this approach can be improved if the business mix changes significantly, and this is allowed for in the loss ratio. A related approach used for reserving for outstanding claims is the Bornhuetter-Ferguson method, which adjusts the ultimate loss ratio for claims reported to date.

5.4.6 The second group of classes is that where the frequency of claims is very low and the size is greatly variable. This generally means catastrophe insurance of some variety. A typical example would be household buildings excess of loss insurance. Here, the approach used would be to consider a range of scenarios for, say, hurricane or flood damage, to calculate the maximum potential loss and to attach probabilities to those scenarios. The scenarios modelled tend to allow for the geographic concentration of risk by post code. In this context, catastrophe risk refers, not only to an exceptional event, but also to the concentration of risks.

5.4.7 This second group is often a type of risk which is reinsured, and reinsurers providing (in particular) excess-of-loss cover face the same modelling problems to a greater extent. If possible, it is preferable for the reinsurer to have details of the underlying risks, so that these, rather than the excess, can be modelled. This is also important in order to ensure that reinsurers do not have any excessive concentration of risk. However, for reinsurers offering retrocession, this might not be possible.

5.4.8 The modelling above is needed for pricing and for calculating unearned premium reserves. Modelling is not often needed for catastrophe reinsurance incurred-but-not-reported (IBNR) reserves — catastrophes are generally well enough reported that claims are highlighted in the press.

5.5 *Credit Risk*

5.5.1 The purpose of modelling credit risk is twofold: how likely a credit event is to occur; and the extent of loss which will be incurred. In this way it is similar to the analysis of actuarial risks, to the extent that both incidence and intensity need to be modelled.

5.5.2 As mentioned earlier, the modelling of the probability of default can be regarded as being particularly similar to the modelling of general insurance risks: high quality credit risks are analogous to low-probability events such as catastrophe insurance; whereas low quality credit risks resemble higher frequency lines, such as motor insurance.

5.5.3 One measure of credit risk is the credit rating given by an agency. If all losses were assumed to be complete and credit ratings were assumed to map directly to default probabilities, then credit ratings could be used as a proxy for credit risk. However, although ratings and default probabilities are linked, as can be seen in the reports produced by the various agencies, one cannot be translated directly into the other. Part of the reason for this is that credit ratings are long-term assessments, considering the position of an entity over an economic cycle. This means that, whilst the risk for each firm will change over the economic cycle, the credit rating will not. Depending on the reason for assessing the default probability, this may be inappropriate. It is also worth noting that the credit ratings do not give a high level of granularity — the number of available ratings is small compared with the number of rated firms. Having said this, credit ratings are unavailable for the vast majority of firms. Obtaining a rating is not free, and, given that the main purpose of being rated is to reduce the cost of borrowing, the level of borrowing needs to be sufficient to justify the expense of obtaining a rating. A further issue is that different agencies can also produce different ratings for the same firm, particularly financials, as highlighted by Morgan (1997).

Finally, the assumption of total loss is overly conservative. For example, de Servigny & Renault (2004) quote ultimate recovery rates of nearly 40% for subordinated debt and nearly 90% for bank debt.

5.5.4 It is possible to try to build a scoring model along the same lines as those used by the rating agencies. If this is done, the first decision which needs to be made is whether the model is intended to reflect the risk over the economic cycle (as with the rating agencies) or over a shorter time horizon. The choice of approach will be determined by the use to which the model may be put. For example, in calculating the Pension Protection Fund risk-based levy, a long-term approach is probably more appropriate; however, a pension fund assessing the strength of the employer covenant might prefer to take account of the risk over the short term. This choice relates to both the calibration of the model and the inputs used for scoring.

5.5.5 Considering the allowance for accounting data, the most familiar (although not the first) approach is the Z-score used by Altman (1968). This uses a technique known as discriminant analysis. Each firm has a number of characteristics (such as financial ratios). The object of discriminant analysis is to find the mix of characteristics which best discriminates between defaulting and non-defaulting firms.

5.5.6 However, the Z-score does not give a probability of default. Two similar approaches which do are logit and probit regressions. These both start by again considering numerical characteristics of firms together with coefficients for these characteristics, but then involve translating the resulting score (the characteristics multiplied by the coefficients, then summed) to a probability between zero and one. The logit approach does this by taking the exponential of the score and dividing by one plus the exponential of the score; the probit approach assumes that the probabilities are normally distributed, and uses the score to derive the distribution function for the standard normal distribution. Such models for discrete choice are discussed in texts such as Greene (2003), and can be applied using standard statistical packages such as R.

5.5.7 The logit and probit approaches can both be described as parametric; however, non-parametric approaches also exist. The first of these is the k-nearest neighbour approach. Firms are classified by considering the characteristics of the k firms nearest to them in terms of a number of explanatory variables. The second approach involves the use of support vector machines, introduced by Cortes & Vapnik (1995), where borrowers are classified as good or bad, and are mapped by a number of variables. The borrowers are then grouped according to each variable by a line (or, if more than two variables are considered, a surface), so that new borrowers can be similarly classified according to their risk factors. Both of these are discussed in detail by de Servigny & Renault (2004).

5.5.8 Having considered the probability of loss, the extent of loss must also be assessed. This too has analogies with general insurance, being similar to the intensity of losses in that area. In practice, the recovery rate rather than the proportion lost is modelled in credit risk. Two distinct measures of recovery are the price after default and the ultimate recovery. The former is a short-term measure and the latter has a longer time horizon. According to Bahar & Brand (1998), the ultimate recovery is often significantly larger than the price after default, offering an internal rate of return of some 20% for those willing to be patient. A number of factors can affect the expected recovery. In particular, those noted by de Servigny & Renault (2004) are:

— seniority of the obligation;
— industry;
— point in the economic cycle;
— degree and type of collateralisation;
— jurisdiction; and
— composition of creditors.

5.5.9 The impact of these factors is often modelled using historical data. The results can be translated into a deterministic expectation of the recovery rate applied to all debt; or stochastic recovery rates can be modelled, allowing for the volatility of recovery rates calculated from historical data as well as from their expected values. If the recovery rate is to be parameterised, a distribution bounded by zero and one, such as the beta distribution, is most appropriate. However, non-parametric approaches using kernel estimation are useful for more complex distributions, including bimodal or polymodal distributions. Kernel estimation involves calculating a smoothed data point from the nearby raw data points. It also allows a data point to be interpolated where no raw data point exists. The weights of the raw data points are determined by the specification of the kernel function, whilst the degree of smoothing is determined by the 'bandwidth'.

5.5.10 A number of kernel functions exist, but two commonly used types are the Gaussian (or normal), which is bell shaped, and the Epanechnikov, which is dome shaped. The former uses all data points, whilst the latter only uses those within the dome. Kernel functions are discussed in more detail by Greene (2003) and others.

5.5.11 Kernel modelling is a useful non-parametric tool in many other situations, and I refer to it a number of times later in this paper.

5.5.12 A different approach to modelling credit risk is to use an equity-based approach, such as the contingent claims model of Merton (1974). This is more appropriate for larger borrowers with liquid, frequently-traded equity stock, since an accurate number for the volatility of the corporate equity is needed. The core assumption with this method is that the value of the firm, as a whole, follows a lognormal random walk, and that insolvency occurs when the value of the firm falls below the level of debt outstanding. This means that the debt is being treated as a call option on the firm. Many subsequent authors have expanded on Merton's initial insight, including additions, such as: an allowance for coupons by Geske (1977); more elaborate capital structures by Black & Cox (1976); and negotiation between equity holders and bond holders by Anderson & Sundaresan (1996). It is worth noting that, in his initial paper, Merton concentrated on debt pricing, but his approach has been used far more widely for calculating predicted default rates, notably by KMV.

5.5.13 It is also worth noting that equity-based approaches can be used to calculate both the probability of loss and the extent of loss, and so to provide a complete credit risk framework.

5.5.14 Credit risks are often assessed together in credit risk portfolio models (CRPMs). Depending on the assumptions for the underlying distributions of the risks, it might be possible to aggregate the results for the individual credit risks analytically; however, if this is not straightforward, then stochastic simulations are required. These are often used by banks for the pricing of instruments such as CDOs, and are of particular interest when it comes to modelling credit risk for portfolios of loans under Basel II.

5.5.15 One issue with such models is that, whilst they model the credit risks in a portfolio sense, they ignore other risks which will be closely linked to credit risk, and most institutions are exposed to a range of risks, of which credit risk is only one. In particular, the market risk of any asset portfolio may well be linked to the credit risks. Pension schemes provide a prime example. They generally have a disproportionally large exposure to the credit risk of the sponsoring employer, but are often subject to significant market risks which are not independent of the credit risk borne. The relationship between various credit risks and between credit and other financial risks therefore needs to be considered — it seems a shame if credit and market risks have each been measured independently using sophisticated methods, only to link them using a crude measure, such as the correlation between the two risks. Modelling credit risk and market risk together and consistently would seem preferable. Correlations and copulas can be used, as described above, but it is worth restating that the former can only be used if the marginal distributions are jointly elliptical (which, for credit risks, they will often not be). Copula distributions are certainly more robust in this regard.

5.5.16 Another fundamental way in which credit risk and market risk are linked is when the credit risks have duration, such as with long-term fixed-rate loans or corporate bonds. In this case, valuing the credit risk involves linking the risks to a yield curve and modelling the yield curve risk as well, as discussed in the market risk section above.

5.6 *Liquidity Risk*

Measuring liquidity risk involves analysing the potential outflows and ensuring that the assets held are sufficiently liquid or provide sufficient cash flows to provide the required liquidity with an acceptable degree of confidence. This means that a maturity schedule is needed. However, given the uncertainty surrounding the timing and/or the amount of any outflows, a deterministic analysis might not be sufficient. It is also worth noting that liquidity risk is not independent of other risks. For example, if there is a downturn in the economy, then the value of liquid assets may well fall as well. Such a scenario might also be of the sort where additional liquidity is required, for example if the level of insurance claims rises or additional margin payments on derivative contracts are required. These linkages should be allowed for, either through scenario analysis allowing for these changes as well as the liquidity of the portfolio, or preferably through stochastic modelling of the liquidity requirements and the available liquid assets together, as part of the more general stochastic asset liability analysis.

5.7 *Operational, Project and Strategic Risks*

5.7.1 Many of these risks are difficult to identify and to quantify, let alone to model. Whilst scenario analysis is one approach, it is perhaps best to try to identify those instances where operational failures might cause large losses, and to modify the operational settings in those areas.

5.7.2 Behavioural risks are amongst the hardest operational risks to control, partly because of the prevalence of unintended consequences. An assessment of behavioural impacts on all aspects of actuarial work, and ways of mitigating the effects — not just the reserve estimation process, as suggested by Jones *et al.* (2006) — is desirable, building on work such as that of Taylor (2000).

5.7.3 One aspect of operational risk where modelling is appropriate is in the link between premium rates and new business volumes for insurance companies. Premium rates are likely to have an impact on the volume of new business, particularly for asset classes where the demand function is stepped (at some point a very small change in a premium results in a very large change in demand). Modelling premium rates in the context of competitors' rates would also seem sensible. There are a number of economic models which capture the appropriate changes in demand, whether they assume perfect or near-perfect competition (as for many broker marketed life assurance products), oligopoly (as for bulk annuity business), monopolistic competition (for highly differentiated products), or some other form. This modelling is also important in the context of maximising the profitability for each insurance class and the return on capital for the insurer as a whole. On a more dynamic level, agent-based models of competitive dynamics — effectively stochastic games — can be used to similar effect, and often with greater success.

6. Assessing Scenarios

6.1 *Introduction*

Once risks have been modelled, the results must be assessed. This is true whether considering a project to be initiated, a product to be launched, or an asset allocation to be adopted. Such analysis will generally involve trying to maximise (or minimise) one variable, subject to a maximum (or minimum) permissible level of another variable. For example, the goal might be to maximise profit subject to a maximum permissible probability of loss; or to minimise the level of pension scheme contributions subject to a minimum probability of maintaining a particular level of funding. This means that measures of risk and return need to be agreed. It also means that, particularly in the context of market risk, optimal combinations of assets need to be highlighted.

6.2 *Risk Measures*

6.2.1 When looking at the criteria for assessing the output of a financial model, it is worth considering the part of the distribution which is of most interest. In particular, if the focus of the analysis is on extreme events (i.e. the tails of the distribution) rather than on the results in average market conditions (i.e. the body of the distribution), then different criteria are appropriate.

6.2.2 The standard deviation of returns is often used as a broad indication of the level of risk being taken, and is used in a number of guises. Tracking error is the standard deviation of excess returns relative to the performance benchmark for an active manager, and this, itself, often feeds into the information ratio, the ratio of average excess returns to the tracking error.

6.2.3 The standard deviation is also commonly used in pension scheme analysis when comparing the efficiency of different asset allocations. Here it may be used, both to derive the set of efficient portfolios (through mean-variance optimisation) and to highlight the risk of the actual and proposed asset allocations.

6.2.4 Using the standard deviation in a dimensionless measure, such as the information ratio, is potentially useful as a ranking tool, although there are those who question the usefulness of the information ratio, because it could lead to closet tracking. The standard deviation also has value as a broad measure of risk, since it is relatively straightforward to calculate for a wide number of financial risks; indeed, and if the correlations are known, it is straightforward to calculate an aggregate standard deviation without having to resort to stochastic simulations (although, unless the underlying distributions are normally distributed, this information cannot be used to derive percentile statistics). However, it is arguable that the standard deviation is less than clear as a measure of risk in its own right. If a particular asset allocation gives an expected funding level of 100% with a standard deviation of 10%, how clear is it to clients (or consultants) what the 10% means? Clearly it is better than 11% and worse than 9%, but, beyond this, it is less useful.

6.2.5 The standard deviation is similarly opaque if extreme events are the concern. It requires additional calculations to be carried out to show the risk of extreme events (these calculations are described below), but it also gives misleading results if the underlying distributions are skewed. Another way of thinking of this is that a symmetrical risk measure is only useful if the underlying distributions are symmetrical. Similarly, the standard deviation underestimates risk if the underlying distribution is leptokurtic. For extreme event analysis, it is necessary to move away from measures of dispersion to measures of tail risk.

6.2.6 A commonly used measure in the world of finance, to the extent that it is the measure of choice in most banking organisations, is the value at risk (VaR). It can be defined as the maximum amount which will be lost over a particular holding period with a particular degree of confidence. For example, a 95% one-month VaR of £250,000 tells us that the maximum loss for one month is £250,000 with a 95% level of confidence. VaR can also be expressed in terms of standard deviations, so, a two-daily sigma VaR of £100,000 tells us that the maximum daily loss is £100,000 with a confidence level of around 96%, if returns are assumed to be normally distributed. The VaR can also be given as a percentage of capital, so that a 95% one-month VaR of −3.2% tells us that −3.2% is the maximum loss over a one-month period with a probability of 95%.

6.2.7 VaR also feature in many pension scheme asset allocation presentations, being calculated over increasing holding periods and presented as the percentiles in a 'funnel of doubt'.

6.2.8 VaR has a number of advantages, as outlined by Dowd & Blake (2006). First, it provides a measure of risk which can be applied across any asset class, allowing the comparison of risks across different portfolios (such as equity and fixed income). Other measures are more closely tied to particular asset classes: duration and fixed-income being prime examples.

6.2.9 VaR also enables the aggregation of risks, taking account of the ways in which risk factors are associated with each other. It also gives a result which is easily translated into a risk benchmark, so judging 'pass' and 'fail' are straightforward. Finally, VaR can be expressed in the most transparent of terms, 'money lost'.

6.2.10 There are broadly three ways to calculate VaR: parametrically, empirically and stochastically. A parametric calculation of VaR simply involves calculating the critical value of an appropriate distribution based on the appropriate mean, standard deviation and (if relevant to that distribution) higher moments; an empirical calculation simply uses raw or adjusted historical data to calculate the VaR; and stochastic calculation uses either bootstrapping or forward-looking simulation to create a large number of scenarios from which to calculate the VaR.

6.2.11 However, VaR is not always appropriate. If it is being used to determine the amount of capital which must be held (thus limiting the probability of insolvency to that used in the VaR calculation), or to determine some other trigger point at which action must be taken, then no assessment of the events in the tail are needed; however, in many instances, it is useful to know something about the distribution of extreme events. VaR gives only the point at which loss is expected to occur with a predetermined probability, and gives no indication of how much is likely to be lost if a loss is incurred. Parametric VaR is also potentially misleading if the assumed distribution does not reflect the risks being borne. A prime example is if normality is assumed for risks with leptokurtic or skewed outcomes. Furthermore, if there is significant tail dependence between risks, and correlations are used to describe the dependence structure rather than copulas, then there is a risk that a VaR calculation will underestimate the risk, since it involves an assessment of extreme scenarios. A further criticism of VaR by Dowd (2005) is that the VaR of the total portfolio does not necessarily equal the sum of the sub-portfolio VaRs. Dowd (2005) also points out that, if VaR is used in regulation, then it might encourage similar hedging behaviour for similar firms, leading to systemic risk.

6.2.12 The reciprocal of VaR is the probability of ruin. Whereas VaR sets the level of confidence (usually 95%) and then considers the maximum loss, the probability of ruin looks at the loss which would bring insolvency, and looks at how likely this is. Ruin probabilities suffer from many of the limitations of VaR. However, provided that they are used to assess the probability of insolvency (rather than the capital needed to meet a particular probability of insolvency), the assessment of loss, if it occurs, is not such a high priority — if ruin occurs, the extent of ruin is, at most, a second order consideration.

6.2.13 A measure of extreme risk related to both of these measures is the expected shortfall. This measure has a wide number of other names, including, according to Dowd (2005), expected tail loss, tail VaR and tail conditional expectation. There are also a number of expressions used for evaluating expected shortfall, although they generally reduce to the same formula. Expected shortfall can be defined as the probability of loss multiplied by the expected loss, given that a loss has occurred.

6.2.14 In fact, VaR and the expected shortfall are both special cases of a group of functions known as spectral risk measures, described by Acerbi (2002). These functions weight the level of loss by a risk aversion function.

6.2.15 One issue with all of these measures is the time horizon or holding period used in the calculation. For a liquid security, in an environment where the measure is being used to assess the risk of holding particular positions, a shorter holding period can be used, since positions can be closed out quickly; however, for analysis including less liquid assets, such as loans to small businesses for a retail bank, or holdings in illiquid assets such as property or private equity, a longer time horizon is more appropriate.

6.2.16 It is also worth noting that scaling of risk measures from one holding period to another (such as monthly to annual) is not always possible, particularly if the underlying statistical distribution is non-normal. Also, if there is non-linearity in any of the investments being analysed — options being the prime example — then separate analyses are needed for different holding periods.

6.3 *Return Measures*

6.3.1 Once the measure of risk has been determined, the measure of return must be agreed. In this way strategies can be compared, and the results narrowed down to a set of efficient opportunities. With these two measures we can answer two questions: "What do we expect to happen; and what are the risks of this not happening?" This suggests that the return measure is a measure of central tendency.

6.3.2 Return measures, though they differ across types of institution, are generally more straightforward than risk measures, because they are often linear, additive measures. The expected return on a portfolio invested in equities and bonds is simply a linear combination of the return on an equity portfolio and the return on a bond portfolio. Expected values have a key role in this kind of two-dimensional analysis, in that they are fundamental to the concept of mean-variance optimisation proposed by Markowitz (1952).

6.3.3 A type of return measure which relates to the previous section is the generic risk-adjusted performance measure. There are a large number of these, including:
- the return on risk-adjusted assets (RORAA);
- the risk-adjusted return on assets (RAROA);
- the return on risk-adjusted capital (RORAC);
- the risk-adjusted return on capital (RAROC); and
- the risk-adjusted return on risk-adjusted capital (RARORAC);

the final three of which are the most common, in banking circles at least, according to Matten (2000). These seek to embody the risk being taken in the return measure itself. The Sharpe ratio could be regarded as a more simplistic version of these measures.

6.3.4 It is worth noting that expected returns are, however, difficult to estimate. This means that the usefulness of the above statistics, which are sensitive to the expected return parameter, is limited.

6.4 *Optimisation*

6.4.1 The classic approach to finding an optimal asset allocation is mean-variance analysis. This involves finding a set of portfolios for which no higher expected return is possible, given a particular level of risk, as measured by the variance or the standard deviation of the portfolios. If a simple single-period optimisation is being carried out and the asset classes have correlated normal distributions, then stochastic projections are not needed — the mean and the variance of any asset allocations can be calculated analytically from the means, standard deviations, correlations and weightings of the underlying asset classes.

6.4.2 If a multi-period analysis is needed to allow for payments in or out, or if there are other complications, then stochastic simulation is required. However, mean-variance analysis is inappropriate if the distributions of the asset classes are not jointly elliptical (broadly, if the links between the distributions are not well described by the correlation). If they are not, then similar approaches where risk is measured by VaR or expected shortfall might, instead, be appropriate.

6.4.3 Even if all of the criteria for mean-variance (or similar) analysis are met, there are a number of issues with this approach. One of the foremost issues is that it can lead to efficient portfolios which appear to be unrealistic or impractical. One example is when the two asset classes have similar expected volatilities, have similar correlations with other asset classes and are highly correlated with each other, but one has a slightly higher expected return than the other. In this case, the asset class with the higher return will tend to feature in the efficient frontier, whereas the asset class with the lower return will not. Another example is where an asset class appears in a far higher concentration in the efficient frontier than would seem prudent or would be acceptable to clients, either through having low correlation with other assets or through having a high expected return, perhaps in combination with a low expected volatility.

6.4.4 One solution to this issue is to choose manually more ‘acceptable’ alternatives which lie close to, but not on, the efficient frontier; another is to place upper (and perhaps lower) limits on the allocations to ‘difficult’ asset classes. Both of these approaches seem too subjective. A third approach is to consider asset classes in broad groups, so optimising using global equities rather than regional equity weights. Whilst this results in subjectivity in arriving at the allocation within such a group, a bigger issue is that it provides no solution for stand alone asset classes such as commodities.

6.4.5 Another approach is the Black & Litterman (1992) approach. This is an approach where the expected returns are such that, given the expected volatilities and correlations, the asset allocation of the market is efficient.

6.4.6 This solves many of the issues, but one additional issue remains. This is that the portfolio in which you would invest to give the maximum expected return is always an investment in a single asset class. One solution which does address this issue is resampling.

6.4.7 The first stage in the resampling approach involves calculating the asset allocations for a single efficient frontier, based on a relatively small number of simulations. This process is then repeated to give a large number of candidate efficient frontiers. The asset weights for each point on the resampled efficient frontier are then calculated as the averages of the asset weights for the same points on the candidate efficient frontiers.

6.4.8 Michaud (1998) describes a patented bootstrapping version of this approach using historical data, but the approach can also be implemented using forward-looking simulated data.

6.4.9 This approach does address all of the issues discussed above. However, there are a number of issues with resampling. On a practical level, it involves significantly more work than more 'traditional' approaches, and can only be implemented using simulations, either historical or forward looking. On a theoretical level, the statistical properties of the points on the resampled efficient frontier are not clear. In particular, it is not obvious that, say, the asset allocations on the ninth point of a series of ten-point efficient frontiers should be considered to be sufficiently related to be combined into a single resampled point.

6.4.10 One aspect of resampling which could be of interest is the maximum return point. It is interesting, for example, to consider the asset allocation which would be appropriate to give the maximum expected return, allowing for uncertainty in those expectations over various periods. For this, the monthly returns on each asset class could be simulated m times, if an investor had a time horizon of m months, and the highest returning asset class noted. If this process is repeated n times, then the proportion of each asset class in the maximum return portfolio can be calculated as the number of times each asset class gave the highest return divided by n. What this shows is that, as the time horizon gets smaller, the allocation tends towards an equal weight in each asset class, whereas, as it gets longer, the allocation tends towards an ever larger weight in the asset class with the highest expected return.

7. Managing Risk

7.1 *Overview*

Having discussed the measurement of risk and the assessment of various strategies, it is time to discuss ways of managing risk.

7.2 *Investment Strategy*

7.2.1 This is arguably the easiest way to manage risk, although the scope for change and the effect of that change will vary across the different types of firm. For banks the effect is reasonably important, but market risk is not generally the greatest risk faced; for insurers, the scope for change is controlled by the degree to which the assets held are admissible from a regulatory point of view. This can mean that assets which are relatively similar from a risk point of view are treated in very different ways from a regulatory point of view. The market risk aspect of the investments is secondary to the admissibility aspect for insurance companies. Market risk is often the key risk for pension schemes, so the investment strategy is a key way of controlling the risk taken, although it is only one aspect, and should be considered in the light of the various other 'levers'.

7.2.2 Duration risk — risk arising from having exposure to different parts of the yield curve for assets and liabilities — suggests a particular type of investment risk management involving interest rate and/or inflation swaps, or pooled funds using these instruments. Swaps such as these allow the separation of rewarded and unrewarded risk, so that any investment risk taken is of the rewarded variety.

7.2.3 Choosing the correct investment strategy also affects the extent to which liquidity risk is managed. This means that the maturity schedule of the liabilities must be borne in mind when constructing any asset strategy. Swaps can also be useful here in ensuring that fixed payments from a swap are received when they must be paid out to meet liabilities, for example.

7.3 *Raise, Distribute or Change Capital*

7.3.1 For a bank, raising or distributing capital, particularly debt capital, is a primary method of managing risk. A typical approach for an investment bank is: to consider the volume of business which it believes it can carry out; to consider the credit rating which it needs to target in order both to write this business and to maximise its risk adjusted return on capital; and then to raise the capital which it needs to achieve this. Predominantly, retail banks are less likely to follow such an approach, being less well able to change the volume of business written.

7.3.2 Whilst insurance companies might take the approach of investment banks, operational constraints faced by insurance companies for many lines of business mean that many insurers are less likely to change their level of business (or capital) on a tactical basis; however, like retail banks, strategic changes are possible if an insurer undertakes a review of its strategic business mix or finds itself systematically unable to invest shareholders' funds profitably.

7.3.3 Pension schemes frequently require additional capital injections from their equity shareholders (the sponsors, in other words), and determining the level of capital injection (or return of capital) is one of the key roles of the Scheme Actuary. However, this should ideally be carried out together with any review of the investment strategy and the value of the sponsor covenant, all of which are inextricably linked. Considering each in turn is likely to lead to inertia.

7.3.4 A secondary question for pension schemes is whether alternative methods of the contribution to cash payments (such as the securitisation of future sponsor earnings or letters of credit) would be appropriate. If such proposals are made, then their amounts should not be taken at face value;

they should also be modelled consistently with the other assets and the liabilities, and should again reflect the credit risk of the sponsor.

7.3.5 Another option for a pension scheme, rather than raising equity capital, is to reduce or to cease the issue of debt capital — in other words, reduce or cease benefit accrual. This has only a gradual effect on the level of liabilities, in particular if a pension scheme is closed only to new entrants.

7.3.6 Rather than raising or distributing capital, an alternative approach might be to change the mix of capital, such as a debt financed equity share buy back. Whilst Modigliani & Miller (1958) show that there is no first order difference in the value of a firm, there are clear second-order advantages relating to tax (Kim, 1978, 1982; Modigliani, 1982; and Graham, 1996a, 1996b; among others), free cash flow (Jensen & Meckling, 1976; and others), transaction costs (Williamson, 1988) and signalling (Ross, 1977; Leland & Pyle, 1977; and others) to name but a few. For pension schemes, the impact of the capital structure of the scheme on the capital structure of the sponsor should also be allowed for, and the two considered together, as described by Sharpe (1976), Black (1980) and Tepper (1981).

7.4 *Change the Volume or Mix of Business Written*

7.4.1 For banks and insurance companies, a simple way to reduce the level of risk — particularly if the level of free capital is low — is to write less business, since capital is required to write business. This is an approach which is likely to be used by an insurance company where the level of capital available varies less over the short term. However, this is not necessarily always the best approach. For example, some risks are reduced if more business is written, for example on a particularly small book of annuity business. Similarly, if the mix of business within a particular class is improved — for example by introducing geographical diversification (either directly or through reciprocal reinsurance agreements), then the level of risk can be reduced without the expected return being diluted by too much.

7.4.2 Similar results can be obtained through similar approaches by diversifying between types of businesses which have low correlations, for example different classes of insurance. An extreme example of this can occur within insurance companies, where the mortality risk borne by the life assurance book can be offset partially by the longevity risk borne by the pensions book. The degree to which this is possible depends on the natures and ages of the two books of business, as outlined in Sweeting (2006b), but Cox & Lin (2005) do find evidence from insurance and annuity premia that implicit hedging occurs in the United States of America.

7.5 *Non-Capital Market Risk Transfer*

7.5.1 A method of risk transfer fundamental to insurance companies is reinsurance. Broadly speaking, this can be proportional (thus allowing an insurer to improve the mix of business written) or excess-of-loss (thus protecting an insurer from extreme events).

7.5.2 Pension schemes use an approach similar to proportional reinsurance when they buy annuities, either as a matter of course for retiring members or as part of a bulk buyout of a tranche of members (perhaps the entire membership). More recently, opportunities for deferred buyout have arisen from a number of specialist providers.

7.6 *Capital Market Risk Transfer*

7.6.1 The advantage of these approaches is that they can be used to transfer the risks fully and are potentially very flexible. However, apart from requiring a small number of providers to pitch for this business, these approaches lack market discipline. Alternative, market-based approaches do exist, in concept or in fact, for some of the mechanisms above and to other issues not covered.

7.6.2 Perhaps the earliest examples of the securitisation of risk was the regulatory arbitrage performed by banks. They found that they were treated more favourably under the Basel Accord if they converted some of their loan portfolios into securities, which were then sold in capital markets. This approach has been extended to instruments such as CDOs, as described above.

7.6.3 Insurance companies also used securitisation to reduce their risk exposures. For example, catastrophe risk can be managed by the issuance of catastrophe bonds, which allow a market price of risk to be obtained. Catastrophe bonds are no longer limited to non-life insurance either — mortality catastrophe bonds have also been issued.

7.6.4 It is more difficult for pension schemes to remove their risks completely by securitisation, since few are large enough to bear the cost of security issuance. However, market-based opportunities do exist in some areas. For example, some pension schemes in deficit can mitigate sponsor risk by buying a credit default swap (CDS), although the extent to which the CDS exposure will cover any deficit can only be approximate, as the size of the deficit is unlikely to be fixed. Longevity bonds, as discussed by Blake & Burrows (2001), and, more plausibly, survivor swaps, as described by Dowd (2003), offer opportunities to mitigate longevity risk (and are also of interest to insurance companies, which might be suitable counterparties to pension schemes), but they are not without their problems, particularly basis risk, as discussed by Sweeting (2006b).

7.7 *Enterprise Risk Management*

7.7.1 Operational, project and strategic risks are less susceptible to mitigation by the methods outlined earlier, but, nevertheless, need to be managed effectively as far as possible. It is desirable that significant risks and uncertainties be managed within an integrated overall system of enterprise risk management (ERM), which enables all those connected with the institution to play their part, without gaps or overlaps. In addition, opportunity maximisation must be considered alongside the mitigation of downside risks.

7.7.2 Managing operational risk largely relies on the operational systems and controls being suitable. This includes reviewing performance incentives in order to minimise agency risks, and includes reflecting, wherever possible, any adverse behavioural finance influences.

7.7.3 The methodology developed by the Actuarial Profession and the Institution of Civil Engineers for the management of the risks in any kind of project is known as RAMP (Risk Analysis and Management for Projects). This approach, which was first published in 1998, is now well established, and consists of eight stages:

— RAMP launch;
— risk identification;
— risk analysis;
— financial evaluation;
— risk mitigation;
— go/no-go decision;
— risk control; and
— RAMP closedown.

7.7.4 Once stakeholders and their viewpoints have been identified (part of the RAMP launch), many of the remaining sections are consistent with the analysis in the preceding sections. Because RAMP is intended for use with capital projects rather than in an ongoing business, a decision on whether to proceed at all is required, and post-project 'closedown' analysis forms part of the process. However, both could, and perhaps should, also be incorporated into broader risk management processes relating to the financial and the non-financial operations of banks, insurance companies and pension schemes.

7.7.5 The methodology enables risks to be expressed in financial terms through the use of an investment model, and facilitates decisions on whether projects should go ahead or not, and in what form. Because risks, including the eventual operational risks, are fully thought through at the outset of the project, costly mistakes should be minimised.

7.7.6 The Actuarial Profession and the Institution of Civil Engineers have also collaborated on an approach to deal with strategic risks, known as STRATrisk. This is intended to bring together the technical and the human aspects of risk management. It stresses the need for risk leadership by the institution's board through the creation of an appropriate culture, internal communication system and risk management framework. The tools recommended include horizon scanning, concept mapping, pattern recognition and risk grouping. The importance of follow-through is also emphasised; it is not enough to be aware of a risk, but it must also be responded to as far as possible.

8. Conclusion

8.1 *Summary*

8.1.1 I have tried, where possible, to look at the similarities between various types of financial institution; however, it is also interesting to look at the differences. For example, in modelling market and interest rate risks, anecdotal evidence suggests that banks attempt to be market consistent in as many of their assumptions as possible, whereas pension schemes tend to be more subjective in the assumptions chosen. This might be a function of timescale: it is perhaps difficult to find market consistent assumptions for an institution with the lifespan of a pension scheme; it might also reflect the fact that many of the valuations carried out by banks are of instruments for which there are liquid markets, so deriving assumptions is more straightforward; whatever the reason, there do appear to be differences in approaches, and it is interesting to see what one party might learn from the other.

8.1.2 Another interesting comparison is in relation to credit risk, in particular the ways in which it is dealt with by banks and by rating agencies, for both of which it has long been fundamental to their analysis, and by pension schemes, which have only recently begun to address the issue in the context of sponsor default risk. Perhaps pension schemes could learn from these other institutions in their approach to this risk.

8.1.3 The analysis above demonstrates, not only that financial institutions are subject to a large number of risks, but also that similar risks are faced by all institutions, albeit to varying degrees. However, many of these risks are also linked to each other, for example credit risk and non-life insurance risk. This suggests, not only that actuaries have a role to play in a far broader range of risk management activities, but that many actuaries already have the skills and knowledge necessary so to do.

8.2 *The Keys to Effective Risk Management*

8.2.1 The most important contributor to good risk management is to actually have a coherent risk management system. This might sound trivial, but actually recognising that risk requires systematic management, through ERM, is an important step forward.

8.2.2 Within such a system, identifying all of the potential risks is key — it is often those risks which are not appreciated which cause the problems. Once the risks have been identified, it is important to know how they behave and, if appropriate, how to model them. This does not just mean how each should be modelled in isolation; it also means that the links between each risk should be allowed for correctly. If risks are positively correlated, then assuming independence can greatly understate the overall level of risk; if risks are negatively correlated, then ignoring this can result in too great a degree of prudence and opportunities being lost.

8.2.3 Once risks have been identified and modelled, the appropriate measures and levels of risk need to be agreed. If the current level of risk is too high, then the next stage is to know how to mitigate the risks.

8.2.4 However, one of the most important aspects of any risk management system is that those subject to the system are correctly incentivised. The system should encourage individuals to take sufficient risk of the right type, when appropriate, but not to take an excessive amount of risk. This is perhaps the key to a good risk management system.

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