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Risk Assessment of Defined Benefit Pension Schemes — An Economic Capital Approach

by

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Contents

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Abstract

In this thesis, we consider the amount of economic capital that defined benefit pension schemes potentially need to cover the risks they are running and to back long-term investment and longevity risks. As pension products offered by European insurance firms will come within the scope of Solvency 2, an insurance firm's pensions customers will benefit from the protections offered by the Solvency 2 regime. However, members of occupational defined benefit pension schemes do not have such a rigorous capital requirement to protect them against the risks the pension schemes are running.

We argue that a risk-based quantitative economic capital requirement could be adopted by occupational defined benefit pension schemes to bring the risk management of pension products on equal footing with insurance firms.

In order to achieve this goal, we first use the Universities Superannuation Scheme as an example to show the risk level of an individual pension scheme using economic capital as a measure of risk. We also show the effect of different risk control actions which can be employed by the pension provider to control its risk exposure, again measured by economic capital.

After quantifying the risk level associated with a defined benefit pension scheme, we extend our analysis to show the possibility of risk control by

changing the design of the pension itself to a hybrid set-up.

Following the risk assessment of an individual pension scheme, we analyse the risk levels of the Pension Protection Fund (PPF) which is a central fund guaranteeing benefits of all eligible UK defined benefit pension schemes. By estimating the risk level on a group basis, we discuss how pension risks can be managed by using a central fund.

We find that the economic capital requirement for an individual occupational defined benefit pension scheme is generally very large. Instead of requiring each individual scheme to hold an economic capital, it is perhaps more practical and efficient for the PPF itself to hold adequate assets to back its own economic capital. However we find that the capital requirement for the PPF is also large and de-risking is needed for the PPF as well.

This thesis illustrates that the economic capital framework can be used as a risk management tool to improve our understanding of the risks embedded in defined benefit pension schemes.

Key words

Defined benefit pension scheme, Economic capital, Solvency, Stochastic modelling, Asset-liability management, Hybrid pension scheme, Pension Protection Fund.

Chapter 1

Introduction

Pensions are arrangements to provide individuals with income after retirement, widely provided to people around the world. After continuous success over centuries, pensions have proved to be a valuable tool for individuals to save towards retirement.

In general, in a pension arrangement, the provider of the pension will guarantee a series of payments for the recipient after retirement in return for a series of contributions made by the recipient before retirement. Individuals can build up their savings, using pensions as a saving device and convert the amount of savings into a series of income at retirement. The process of converting a pension fund into a series of payments is known as the crystallisation of benefit.

A pension can also provide an income to the recipient's dependants even after the death of the recipient of the pension. For example, the spouse of a pension recipient can have a reduced amount of the recipient's pension payable after the death of the pension recipient.

A pension can last a lifetime, an individual typically enters a pension scheme when he or she starts working and exits the scheme at death. If the market conditions or mortality changes dramatically during this period, the cost of the pension will also change dramatically. This makes the pension guarantee a very risky business as it is difficult to predict what is going to happen over decades. Risks in a pension scheme can be borne by the pension provider or the recipient of the pension depending on the design of the pension scheme.

Historical high returns in equity markets have made pensions sustainable. Hence many UK pension schemes provided generous benefits for their members, expecting the cost of pensions can be easily covered. On the other hand, it can also be argued that the true cost of these pension promises was hidden by the long bull market in equities in the 1980s and 1990s.

In the 1990s, as UK pension schemes were enjoying high funding levels (assets at a relatively high level compared to the level of liability) due to high investment returns, actuaries were even advising some schemes to take payment holidays (stop contributing to a pension scheme for a period of time) and increase benefit guarantees because they thought pension schemes were in a very secure position and high investment returns would continue. At the same time, as the providers of pensions became more and more optimistic, the true costs and risks associated with a pension have not been dealt with enough care.

Only in the 2000s, the financial downturns and crisis revealed that pension guarantees are much more expensive than previously thought to be. The pension providers also found that cutting off pension benefit is not as easy as increasing it. The assets of many pension schemes after the market crash seems not enough to meet pension payments which are on the other hand, increasing steadily with the growing life expectancy.

In the UK and worldwide, many pension schemes are currently in a state of turmoil as a result of ageing populations, poor investment returns and high volatility in the financial markets. An apparent lack of formal research on the stochastic and multivariate nature of the true risks underlying pensions has resulted in their true costs perhaps having been underestimated.

The financial crisis of 2007 highlighted the increasingly interconnected nature of global financial markets and the need for an effective unifying framework to monitor and manage risk across the entire financial services sector. Banking and insurance sector supervisors should be applauded for having introduced risk-based economic capital supervisory approaches like Basel 2, 3, and Solvency 2 respectively.

In this thesis, we demonstrate that the principles of economic capital can be extended and applied to quantify and help manage the risks of pension schemes. This brings the pension sector under the same unifying economic capital framework that we believe is applicable to the entire financial services sector.

Successful implementation of a unifying economic capital framework will help supervisors to ensure that all financial services entities are treated on a broadly consistent equal footing, so helping to eliminate inefficiencies in financial markets and opportunities for regulatory capital arbitrage.

Although the risks that pension schemes collect and manage are essentially the same as those collected and managed by insurance firms, their risk management and regulatory treatments have been somewhat different. Whilst insurance firms have made explicit use of Asset and Liability Management (ALM) techniques to test the robustness of their balance sheets, and have been subject to rigorous regulatory solvency requirements, the pension model has focused more on funding levels and contribution rates.

In other words, pension schemes have tested the adequacy of the funding of their scheme benefits and risks with the focus being that, over the medium to longer terms, funding levels should be set at appropriate levels to finance the benefits.

It is not the purpose of this thesis to argue in favour of either approach. Our aim is to illustrate the results of applying a general economic capital approach to pension schemes. A very good discussion of the issues is provided by Barrie (2010) who also covers the potential application of Solvency 2 to pensions schemes as suggested by Green Paper: Towards Adequate, Sustainable and Safe European Pension Systems (European Commission (2010)), on the future of pensions. The recent Call for Advice from The European Insurance and Occupational Pensions Authority for The Review of Directive 2003/41/EC (European Commission (2011b)) requests to the European Insurance and Occupational Pensions Authority (EIOPA) for advice on the commission's review of the Institutions for Occupational Retirement Provision (IORP) Directive also sets out the issues very clearly.

We are planning to employ a comprehensive stochastic structure using economic capital as a measure of risk to estimate the risk level associated with a pension. Having considered the risks embedded within a pension, we propose different ways to manage risks through the lens of economic capital.

In order to achieve this goal, we first use the Universities Superannuation Scheme (USS) as an example to show the risk level of an individual pension scheme under the scope of economic capital. We also show different risk controls which can be implemented by the pension provider. The effects of these risk control approaches are also analysed using economic capital.

After examining the risk level associated with a pension scheme and the methods that could be adopted by the pension provider keeping the current design intact, we extend the research to show the impact on the risk profile of changing the design of the pension itself. We test the effect of changing the pension design of USS into a hybrid structure on the level of risks.

Following the risk assessment of USS which illustrates the risk level of an individual pension scheme, we test the risk level of the UK's Pension Protection Fund (PPF), which is a central fund that guarantees benefits of a group of eligible defined benefit pension schemes. By estimating the risk level on a group basis, as illustrated by the PPF, we discuss how pension risks can be managed by using a central fund which pools risks from a group of pension schemes together.

By doing these three projects, we first identify the risks inherent in an individual occupational pension scheme by calculating the amount of economic capital needed to cover the risks. We then discuss possible approaches that could be adopted to reduce pension risk under the current pension set-up without changing the pension design. On top of that, we analyse the risk level of individual pension scheme under a different pension design. Finally, we discuss how pension risks can be managed on a group basis. We hope to provide a comprehensive study of managing pension risks following this route.

Before presenting the pension model, background information for pensions is provided in this chapter in the following order: in Section 1.1, we provide a very brief introduction to pensions including the definition of pensions, the elements of pensions and stakeholders of pensions. We focus on the history of pensions in Section 1.2. In Section 1.3, the development of different forms of pensions is discussed. An overview of investment of pension schemes is included in Section 1.4 and, in Section 1.5, we discuss pension risk factors and how these risks are shared between stake holders. In Section 1.6, regulations for financial products are introduced. In Section

1.7, we set out the structure of the remaining part of the thesis.

1.1 Overview of Pensions

In this section, we provide an overview of pension schemes where the basic concepts of pensions are introduced. Unless otherwise stated, pension or pension scheme refers to funded occupational pension schemes in this thesis.

In general, a pension scheme is defined as an arrangement between an individual (often an employee) and the pension provider (often an employer) during the individual's lifetime, in which the individual will receive an income after retirement.

The primary purpose of a pension is to provide adequate, affordable and sustainable retirement benefits. This purpose is achieved by redistributing an individual's income: a percentage of the individual's income during working life is saved towards retirement and used to provide an income until death.

The common use of the term pension is to describe the payments a person receives upon retirement. The amount of the payments usually depends on predetermined legal and contractual terms. The annual pension expressed as a percentage of the annual income before retirement is called the replacement ratio. This is used as a measure of the living standard after retirement. The higher the replacement ratio, the higher is the living standard that can be achieved by pension payments.

For simplicity, the following terms are interchangeable in the rest of the thesis:

- The employer, the sponsor of the pension scheme and the pension provider;

- The employee, the recipient of the pension and member of a pension scheme.

The government encourages pensions so that individuals can have an income to depend on after retirement. Tax reliefs such as paying less taxes or deferring taxes to later dates, are usually used by the government as incentives to encourage pension contributions. The pensioner can use this pension to sustain his or her standard of living or at least meet minimum living standards. Pension provided by government and public sector organisations are called public pensions. Pension schemes can also be provided by private institutions and employers which are known as private pensions.

An occupational pension is a pension to which an employee gains entitlement because of his or her service with the sponsoring employer. The pension could, theoretically, be paid directly by the employer after the employee's retirement. This would mean that the retired pension's income depended entirely on the ongoing ability and willingness of the employer to keep paying the pension. This would be a very insecure situation, unless the employer was a government body. So private employers usually accumulate a fund of money, separate from the company's assets, from which to pay pensions. If this fund has enough money in it to meet all the pension commitment made, i.e. its assets at least equal its liabilities, the occupational pension scheme is said to be fully funded. The existence of this fund gives some security to the members. However, if the pension provider gets into financial difficulties at a time when the pension scheme is under-funded, it might be difficult for the pension provider to contribute to the pension scheme.

Even a well-funded scheme depends on the continuous existence of the pension provider, as the pension scheme could still be left in deficit if adverse experience reduced the assets or increased the liabilities, requiring additional support from the sponsor. It can be argued that the security of a pension scheme's members, in respect of their accrued benefits, should be provided by resources controlled by the scheme itself. There should not be a dependency on the scheme sponsor to provide support in times of stress as the sponsor may themselves not be in a position to provide this support.

We will focus on occupational pensions provided by employers to their employees in the remaining part of the thesis, because the members' benefits from an occupational pension scheme are not protected especially in case of scheme provider's insolvency.

As a result, we propose an economic capital approach to protect occupational pension scheme members' benefits. By holding economic capital on top of the best-estimate liabilities for a pension, the deficit in a pension scheme can be met by this economic capital under stress without requiring additional capital injections from the pension sponsor. The economic capital can also be used as a measure of the risk a pension scheme is running. The risks of government pension schemes are not considered in this thesis as the government can meet the pension expenses from taxes, although, the economic capital principles for risk assessment purposes still apply for government pension schemes.

A pension arrangement can last for many years. If we divide a pension into different parts, it can have the following phases:

- **The accumulation phase**: The period in which the pension provider, and possibly the member, contribute to the pension scheme before the member's retirement age. A percentage of member's salary will usually be paid into the pension scheme every month.
- **The normal retirement age**: A time point when members retire

and receive full benefits from the pension scheme. Retirement before the normal retirement age may result in a reduction in pension benefits. The normal retirement age for government pensions in UK is 65 for male and 60 for females in year 2008. However, individual scheme rules can set a different normal retirement age.

- **The pension phase**: The period during which a stream of pensions is paid from the pension scheme to the recipient of the pension after retirement.

- **Deferment period**: If a member withdraws from a pension scheme before normal retirement age, i.e not contributing to the pension scheme anymore, the individual might have to wait until normal retirement age to have the pension benefit payable. The waiting period is known as the deferment period.

Members can have different membership status in a pension scheme. A member who is contributing to a pension scheme is called an active member. If an active member withdraws from a pension scheme he or she then becomes a deferred member who will receive a deferred pension from normal retirement age. However, under certain circumstances, an active member who leaves a scheme may receive a refund or transfer benefits to a new scheme. A recipient of a retirement pension is known as a pensioner or retiree. Dependants may also be entitled to a pension after the death of the member.

There are five important elements in a pension scheme: benefits, contributions, contingency events, investment returns and inflation.

- Benefits are the payments a member receive from the pension scheme. The benefit can be a lump sum at retirement and/or a series of payments after retirement. The pensioner can also be entitled to other benefits such as illness cover, a lump sum on death in service and a residual pension payable to dependants after death. The amount of benefit can be determined in various ways, which will be discussed in Section 1.3. The pension benefit can be a fixed value over years or increase in line with inflation or other factors.

- Contributions to accumulate a fund are normally made by the member and the sponsor. This fund is the source of benefits. Usually the member's contributions are a percentage of salary. The sponsor may also pay a percentage (not necessarily the same) or some other amount. Pension schemes can also be non-contributory, where members do not pay contributions and the sponsor pays all the contributions.

- Contingency events are those events triggering a pension payment or an alteration of pension benefits. These events include: death, withdrawal, retirement, early retirement and so on. For example, the contingency event triggering the payment of the dependant's pension is the death of the primary beneficiary.

- Investment returns are crucial for a funded pension because in most cases pension payments occur many years after the first contribution. The pension fund can grow significantly if the investment return is good. On the other hand, the fund value can shrink a lot if the investment return is poor.

- Benefits are often linked in some way to inflation, in which case high inflation risk will greatly increase benefits.

1.2 History of Pensions in the UK

We have introduced some basic concepts of pension schemes. We now consider how and why pension designs have developed along with some current issues in the pensions market.

Pensions have a very long history. The Chatham Chest has been described as the world's first occupational pension scheme. It was originally conceived as a charity fund for disabled seamen in war. It is established in the UK around 1590 and the assets of the scheme were held in an actual chest which was also called the Chatham Chest.

At around the same time, every parish in the UK was to appoint overseers of the poor to find work for the unemployed and set up parish-houses for poor people who could not support themselves. This can be considered as a form of pension benefit which provided for people who cannot sustain a minimum standard of living. These kind of benefits, not necessarily in monetary term, are the predecessors of pensions.

Another recorded pension in the UK is the pension scheme for Royal Navy Officers in 1670s. It provided full salary to officers who could not work due to old age after 15 years of completed service.

After that, in the pre-industrial and early industrial ages, older workers were accustomed to keep less demanding work at lower pay rate. Followed by this, was the funeral benefit provided by mutual-benefit friendly societies (sometimes called a mutual society, benevolent society or fraternal organisation) formed by workers in the late 17th century provided sickness and funeral benefits to members in return for a regular contribution. However, it did not provide an income stream for a worker's later life. The number of friendly societies peaked in the 19th century.

In the 1830s, public bonds were available in the market. Insurance houses were able to provide annuity contracts to customers by investing in the bond market. Actuarial principles were used at that time to predict the cost of annuities on a group basis. Based on these developments, public pension schemes were devised as an inducement to attract or retain favoured or strategic civil servants.

Subsequently, some well-established corporations were able to offer their own pension schemes. Many cooperative employees and superannuation pension schemes were formed. The benefits were usually defined by formulae set out by actuaries taking into account the length of service and the employees' final, or average salary. No inflation-linking of pensions in payment or deferment was included at that time. Actual experiences were used in setting provisions during this period.

1909 saw the first non-contributory old age pension in the UK. It was paid by the government on a means tested basis (the pension was only payable to citizens over 70 with an income lower than a certain limit) and required no contributions from the recipient of the pension.

In 1921 the first tax relief was granted to pension schemes that satisfied certain conditions. This is considered as a tax incentive provided by the government to encourage savings towards pension. However, limits on the amount of tax relief and the proportion that could be taken as a lump sum at retirement were imposed in 1947 by the Finance Act. By limiting the proportion that could be taken as a lump sum, more pensions were forced to be paid as a lifetime annuity. This ensured that pensions would be used to maintain a standard of living throughout the member's life rather than as a one-off spending.

In 1986, the Financial Services Act set out terms and conditions under which investment businesses including pension schemes could be conducted. The appointment of an investment manager was required for pension schemes. Since then, a lot of regulations to protect securities of pension schemes have been introduced.

In particular, the 1995 Pensions Act introduced the Minimum Funding Requirement (MFR). Pension schemes were required to pay off any deficit over a period of 10 years if the funding levels were below 100% (the funding level is defined as the amount of asset over the amount of liability).

In 2001, due to realisation of a lot of deficits in pension schemes which resulted from heavy losses on the stock market, new Financial Reporting Standard (FRS) 17 accounting rules were introduced. According to this new regulation, companies were required to report pension deficits and surpluses in the year in which the deficit or surpluses occurred.

In 2004, The Pensions Act introduced the PPF which is a central fund collecting premiums from eligible pension schemes in the form of a compulsory levy and, in return, guaranteeing pension payments, up to a limit, in cases of winding up of contributing schemes. Most defined benefit occupational pension schemes and defined benefit elements of hybrid schemes in the UK are eligible for the PPF. Schemes exempt from the PPF are those schemes which are unfunded or covered by a crown guarantee (liabilities of those schemes which are underwritten by the government). All eligible schemes are liable to a compulsory PPF levy payable annually. The PPF itself has, however, experienced some funding difficulties in recent years. As reported by the Purple Book 2011 (The Pension Protection Fund and The Pensions Regulator (2011)), the aggregate balance of all schemes covered by the PPF has varied by around £410 billion (with the greatest surplus in June 2007 at £142 billion and the greatest deficit in December 2011 at £271 billion).

More detail on the recent regulatory developments in the pensions market is provided in Section 1.6.

1.3 Different Types of Pensions

After centuries of development, pension schemes have evolved into many different forms. From the perspective of how pension benefits are determined, pension schemes can be classified into the following three main categories: Defined Benefit (DB) schemes, Defined Contribution (DC) schemes and hybrid pension schemes.

In a DB pension scheme, the level of pension benefit is predetermined by formulae and contribution rates are then set according to the level of benefit provided. In a DC pension scheme, the level of contribution rate is specified and the level of benefits depends on the investment return achieved on the contributions and the conversion rate at retirement when the accumulated fund is converted into monthly pensions. Hybrid schemes are schemes with both DB and DC elements.

1.3.1 Defined Benefit Pension Schemes

The benefit entitlement of a DB pension scheme is determined by a set formula rather than accumulated fund values. The formula typically incorporates the employee's salary, years of pensionable service, age at retirement and other factors. For example, a pension for life commencing on retirement at a certain accrual rate of pensionable salary for each year of pensionable service can be calculated by the following formulae:

$$\text{Annual pension} = \text{Accrual rate} \times \text{Pensionable service} \times \text{Pensionable salary};$$

$$\text{Lump sum at retirement} = 3 \times \text{Annual pension}.$$

The accrual rate is the rate at which employees accumulate retirement benefits and is usually referred to in fractional terms. Typical accrual rates can be 1/60th, 1/80th, 1/100th and 1/120th where 1/60th accrual rate means a member with 30 years pensionable service will achieve a pension of 1/2 of the full pensionable salary. At retirement, the pensionable service is the number of years of service used to calculate the amount of pension payable. It might be restricted after normal retirement age for late retirements. The pensionable salary is a function of the member's salary used to calculate the amount of pension payment. It can be based on final salary, career average salary or revalued salary depending on the design of pension scheme.

Some schemes also provide a lump sum payment at retirement age, usually based on the amount of annual pension (typically, 3 times of the annual pension as shown in the formula).

The members pay a defined rate of contributions. The employer pays the contributions that are required, in addition to members' contributions and investment returns, to meet the liabilities. So all the investment risks and longevity risks are borne by the employer in a DB pension scheme.

1.3.2 Defined Contribution Pension Schemes

In a DC pension scheme, however, the rate of contributions by both members and sponsor is defined in advance and the amount of pension is not guaranteed. Contributions for each member of a DC scheme are usually allocated into individual accounts. The money in these individual accounts roll up with investment returns until the pension commencement date and converted into annuities to provide a lifelong pension for the member. In some pension schemes part of the fund can also be taken out as lump sum at retirement. As in a DC scheme, the amount of pension depends on the investment return, the members bear all the investment risks.

1.3.3 Hybrid Pension Schemes

Hybrid pension schemes are usually a mixture of DB and DC schemes. Although there are many different kinds of hybrid schemes, in one typical form, the employer pays the member the greater of the calculated value of DB and DC pensions. This type of pension provides the best benefit for members as it gives a greater value calculated by DB method and DC method.

However, this is more expensive than single DB or DC scheme with the same accrual rate and more difficult for the sponsor to run. So to control costs, the DB accrual rate in a hybrid scheme is usually set at a lower value than in a pure DB scheme. In general, the employer and employees share risks in a hybrid pension scheme. More discussions on hybrid pension schemes are provided in Section 1.5.

1.3.4 The Development of Different Types of Pensions

As mentioned in Wesbroom and Reay (2005), before the 1970s, the UK pension market was primarily dominated by DB pension schemes including pension schemes guaranteeing a fixed amount of payment and final salary pension schemes. The reason behind DB schemes domination of the UK market was probably that they provided guaranteed benefits linked to salary which are preferred by members.

At the same time, DB schemes were heavily invested in the equity market. Historical high returns generated by equity market made DB schemes appear easily sustainable. However, after several financial downturns and continued mortality improvements, companies started to realise that the DB pension guarantees were too costly and risky to provide. The promised pension benefit started appearing unaffordable after suffering from poor equity market return and faced with the steadily increasing life-expectancy.

Many employers found DB benefits no longer affordable and the guarantees they gave many years ago were proving increasingly difficult to meet.

The number of DC schemes as well as hybrid schemes started to increase from the 1970s. Since then, more and more UK companies started switching from DB to DC or hybrid schemes to reduce their risk levels. By having a DC or hybrid structure, some or most of the risks can be transferred to scheme members.

Many DB schemes are also becoming closed to new members or future accruals in order to limit future risk exposures. Table 1.1 extracted from Wesbroom and Reay (2005) displaying the number of different types of schemes as percentages of all schemes shows a clear trend of DB schemes switching to DC pension schemes between year 1990 and 2004. However, the number of hybrid schemes remains under 10% during this period.

Table 1.1: UK private sector pension schemes from National Association of Pension Funds Surveys.

Survey Year	1990	1993	1998	2002	2004
Defined Benefit	89%	87%	80%	69%	51%
Defined Contribution	6%	7%	12%	25%	40%
Hybrid	5%	6%	8%	6%	9%

After the economic down-turn around 2000, the decline of DB schemes continued. The membership of DC and hybrid schemes kept increasing after year 2004. However, the membership in hybrid schemes still remains very small compared to DB and DC schemes.

However, schemes switching to DC schemes and transferring most of the risks to scheme members might not be the ideal solution. Since DB schemes have some attractive features to employees, companies who want to attract and retain high quality staff may find that abandoning DB provision is detrimental to their business. It might be argued that DB types of benefit including hybrid structure can still be provided if the underlying risks are understood and managed properly.

The Pension Trends (Office for National Statistics (2011)) published by The Office for National Statistics provides a statistical backdrop for the debate on pensions. Detailed statistics for schemes, memberships, funding, the level of pension benefits and other relevant information is provided in this document. It shows two dramatic transitions for pension schemes: firstly, a shift from unfunded social security towards private funding and secondly a shift from DB schemes towards DC schemes. Recent regulatory reforms are also discussed in this document. According to the report, these reforms will be carried out to increase coverage of private pensions and could double the membership of DC pensions. The reforms are likely to result in the majority of active members of pension schemes in the UK to be in DC pensions by the end of this decade.

As schemes are switching to DC structure, a lot of attention is also paid to the DB pension risk management, most of which is focused on the quantification of risks for DB pension schemes.

1.4 Pension Scheme Investments

From the statistics obtained from Organisation for Economic Co-operation and Development (OECD) reported in Pension Markets in Focus 2007 (Organization for Economic Co-operation and Development (2007)), the size of the global pension industry including both occupational (workplace-related) and personal arrangements, was valued at approximately $24.6 trillion in year 2006.

Table 1.2: Asset split for UK DB pension schemes form The Purple Book 2008.

	2007	2008
Equities	53.5%	50.6%
Gilts and fixed interest	24.0%	26.7%
Insurance policies	13.7%	12.8%
Cash and deposits	3.7%	4.4%
Property	2.5%	2.9%
Other investments	2.6%	2.6%

According to this report, in year 2006, the size of pension funds in the UK was $1.8 trillion split fairly evenly between DB and DC schemes.

In the OECD and selected non-OECD countries as a whole, bonds and equities remain the two most important asset classes for pension funds investments and accounted for half of the total investments in most countries in 2006. In many countries, these two asset classes accounted for over 80% of the total investments. The highest equity allocations were observed in the Russian Federation (59.9%), the Netherlands (54.6%), and United States (49.6%).

The asset split for UK DB pension schemes from The Purple Book 2008 (The Pension Protection Fund and The Pensions Regulator (2008)) is shown in Tables 1.2.

It can be seen from these statistics that the UK pension market is heavily invested in relatively risky assets. This implies a high long-term volatility of asset returns which might endanger the pension schemes' funding positions. As reported in Occupational Pension Schemes Annual Report 2010 (Office for National Statistics (2010)), the aggregate funding position for schemes covered by the PPF moved from a funding position of £129.7 billion in surplus in June 2007 to a deficit of £242.0 billion in March 2009.

1.5 Pension Scheme Risks

The DB scheme's survival for many years is proof of its value to employees, as a provider of retirement income, and also to employers, as a means of attracting and retaining high-quality staff. Sweeting (2008b) discusses reasons for the historical success of DB pension schemes. However, the providers of DB pension schemes have to deal with the associated risks.

The risks relating to any pension scheme could be borne by the employer or employees, or shared between the two. How the overall risk is distributed between the two stakeholders is determined by the design of specific pension schemes.

DB pension schemes have their risks placed on employers because ultimately it is the employers' obligation to meet guaranteed pension payments regardless of fluctuations in investment returns and mortality changes. DC schemes, on the other hand, place most of the risks on the scheme members. Hybrid schemes are somewhere in between, employers and employees share the risks arising from investment and longevity.

As pensions have very long durations, DB pensions have substantial uncertainty in investment return, mortality improvement and even potential changes in legislation. The value of the pension fund can fall in a bear market potentially leading to a deficit when the DB benefits fall due.

DC types of pension schemes are preferred by employers as most of the risks are transferred away from the scheme sponsor to employees and they are therefore lower risk. They typically provide lower benefits than DB schemes and are therefore cheaper. DC schemes are also administratively easier to operate. They may appear less attractive compared to DB schemes from the perspective of employees as the employees face exposure to all the risks of the pension plan. However, DC schemes, being more flexible and more easily transferable between employers, are sometimes favoured by a section of workforce who want greater control over their investments and who expect to change jobs frequently.

As mentioned earlier, many pension providers are trying to switch to a DC structure in order to de-risk. It might be argued that as long as the risks embedded in DB schemes are appreciated and managed in an adequate way, there is no need to avoid providing DB benefit. The risks associated with DB schemes are indeed very large, however, by de-risking and managing these risks in an appropriate way, DB schemes or schemes with DB elements can still be provided with an acceptable level of risks.

Many of the remaining DB schemes are struggling to survive and seeking ways to reduce the level of risks they are facing. In terms of scheme design, from the employer's point of view, there are two main ways of de-risking pension schemes: reducing the overall level of risks by reducing the overall value of the benefits provided by the sponsor or by sharing part of the risks with employees.

In order to reduce the overall risk level, pension providers have the following options:

- Increase retirement age: By increasing the retirement age, schemes have a longer period for accruing benefits and building up the pension fund, while at the same time the period of paying pensions to members is shortened. One possible drawback of this approach is that for some final salary pension schemes, the amount of pension calculated from member's final pension might be higher, resulting in a larger overall liability for employers. However, in most situations, increasing normal retirement age does help to improve the financial strength of pension scheme as the length of the contribution period is increased while the length of pension payments is reduced.

- Reduce accrual rate: By having a lower accrual rate, the amount of pension members are entitled after retirement is lowered, making it easier for the pension provider to meet their pension obligations.

- Increase member's contribution rate: Increasing contribution rates can help the scheme's financing status. By contributing more into the scheme fund, there is a larger chance that the assets in the fund will be enough to meet the pension payments even if investment returns are poor.

However, these adjustments mentioned above are extremely unpopular with scheme members. Moreover, the benefits already accrued have significant amount of risks remaining at least in the short term.

Another way of de-risking DB pension scheme from employer's point of view is to share risks with members. By transferring part of the risks to employees, the risks faced by the employers can be reduced accordingly.

There are different ways of sharing risks between employers and employees. For example, final salary DB schemes in Netherlands have already started to apply conditional indexation arrangements. By adopting conditional indexation arrangements, sponsors of pension schemes are allowed to revalue the benefit level subject to the financial strength of the pension scheme. If the funding level of a pension scheme falls below a prescribed level, the pension benefit could be re-valued using a different salary basis or different indexation, and the normal retirement age could also be adjusted. Once the funding level of the scheme has recovered, the sponsors are required to reinstate the amount of pension entitlements. The conditional indexation arrangement allows the pension benefit to be reduced when the financial strength of the scheme is weak.

By using this approach, part of the investment risk is transferred to scheme members. However, sponsors still bear part of the investment risks because they still have to pay the amount of revalued pension. If the asset level of the pension fund is not enough to meet the liability after the revaluation, the sponsor can still be left with a pension scheme in deficit.

The conditional indexation arrangement is very useful in controlling investment risk but is difficult and costly to administer and also difficult to communicate with members about their pension entitlement. It is also subject to moral hazard and irresponsible investment of the employer as the employer has the power to reduce the amount of benefit if investment returns are poor.

Another way of sharing risks with employees is to adopt a hybrid structure. The risk allocation differs according to different scheme designs.

We will use the following definition of hybrid scheme "Hybrid pension schemes are private pension schemes which are neither pure DB nor DC arrangements, where pure DB arrangements are taken to mean final salary pension scheme, career average pension schemes and schemes with fixed benefit structure." The overall risk level of a hybrid scheme can be lower than a pure DB scheme while retaining some favourable features of DB schemes. A hybrid pension with a mixture of DB and DC characteristics enables members to benefit from favourable market movements while providing a guaranteed minimum level of pension payment. Hybrid schemes can also help the employer's work force management.

As mentioned in Pugh and Yermo (2008): "The growth of hybrid pension plans in recent years in some OECD countries (primarily Japan, the United Kingdom and especially the United States) is partly a response to external pressures on these plans that call for a re-balancing of the burden of risk-bearing between employers and employees."

Typical hybrid scheme structures and their respective risks are discussed below:

- Combined DB and DC pension scheme: Members accrue both DB and DC benefits and have benefits from both of them (having a DB and a DC pension scheme at the same time). The risks to the employer depend on the weighting of the DB scheme element while the risks to the employee depend on the weight of the DC part of the pension scheme.

- Underpin arrangements: Members receive the better of DB and DC benefits. Under circumstances in which the DC outperforms DB and the DC fund is used to buy an annuity at retirement age, there is no risk arising from the underpin from the employers' point of view. If pensions are paid from the DC fund itself, the employers are still subject to investment and longevity risks in respect of this element. The risk sharing depends on the level of the DB guarantee. If the guarantee is low and will only take effect in extreme conditions, the sponsor bears the risk of extreme conditions and the members bear the risk of less severe situations.

- Cash balance or retirement balance pension plans: A DB pension plan which is defined in terms of a hypothetical account balance. The fund in the account can increase with agreed rate of return. The risks for a cash balance plan depends on how the rate of return earned by the fund is structured.

- Self-annuitizing pension plan: A DC plan with in-house annuity conversion. The risks to the employer depends on the difference between the market annuity conversion rate and the in-house conversion rate. After the conversion, the sponsor is still subject to longevity risks and investment risks of the fund. The risk to employees are mainly from investment risks before retirement and converting the pension fund into annuity at retirement age.

- Sequential hybrids: Members are allowed to join a DB pension scheme after a period of DC membership. For the employer, the risks mainly depend on the timing of conversion. The earlier the membership can be switched to a DB status, the greater is the risk as the accumulated DB benefits will be higher. For the employees, risks will depend on the amount of DC benefits accrued.

In this thesis we will focus on the underpin pension arrangement which will be discussed in detail in Chapter 5.

1.6 Regulatory Developments

Historically financial markets have experienced a lot of turmoil. Crashes in stock prices, asset price bubbles and the recent credit crisis have proven that the financial market can do far worse than expected. If a pension fund is heavily invested in equities, the funding level can be quite volatile and in the case of the sponsor's insolvency, a pension scheme can be left under-funded and members may lose part or all of the benefits they are relying on in retirement. As a result, regulations are needed to protect members' interests and to supervise and maintain confidence within the whole industry.

In the UK pension market, there are mainly two providers of pensions:

the insurance companies and the occupational pension schemes. However, the regulations governing these providers are vastly different.

The banking and the insurance sector regulators have started to move towards risk-based economic capital supervisory approaches via Basel 2, 3 and Solvency 2 respectively. These regulations have imposed minimum capital requirements for financial firms. As a result, pension arrangements provided by insurance companies will be backed by regulatory capital requirement in the near future. As there is no regulatory requirement for occupational pension schemes to hold explicit capital to back risks, the security level of occupational pension schemes is potentially lower than those of insurance companies. For the purpose of fairness and better risk management, we will argue in this thesis that it is imperative that each pension scheme also holds adequate capital in order to manage and mitigate the underlying risks.

Following the financial crisis, Basel 2 is now being strengthened in certain areas, especially in respect of the quality and amount of capital backing and liquidity requirements. Solvency 2 is expected to be implemented on 01/01/2014 and will introduce risk-based supervision for the UK markets.

Solvency 2 requires insurance companies' assets and liabilities to be valued on market consistent bases, with capital based on a 1-year Value-at-Risk (VaR) measure at the 99.5th percentile level. Pension products offered by European insurance firms will come within the scope of Solvency 2, therefore ensuring that an insurance firm's pension customers will benefit from the protections offered by the Solvency 2 regime. These protections also include the qualitative governance, risk and capital management requirements of Solvency 2, as well as the hard capital requirements.

Within Europe, the IORP Directive (European Commission (2011b)) set out the broad principles that IORPs should follow in respect of capital buffers and technical provisions. One of the aims of the European Commission in reviewing the IORP Directive is most clearly the introduction of a Europe wide risk-based solvency regime for DB pension schemes based on Solvency 2. However the UK has been granted an exemption from the capital buffer according to Article 17 of the IORP Directive, and this Article refers to the existing Solvency 1 rules for insurance firms. At least in the short term, we can expect that this exemption will continue and so UK DB pension schemes will not be required to comply with Solvency 2, when it replaces Solvency 1, and therefore they will not be required to hold risk-based capital to cover the risks they are running.

DB pension schemes and other types of occupational pension schemes, not held on insurance firms' balance sheets, are therefore likely to remain outside of the scope of Solvency 2, at least for the moment. In the UK, DB pension schemes are not required to value their assets and liabilities on market consistent bases nor, perhaps more importantly, to hold capital to protect their members from scheme insolvency. As a consequence, UK DB pension scheme members are not subject to the same strong regulation and protection that apply to customers of life insurance firm pensions products.

The UK pensions industry has been subject to a very large amount of regulatory change over recent years. In particular as mentioned in Section 1.2, Pension Act 2004 brought into being the PFF, and also put in place the Pensions Regulator. The Pensions Regulator has some powers to help it regulate DB pension schemes. In particular it can require scheme sponsors to put in place funding plans to eliminate scheme deficits. It has to be said, however, that these powers seem fairly weak, as compared to those of the Financial Services Authority, for example.

Current UK DB pension scheme regulations require triennial valuations of assets and liabilities. If liabilities exceed assets, a recovery plan from the sponsor must be put in place to eliminate the deficit, typically over a period of 10-15 years. This crucially depends on the ongoing financial health of the sponsor and this is therefore not guaranteed. Furthermore, triggering a recovery plan might require alterations to the scheme, such as an increase in future members' contributions or a reduction in future benefits, or the pension scheme stopping future accrual of benefits. In the event that the sponsoring employer of a DB pension scheme in deficit becomes insolvent, the scheme will be taken over by the PPF and a certain minimum level of pension benefits guaranteed.

As evidenced by the recent Green Paper published by the European Commission (European Commission (2010)) on the future of pensions, there does appear to be momentum gathering in Europe, supporting the application of a risk-based regime, like Solvency 2, to DB pension schemes. The recent European Commission (2011b) of the IORP Directive confirms this and Barrie (2010) also provides some useful commentary.

In this thesis we set out to determine the amount of risk-based capital requirement that would be needed to provide DB pension scheme members with the same level of protection as insurance firm pension customers. Scheme members would then not have to rely entirely on the scheme sponsor for support in times of trouble as this capital will provide a certain level of protection.

1.7 Structure of the Thesis

The structure of the remaining part of the thesis is as follows: In Chapter 2, we introduce economic capital and the methodology of economic capital calculation. In Chapter 3, the economic and demographic models required for economic capital calculations are discussed. We quantify the economic capital requirement for USS in Chapter 4. In Chapter 5, we test the economic capital level for a hybrid pension scheme structure. In Chapter 6, we estimate the risk level for the PPF to see the effect of managing pension risks on a group basis. In Chapter 7, we draw our conclusions.

Chapter 2

Economic Capital

In this thesis, we are going to propose an economic capital approach towards risk assessment of DB pension schemes. In this chapter we will provide a definition of economic capital and discuss its relevance in the context of pension schemes. We will also outline the steps for calculating economic capital.

2.1 Economic Capital Definition

The term "economic capital" is widely used within the financial sector. However, there is still no commonly accepted standard definition of it. Basel 2 defines economic capital as the amount of capital, as self assessed by banks, that is needed to cover the risks on the balance sheet under stress for a specified probability. Solvency 2 defines economic capital as the 1-year VaR measure calibrated to a 99.5th percentile level.

A comprehensive definition, applicable to any financial services firm, is provided by Porteous and Tapadar (2008) and is reproduced below:

> **Definition 1:** Economic capital is the amount of capital required to ensure that the realistic balance sheet of a financial services firm remains solvent, over a specified time horizon, with a prescribed high probability.

Definition 1 of economic capital given above may not appear to be directly applicable to pension schemes and the PPF, as they are managed through funding levels, rather than balance sheet strength. Similarly, sponsor covenants and recovery plans, in cases of under funding, hide the true financial strength of pension schemes.

A sponsor's inability to fund future benefits because of insolvency, for example, is relevant if we wish to study a pension scheme that is closed in respect of future benefits and funding. However, we focus on pension schemes that are open in respect of future benefits and funding. We propose the following alternative, but equivalent, definition of economic capital that may be a more natural fit to pension schemes:

> **Definition 2:** Economic capital is the excess of assets over liabilities required to ensure that the realistic, or market, value of assets exceeds liabilities at all times, over a specified time horizon, with a prescribed high probability.

Definition 2 uses a realistic, or market, value of assets, consistent with the approaches proposed in FRS 17 issued in 2005, the Basel 2 and Solvency 2 regimes. We are aiming to apply economic capital principles which have been adopted by banks and insurance companies to occupational pension schemes and the PPF in order to show that they can all be managed on an equal footing.

For individual pension schemes, economic capital is especially useful when the pension provider goes insolvent. By adopting an economic capital approach, the security of the pension scheme can be protected from within the scheme itself without depending on the financial status of the pension provider which is not guaranteed.

2.2 Asset and Liability Valuation

The asset and liability calculation for our economic capital calculation mechanism is introduced in this section. We are going to apply economic capital concept to an individual open DB scheme, the USS, and the PPF. For the USS, we will consider both the traditional DB design and also a hypothetical hybrid scheme variant.

For liability calculations for both traditional DB design and the hybrid variant, we use best-estimate liabilities without any risk margin. It is because we are interested in economic capital net of such a margin. Our economic capital measure therefore assesses the amount of surplus assets required to ensure that best-estimate liabilities can be covered following a stress event.

A risk margin can be included, if required, and it is interesting to note that in practise under Solvency 2 when calculating capital requirements, own fund movements are determined on the assumption that the risk margin is constant under stress. In practise, this means that Solvency 2 capital requirements are independent of the risk margin. In any case, our approach can easily accommodate a risk margin if this is believed to be appropriate.

The liability valuation for the PPF differs from that of USS. The valuation outlined in Section 143 and Section 179 of the Pensions Act 2004 is used for the PPF and its eligible pension schemes instead of best-estimated liabilities. Section 143 valuation determines whether the PPF should assume responsibility for a scheme while Section 179 is used to determine the levy payable to the PPF.

Section 143 and Section 179 valuation for the PPF is based on the amount of benefit scheme members can receive from the PPF if the PPF takes over a pension scheme. In general, PPF guarantees benefits for active members up to 90% and benefits for pensioners up to 100%. As a result, PPF valuation method used in this thesis is based on Section 143 and Section 179 valuations. As the PPF provides a reduced level of pension protection, Section 143 and Section 179 valuations produce substantially lower liabilities compared to best-estimate liabilities (see Appendix A for more detail on the Section 179 valuation).

The Pensions Act 2004 requires that the triennial actuarial valuations produce technical provisions calculated using an accrued benefits method. We selected the Projected Unit Method (PUM) which is consistent with the USS as our funding method in this thesis. So, the same PUM is used for valuing liabilities of the USS (both traditional and hybrid scheme structure) and the PPF.

The PUM estimates the actuarial liability of a pension scheme for each member based on past service accrued as at the valuation date and taking into account future salary inflation. This requires assumptions for future salary inflation, the risk discount rate, as well as withdrawal and mortality rates.

The requirement to use the yield on an AA rated corporate bonds of different durations as the risk discount rate in FRS 17 accounting standard creates an artificial mismatch between liability valuation and the actual assets backing the liabilities. In times of market stress, the liability values can become insensitive to the actual movements in the backing assets resulting in a deficit in balance sheet. In this thesis, we use a risk discount rate that reflects the price movements of actual assets backing the pension scheme's economic capital.

2.3 Economic Capital Calculations

Based on the economic capital definition set out in Section 2.1, we describe the calculation of economic capital in mathematical terms here. We will use the term "pension scheme" to refer to both the USS and the PPF in this section.

2.3.1 Notations

First we define $[0, T]$ to be the entire run-off of the pension scheme under assessment, i.e. T is the time when the last of the current members of the pension scheme leaves the scheme through death or withdrawal.

Let $[0, H]$, where $0 < H \leq T$, denotes the assessment horizon over which the solvency of the pension scheme needs to be assessed. In this thesis, we advocate the use of a run-off approach to calculate economic capital. i.e. $H = T$, reflecting the view that most pension scheme risks arise in the long term and this should be taken into account while assessing solvency. However, we also present economic capital requirements based on a shorter 1-year assessment horizon to check the impact of time horizons on solvency assessment.

We assume that the pension scheme's balance sheet is produced at annual intervals, for which the assets and liabilities are valued in accordance with the discussions in Section 2.2. Although the current regulations only require triennial valuations of UK DB pension schemes, annual valuations are more prudent as it enables quicker corrective actions and also this is consistent with the solvency assessments of other financial institutions like banks and insurance firms. For the sake of simplicity, we also assume that all cash flows of the pension scheme occur at the end of a year.

Now suppose that the economic and demographic profiles of the pension scheme, along with the relevant cash flows, are projected forward till run-off. For a single realisation of the future, let:

X_t denote the net cash flow, taking into account the benefit payments, expenses and contributions, but excluding investment income and capital gains;

L_t denote the value of liability;

$I_{s,t}$ denote the accumulated value of £1 over the time period $[s, t]$ as per the investment strategy of the pension fund;

$D_{s,t}$ denote the present value at time s of £1 payable at time t, so that $D_{s,t} = I_{s,t}^{-1}$;

where $0 \leq s \leq t \leq T$.

To start, let us first assume no formal capital requirement for pension schemes so that sponsors are allowed to run schemes with just enough assets backing the liabilities. This assumption is an idealised version of the current regulatory environment, in which depending on the surplus (or deficit) status of the pension scheme, a sponsor is allowed contribution holidays (or required to meet any deficits), although an extended amortisation period may be allowed.

Based on this simplified assumption that any surplus (or deficit) can be released (or injected) immediately, the "profit vector", P_t, at every valuation date $t = 1, 2, \cdots, T$, is defined as:

$$P_t = L_{t-1}I_{(t-1,t)} - X_t - L_t,$$

along with an assumption that, P_0, the excess assets at time 0 which can be released, is known. Note that the profit vector, P_t, is an additional amount, that can be released to (or injected from) the sponsor, on top of the standard contributions already included in the net cash flow X_t.

The profit vector, P_t, leads to two related concepts:

$R_t = \sum_{s=0}^{t} P_s I_{s,t}$ quantifies the amount of accumulated "retained profits" until time t, if the scheme surplus (or deficit) is allowed to build up as a fund;

$V_t = \sum_{s=t+1}^{T} P_s D_{t,s}$ quantifies the present "value of future profits" at time t, taking into account the profit vector emerging over $[t+1, T]$.

R_t and V_t are related through the following result, to be utilised later:

$$(R_t + V_t)D_{s,t} = R_s + V_s, \; \forall \, 0 \leq s \leq t \leq T.$$

2.3.2 Economic capital calculation for USS

For an individual pension scheme, like USS, we make a strong, but prudent, assumption that a sponsor will not build up a buffer fund from retained profits, R_t. This is a realistic assumption because unless it is obligatory, a sponsor will prefer to run a pension scheme with just enough assets to back the scheme liabilities and deploy any spare assets strategically elsewhere within the business.

On this assumption, the solvency of a pension scheme depends entirely on the existence and willingness of the sponsor to meet any deficits arising over the assessment horizon, which is not necessarily guaranteed. In particular, default of a sponsor when $V_t < 0$ implies that the pension scheme will not be able to meet all of its future obligations. The problem is most acute if the sponsor defaults when the discounted present value of future losses is maximum.

To guard against such an eventuality, and in absence of any buffer of retained profits, an amount of capital, C_t, defined as:

$$C_t = \max\left[-\min_{s=t}^{H} V_s D_{t,s}, 0\right],$$

needs to be set aside at time t $(0 \leq t \leq H)$ in a separate capital fund. (The minimum value of zero ensures that the capital fund is not negative.) The above formulation of C_t aims at making the pension scheme self-sufficient even if the sponsor defaults at the most inopportune time for the scheme.

To illustrate, let $(\min_{s=t}^{H} V_s D_{t,s})$ be negative and the minimum occurs at time, τ, $(t \leq \tau \leq H)$. Now, if the sponsor defaults at time τ, the accumulated value of the capital fund, $C_t I_{t,\tau}$, will just be enough to offset the negative V_τ, i.e. $C_t I_{t,\tau} + V_\tau = 0$, ensuring that the pension scheme will still be able to fulfill all its future obligations.

If the sponsor does not default over $[t, t+1]$, any excess capital, $(C_t I_{(t,t+1)} - C_{t+1})$, is released back to the sponsor at time $(t+1)$. However, note that, if $t+1 < \tau$, then $C_t I_{(t,t+1)} - C_{t+1} = 0$, implying that no capital is released over the period $(t, \tau]$, as capital is accumulated to meet the eventuality that the sponsor might default at time τ. A certain amount of capital will be released at time $(\tau + 1)$ as a smaller amount of capital is needed to meet $(\min_{s=\tau+1}^{H} V_s D_{t,s})$ over $[\tau + 1, H]$.

This algorithm is applied over the period $[0, H]$ to calculate capital requirement and release until the end of the assessment horizon. Note that this approach ensures that once the initial capital, C_0, is set up at time 0, no further capital injection is required over the assessment horizon.

At the end of the assessment horizon H, $C_H = \max(V_H, 0)$, provides protection against sponsor default only at time H. So, if $H < T$, C_H may not be adequate if the sponsor defaults over the period $(H, T]$. This is a major drawback of an assessment horizon shorter than run-off.

In summary, the above approach requires a sponsor to set up a separate capital fund with an initial capital C_0 in addition to regular contributions to the pension scheme assets. If the sponsor does not default over the assessment horizon, it releases (or injects) profit vector, P_t, from (into) the pension scheme to maintain pension scheme assets to be equal to the scheme liabilities. In addition, capital is released periodically from the capital fund as and when it is not required. If the sponsor defaults during the assessment horizon, the capital fund, as calculated above, ensures that the pension scheme is able to meet all its future obligations. A schematic diagram of all the cash flows are shown in Figure 2.1.

So far we have developed our formulation based only on a single realisation of the future. Generalising the notion to multiple realisations, provides a distribution of capital requirements, C_t, at each time t, over the assessment horizon $[0, H]$. Economic capital requirement at time t is then defined as $\rho(C_t)$, where $\rho(\cdot)$ is a specific risk measure. For the purpose of this thesis, we have only considered the Value-at-Risk measure. So, economic capital, $\rho(C_t)$ at confidence level p, signifies the amount of capital required at time t, to ensure that the pension scheme remains solvent over the specified assessment horizon with probability p under multiple projections of the underlying stochastic model.

We calculate economic capital by projecting the asset, liability level as

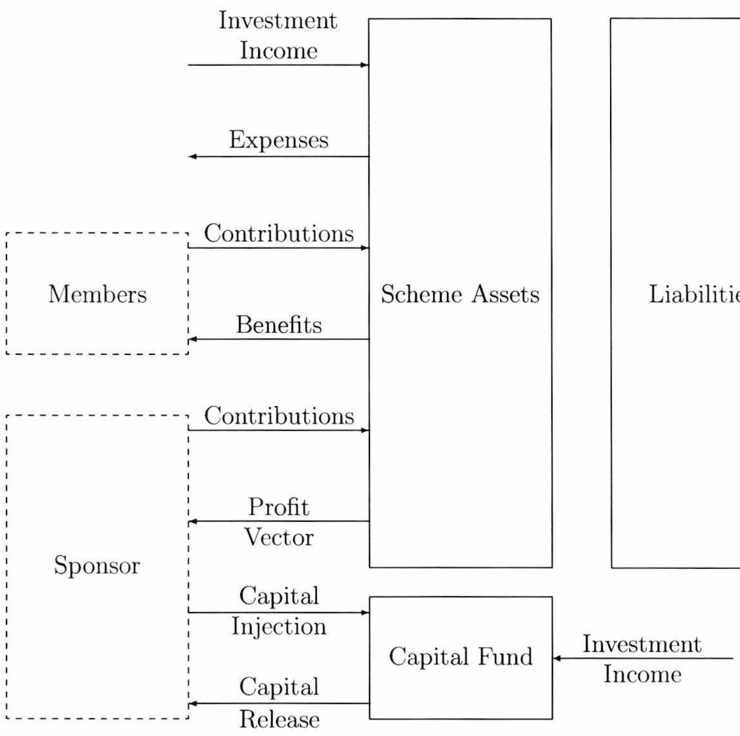

Figure 2.1: The cash flow structure.

well as the cash flows of the pension scheme till run-off. For each single realisation of possible future path, we calculate the capital required to ensure the pension scheme is solvent at each time point for this simulation. The economic capital, can be found as the 99.5th percentile of capital requirement across simulations. As a result, our economic capital is based on the capital requirement calculated from every single simulations. Each simulation will generate a sequence of capital requirement from time 0 till the run-off of the pension scheme. After 10,000 simulations over 80 years for example, we will obtain an matrix of capital requirement with size $10,000*80$. Our economic capital for each year is the percentiles of capital requirements across simulations.

It is important to note here that $\rho(C_t)$, as defined above, provides an unconditional economic capital requirement at time $t \geq 0$ based only on the information available at time 0. Ideally, we would like to compute $\rho(C_t|F_t)$ where F_t denotes filtration or history up to time t. However this is beyond our current computing power because even in an annual binomial tree set-up it would require capital calculation for 2^{90} nodes, if projecting over 90 years (note that economic capital calculation is path dependent).

However, to check the difference between the unconditional and conditional approaches, we have computed economic capital at the 95^{th} percentile level for USS, using the unconditional $\rho(C_{20}) = \rho(C_{20}|F_0)$ approach and 100 random samples of conditional $\rho(C_{20}|F_{20})$ where the random samples denote 100 different realisations leading to time 20. Figure 2.2 shows $\rho(C_0)$ as the horizontal line at £33 billion along with 100 $\rho(C_{20}|F_{20})$'s presented in descending order for ease of comparison. As can be seen from the figure, about 4 out of 100 $\rho(C_{20}|F_{20})$ exceeds $\rho(C_{20})$ which is approximately what is expected at the 95^{th} percentile economic capital level.

2.3.3 Economic capital calculation for PPF

The calculation of economic capital for PPF requires simple adaptations of the above concepts. For example, the net cash flow X_t would now include, in addition to expenses, PPF compensations for schemes transferred to the PPF, PPF levies from eligible schemes along with scheme assets transferred into the PPF. Most importantly, the assumption of non-inclusion of retained profit to calculate USS economic capital needs to be dropped, as

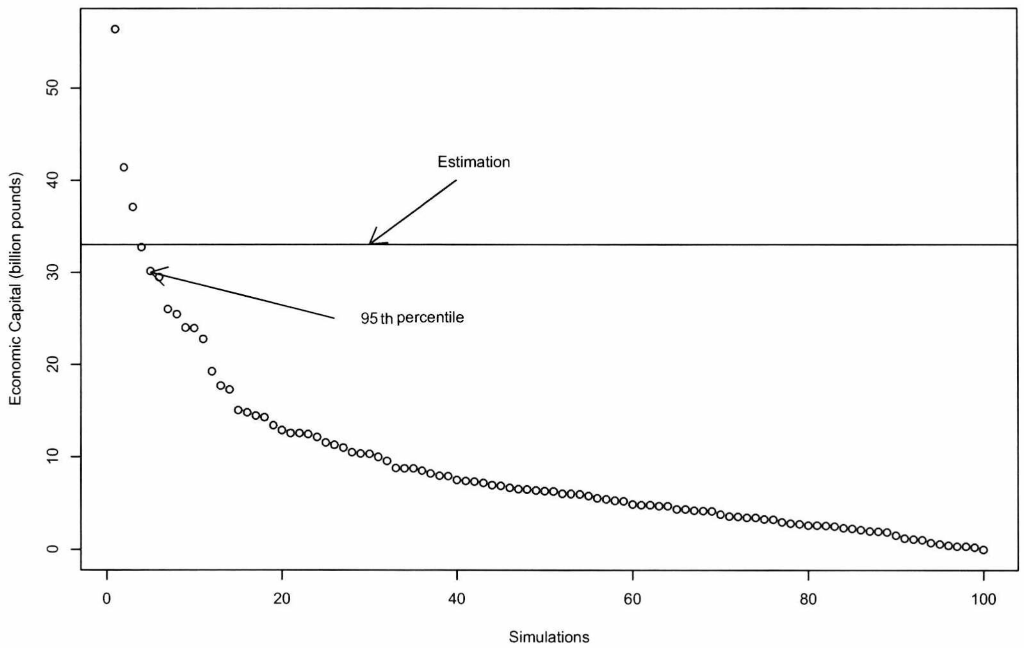

Figure 2.2: Comparison between economic calculation methods.

the main purpose of PPF is to be develop a self-sustainable fund over time through accumulation of collected levies. We also ignore future profits in our calculations as we use a fully retrospective approach.

Taking these into account, the revised formulation of capital requirement for PPF over a single realisation is as follows:

$$C_t = \max\left[-\min_{s=t}^{H} R_s D_{t,s}, 0 \right].$$

In other words, the capital requirement for PPF ensures that there is enough assets in the capital fund to cover the maximum accumulated loss over the assessment horizon, i.e. the total assets, including capital funds, is adequate to back the underlying liabilities.

Once the initial capital is injected at time 0, any excess capital is released in the same way as in Section 2.3.2, i.e. $(C_t I_{(t,t+1)} - C_{t+1})$ is released at time

$(t+1)$. Note again that if τ is the time where $(\min_{s=t}^{H} R_s D_{t,s})$ is minimum, no capital is released over the period $[t+1, \tau]$, followed by a release at time $(\tau+1)$. This algorithm is followed over the entire assessment horizon $[0, H]$ to calculate capital requirement and release as in Section 2.3.2. A schematic diagram of all the cash flows relevant for PPF is shown in Figure 2.3.

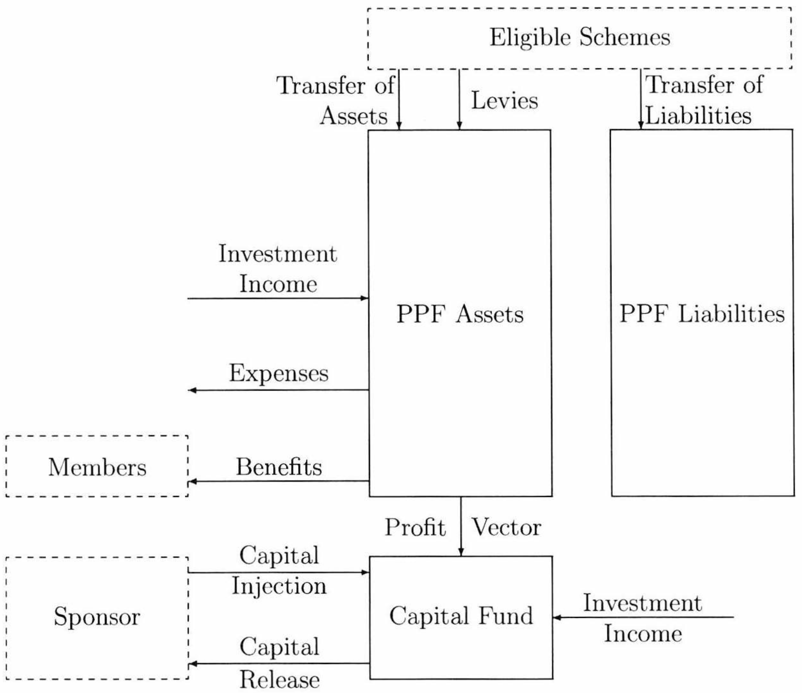

Figure 2.3: The cash flow structure for PPF.

Chapter 3

Economic and Demographic Models

As mentioned in Chapters 1 and 2, we adopt a fully stochastic framework in order to quantify economic capital based on VaR. In this chapter, we will discuss the relevant economic and demographic stochastic models.

3.1 Economic Model

For the economic variables, a number of stochastic economic models could have been used to simulate future economic scenarios. One possibility is Wilkie's model from Wilkie (1986) where Retail Price Index (RPI) , share dividend, share yield and Consols yield are modelled using autoregressive time series. Wilkie (1995) introduced more economic variables namely wages index, short-term interest rates, property rentals, property yields and index-linked stock yields. The Wilkie models have been widely used in actuarial work.

In this thesis, we adopt the stochastic economic model proposed in Porteous and Tapadar (2005). This model is relatively straightforward, whilst still capturing the key features of the systems they are modelling. Porteous and Tapadar (2005) also provide evidence that their model generates economic capital amounts similar to those determined by an equivalently calibrated Wilkie (1995) model, which has been very extensively tested and used for modelling economic variables, in many circumstances, over many years.

The structure of Porteous and Tapadar (2005) is shown in Figure 3.1. In total 21 economic variables were included in this model.

Porteous and Tapadar (2005) denotes Z_{it} for asset returns which is the i-th response variable at time t. Z_{it} consists of two parts: μ_i which is the unconditional expectation and a first order autoregressive time series with constant volatility Y_{it}. This relationship can be defined as follows:

$$Z_{it} = \mu_i + Y_{it}, \text{ where}$$

$$Y_{it} = \beta_i Y_{i(t-1)} + \varepsilon_{it},$$

and β_i is the autoregressive parameter. The error terms $\varepsilon_{it} \sim N(0, \sigma_i^2)$ are assumed to be independently distributed across time t.

Based on this formulation, the conditional expectation of Y_{it} is $\beta_i Y_{i(t-1)}$ and the conditional variance is σ_i^2. The unconditional expectation of Y_{it} is 0 and the unconditional variance is $\frac{\sigma_i^2}{(1-\beta_i^2)}$.

Table 3.1 shows the parameterization of the individual economic random variables, the annual expected values, μ_i, and the annual unconditional standard deviations, $\frac{\sigma_i}{\sqrt{(1-\beta_i^2)}}$. The model variables have been parameterized using an analysis of the global historical financial data provided by Dimson and Marsh (2001) where statistics are provided for UK financial assets including equities, bonds, bills, and inflation based on historical data from 1955 to 2000.

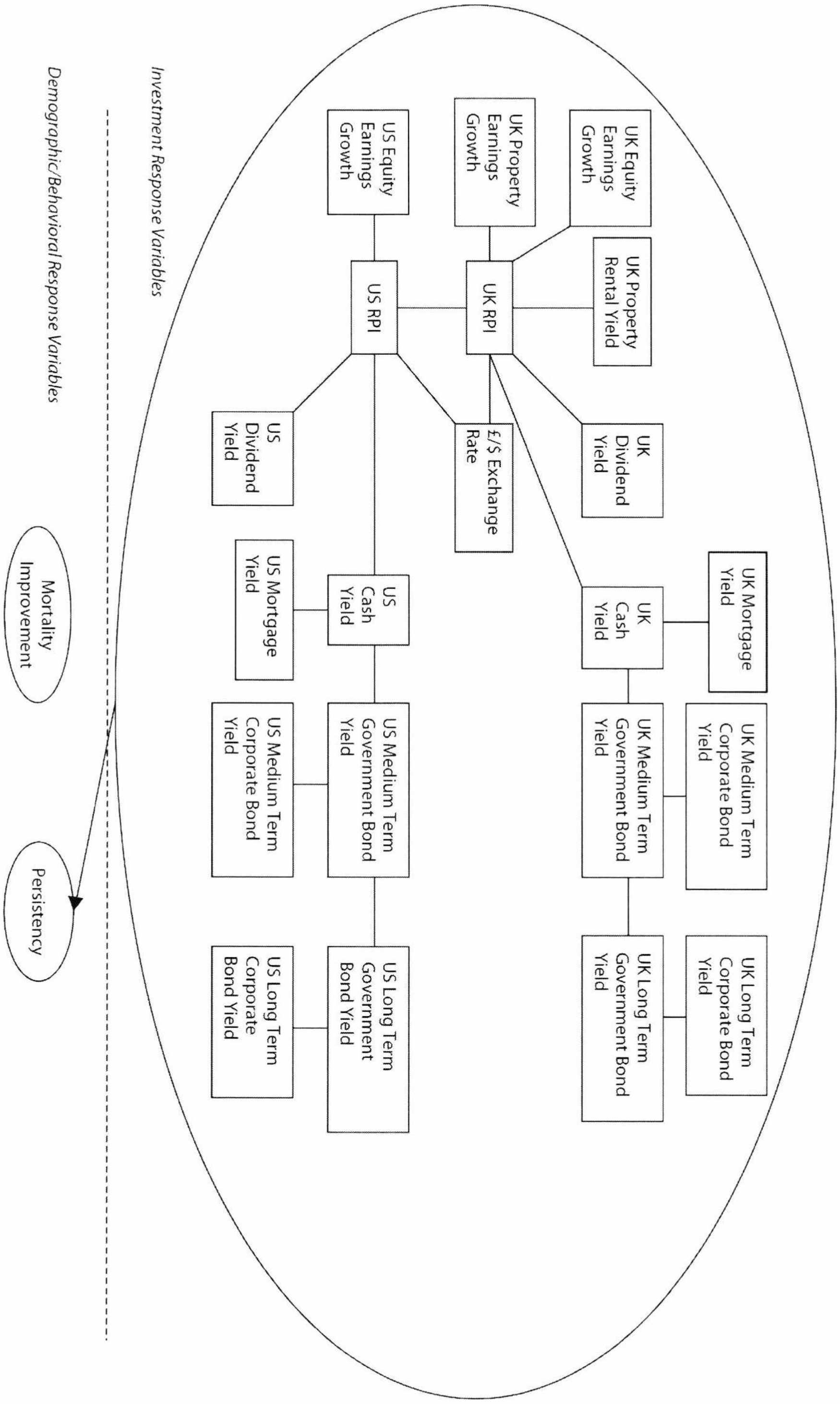

Figure 3.1: The stochastic model of Porteous and Tapadar (2005).

Table 3.1: Stochastic model parameterization.

	Investment Response Variable	Unconditional expectation μ_i	First order autoregressive parameter β_i	Unconditional standard deviation of error terms $\sigma_i/\sqrt{1-\beta_i^2}$
	UK Economic			
1	Retail Price Inflation ("RPI")	0.0275	0.975	0.00750
2	Equity earnings/dividend growth	0.0425	0.950	0.02000
3	Equity dividend yield	0.0325	0.975	0.00750
4	Short-term cash yield	0.0475	0.975	0.00750
5	Medium-term government bond yield	0.0500	0.975	0.01875
6	Medium-term corporate bond yield	0.0550	0.975	0.01875
7	Long-term government bond yield	0.0525	0.975	0.01875
8	Long-term corporate bond yield	0.0575	0.975	0.01875
9	Mortgage yield	0.0575	0.975	0.00750
10	Property rental growth	0.0325	0.950	0.01875
11	Property rental yield	0.0425	0.975	0.00750
12	£ appreciation against $	0.0200	0.000	0.02500
	US economic			
13	Consumer Price Inflation ("CPI")	0.0200	0.975	0.00750
14	Equity earnings/dividend growth	0.0625	0.950	0.02000
15	Equity dividend yield	0.0200	0.975	0.00750
16	Short-term cash yield	0.0200	0.975	0.00750
17	Medium-term government bond yield	0.0375	0.975	0.01875
18	Medium-term corporate bond yield	0.0425	0.975	0.01875
19	Long-term government bond yield	0.0450	0.975	0.01875
20	Long-term corporate bond yield	0.0500	0.975	0.01875
21	Mortgage yield	0.0425	0.975	0.00750

The correlation structure of the error terms is modelled using a graphical model, as displayed in Figure 3.1. As shown in this figure, economic random variable error terms that are directly connected to each other are dependent, with the assumed constant correlation coefficient values ρ_{ij} set out in Table 3.2. Economic random variable error terms that are indirectly connected in Figure 3.1, via other directly connected error terms, are still statistically dependent, but more weakly so. Such error terms are, however, conditionally independent of each other, given the error terms that connect them, this being a property of graphical models.

Graphical models, fully described in Lauritzen (1996) and Porteous and Tapadar (2005), are useful dimension reduction tools that can be used to

Table 3.2: Stochastic model correlation coefficients of error terms.

ε-pair	Correlation coefficient ρ_{ij}
1,2	0.1
1,3	0.3
1,4	0.6
1,10	0.1
1,11	0.3
1,12	0.6
1,13	0.3
4,5	0.6
4,9	0.6
5,6	0.6
5,7	0.6
7,8	0.6
12,13	0.6
13,14	0.1
13,15	0.3
13,16	0.6
16,17	0.6
16,21	0.6
17,18	0.6
17,19	0.6
19,21	0.6

explain very high dimensional dependency relationships amongst random variables using low dimensional clusters, or cliques.

To use this model we need to simulate the core variables of the model which are the UK RPI, US RPI and the £/$ exchange rate. These three response variables are all connected to each other. The simulation of the three dimensional multivariate normal random error terms can be done using the Cholesky decomposition approach. Conditional on these error terms, the error terms of response variables directly connected to the core variables can then be generated one by one following the arrows as shown in graph 3.1. Following this method iteratively, we can obtain the error terms of all the 21 response variables.

For the purpose of modelling pension schemes, we use a subset of Porteous and Tapadar (2005) graphical model as shown in Figure 3.2. In order to introduce a variable capturing salary index within the graphical model, we have created a new response variable, UK salary growth, and linked it directly to the UK RPI as shown in Figure 3.2. The relevant additional parameters are estimated using UK national statistics (http://www.statistics.gov.uk) whereby the unconditional mean salary growth is set at 4.25% per year, the unconditional autoregressive variable is 0.975, the standard deviation of error terms is 0.0075 and the correlation coefficient between the UK RPI and UK salary growth is 0.8.

The mechanism of producing total return index from bond yield is included in Appendix E. The equity total return index is derived from calculating the price per share from equity earning growth and dividend yields.

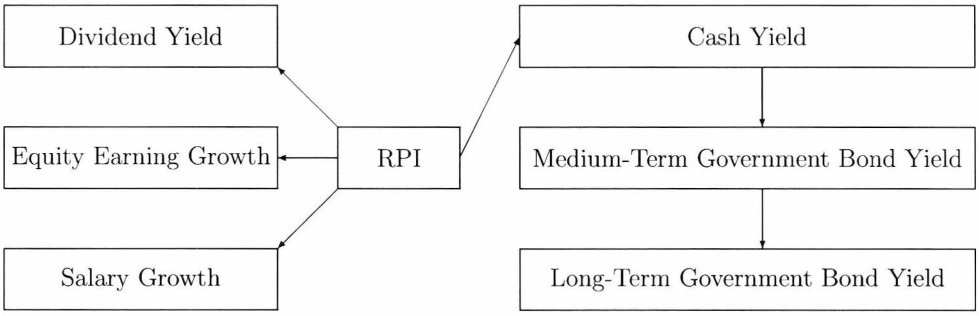

Figure 3.2: The subset of Porteous and Tapadar (2005) graphical model adopted in this thesis.

3.2 Mortality Model

In this section, we introduce the stochastic mortality model which is used in conjunction with our economic model from the previous section.

The key component of a stochastic mortality model is the rate of mortality improvement. Mortality studies in the UK have extensively documented the cohort, age-related and period-related improvement effects for both males and females. However, actual experience of mortality improvement rates have been much higher than expected, particularly in older age-groups, leading to major uncertainties in determining pension scheme costs. Willets *et al.* (2004) provides a detailed analysis of mortality improvements, mortality trends and cohort effect. It is important for a mortality model to capture the current shape of mortality rates and anticipate future mortality improvement.

Our approach to modelling mortality improvement is to start with the base mortality tables PMA92Base and PFA92Base, for males and females respectively, published by the UK Actuarial Profession in their Continuous Mortality Investigations (CMI) Working Paper 1 (CMI (2002)). We then project the base tables forward to the starting point of our pension model (2008 for the USS and hybrid pension scheme, 2010 for the PPF) using middle cohort improvement factors for these tables published in CMI Working Paper 37 (CMI (2009)). These projected mortality tables are used to represent the mortality rates for people in different age groups at the start of the projection period. Although more recent mortality tables are available from the CMI, this approach is consistent with the mortality assumptions used in the USS 2008 valuation.

Future stochastic mortality is then handled using the approach of Sweeting (2008a) who has developed a pragmatic method of modelling stochastic uncertainty around the central mortality projection. Specifically, if $q_{x,f}$ denotes the central projection of mortality rate for future year f and age x, the logit of central mortality rate is defined as:

$$lq_{x,f} = \ln\left(q_{x,f}/(1 - q_{x,f})\right).$$

Then the logit of the stochastic mortality rate, modelling future uncertainty, is defined as:

$$LQ_{x,f} = lq_{x,f} + A_{x,f}, \quad \text{where } A_{x,f} = \sum_{k=0}^{f}(0.262 - 0.00358x)Z_k,$$

and Z_k are independent standard normal variables.

Sweeting (2008a)'s proposed stochastic mortality fluctuations are based on England and Wales male lives aged 50 to 90. We have used the same approach for all members in our model.

As evidenced in Cairns *et al.* (2009), and references therein, there is a very rich literature on stochastic mortality models and any of these models could have been used in our modelling work. However, it is not the purpose of this thesis to compare and contrast different stochastic mortality models, but rather to investigate pension scheme economic capital. We defer the investigation of the impact of different mortality models on economic capital for future work.

By using economic model in conjunction with the mortality model, economic capital can be produced by allowing for both investment risks and mortality risks together. The interactions and possible diversification benefits are included in our economic capital automatically by using this set-up. This model framework can take most of the available information from both economic and demographic part to produce results reflecting the risks faced by a pension scheme or the PPF at any time point.

Other mortality and economic models like the Wilkie (1986), Wilkie (1995) economic models and Cairns-Blake-Dowd stochastic mortality models (Cairns *et al.* (2009)) can also be easily employed in our model. The effect of different models on pension scheme economic capital, is deferred for future investigation.

Chapter 4

Universities Superannuation Scheme

As set out in Chapter 1, we will first focus on the risk quantification of an individual DB pension scheme using economic capital. The USS is used as an example to show how economic capital concepts can be applied.

This chapter includes the following sections. In Section 4.1, we discuss relevant literature reviews focused on individual pension scheme risks. In Section 4.2, we provide a brief introduction of USS. In Section 4.3, we set out assumptions for the USS model. In Section 4.4, economic capital for USS is quantified to demonstrate the usefulness of economic capital as a risk management tool for DB pension schemes. In Section 4.5, we summarise our findings.

4.1 Literature Review

There has been much recent research carried out on the very topical area of pension scheme risk management. A brief summary of the relevant latest research is given below.

Olivieri and Pitacco (2003) investigated a life insurance firm selling immediate annuities. The focus of Olivieri and Pitacco (2003) was primarily to analyse longevity risk prevalent in pension annuities, using a simple Vasicek interest rate model to reflect fluctuations in the investment market. As a consequence of the simplicity of their assumed interest rate modelling, the aggregate effect of longevity and financial risks were not fully reflected in their economic capital. Further, as the functioning and complexity of a full DB pension scheme is not captured only by immediate annuities, we provide a much more comprehensive analysis in this chapter by considering all scheme members in our study - active, deferred, pensioners and dependants.

Blake *et al.* (2001) used a variety of stochastic models to assess the VaR for a pension scheme during the accumulation phase (before retirement) by simulation method. They considered the pension risk for scheme members as how much pension they are going to get after retirement. The pension payments after retirement are valued as a single premium annuity priced at the member's retirement age. One of the key findings is that the VaR for members is very sensitive to the choice of asset-allocation strategy and the form of benefit given. They also concluded that conservative bond-based asset-allocation strategies require substantially higher contribution rates than more risky equity-based strategies. Our findings in this thesis also suggest that bond-based asset-allocation strategies will not generate enough return for salary and inflation linked type of benefits. An investment mix of bond and equity can achieve better result than pure bond or equity investment in terms of economic capital.

Sweeting (2008b) investigates the cost and value of UK DB pension provision and proposes a combination of increasing retirement age and lowering post-retirement incomes as possible solutions to deal with the increasing cost of DB schemes. The author concentrates on expected costs and their sensitivities, but we believe that an economic capital approach, incorporating the full stochastic and multivariate nature of the economic and demographic variables that affect DB pension schemes, is needed to provide greater insight into the risks associated with DB pension schemes.

Olivieri and Pitacco (2008) investigate solvency requirements for immediate annuities based on the Heligman and Pollard (1980) law for mortality rates and a fixed annual interest rate of 3%. The authors find that, for 65 year olds, the solvency requirement at the 99.5th percentile level is 10% of best-estimate liabilities, on a run-off basis. For shorter time horizons, the requirements are lower. However, we are going to incorporate the actual investment strategy in a real pension scheme to estimate the solvency requirement of a pension scheme. In this thesis, we include both the accumulation phase and the pension phase into the risk assessment.

Hari *et al.* (2008) have investigated the effect of longevity risk for pension annuities based on the Dutch population experience, both in isolation and in conjunction with market risk. The authors used a generalised two-factor Lee-Carter model for longevity risk, a mean-reverting process for interest rates and a simple random walk with drift for excess equity returns. They observed that when market risk is perfectly hedged, longevity risk economic capital, at the 97.5th percentile level for 5-year time horizon is 10% of market consistent liabilities, if the age and gender distribution reflects the entire Dutch population. When market risk is included, with 50% equity content, the combined market and longevity risk economic capital substantially increases to 33% of market consistent liabilities.

Stevens *et al.* (2009) analysed the longevity risk in a portfolio of annuity products based on the Dutch population. This was done on a run-off basis and it was found that joint-life annuity economic capital at the 97.5th percentile can range from 20% of best-estimate liabilities, for a cash flow matched hedging strategy using zero-coupon bonds, to as high as 88% of best-estimate liabilities if assets are invested solely in one-year default-free zero-coupon bonds. The authors also reported a significant increase in economic capital if assets are heavily invested in equities. However, the authors take a short-term approach to their economic capital calculation, with the maximum time horizon investigated being 5 years. In this thesis, we take the view that risks inherent in pension funds can take a longer time to manifest themselves and advocate a run-off approach for analysing assets and liabilities, until the last existing member leaves the scheme. This long-term approach implies a significant increase in risk as it considers the impact of extreme events, or tail risk, over this longer period of time.

Boerger (2010) investigates the adequacy and appropriateness of longevity risk capital in the Solvency 2 Standard Solvency Capital Requirement (SCR) which is defined as a flat 25% reduction in mortality rates in annuity portfolios, and tested in the Quantitative Impact Study 4 exercises. The author compares the Standard model results with a 99.5th percentile VaR approach, based on a modified version of the forward mortality model introduced by Bauer *et al.* (2008) and Bauer *et al.* (2010). The assets were assumed to be invested in risk-free assets. For a representative portfolio of annuities, the Standard SCR produced was 5.7% of best-estimate liabilities.

Liu and Tonks (2009) have produced models to quantify the risks of financial distress for UK Higher Education Institutions contributing to the USS and compared them with the annual risk-based levy imposed by the PPF. The authors found that the USS is paying less than the fair risk-based levy and that there are significant cross-subsidies between participating USS institutions. However, in this thesis, we model USS as a whole and come up with an aggregate figure as the estimation of risk. The effect of cross-subsidies between participating USS institutions and whether the premiums are fairly charged by comparing institutions are not discussed.

Our economic capital approach differs from the Solvency II approach as our approach requires that economic capital is sufficient to ensure that assets cover best-estimate liabilities, rather than market consistent liabilities, over the entire duration of the lifetime of in-force contracts, rather than Solvency 2's one year own funds value at risk movement requirement. We are planning to use economic capital as the measure of risk to estimate the risk associated with an individual final salary DB pension scheme. An insurance firm balance sheet asset liability management approach is adopted to see how much economic capital is required if the occupational pension scheme is regulated as an insurance firm.

In this thesis we take the view that the protection and security of a DB pension scheme's members in respect of their accrued benefits should be provided from within the scheme itself. There should be no explicit reliance on the scheme sponsor to provide this protection in times of stress. The security and protection of future benefits should, again, be provided from within the scheme itself.

4.2 Universities Superannuation Scheme

The USS was established in 1974 to administer the principal pension scheme for academics and administrative staff in UK universities and other higher education and research institutions. In 2008, it was one of the largest open DB pension schemes in the UK. Based on the information available from the full triennial actuarial valuation on 31 March 2008, and associated published financial reports and accounts, USS is a multi-employer scheme covering 391 participating employers. Membership statistics are provided in Table

4.1 from the Actuarial Valuation Report as at 31 March 2008 (USS (2008)). For comparison purposes, in Table 4.1 we have also included membership statistics for all UK DB pension schemes and open DB pension schemes from The Purple Book 2009 (The Pension Protection Fund and The Pensions Regulator (2009)).

Table 4.1: Membership statistics of USS, all UK DB pension schemes and all UK open DB pension schemes.

Membership status	USS	All UK DB schemes (millions)	All UK open DB schemes (millions)
Active members	130,450	2.74	1.56
Deferred members	76,104	5.23	1.99
Pensioners	40,945	4.43	1.92
Dependants and children	8,951	–	–
Total	256,450	12.40	5.48

These figures show that USS has more than 8% of all active members of open UK DB pension schemes, but only 2% of pensioners (less than 1% if closed schemes are also considered). This is because USS was only established in year 1974 and it has not yet achieved a stable membership distribution. As most members are active, USS can be considered a relatively young pension scheme.

In the following subsections, we will provide a broad outline of USS based on the detailed scheme rules which are available on the USS website: http://www.uss.co.uk/.

4.2.1 Benefit Structure

USS is a final salary DB pension scheme with normal retirement age 65 for males and 60 for females in year 2008. Pensions and cash lump sum benefits on retirement are calculated using an accrual rate of 1/80th as follows:

$$\text{Annual pension} = \text{Accrual rate} \times \text{Pensionable service} \times \text{Pensionable salary};$$

$$\text{Lump sum} = 3 \times \text{Annual pension}.$$

Pensionable service denotes the duration of employment in one or more USS participating employers. Pensionable salary is the highest revalued annual salary during the last three years, or the highest revalued salary averaged across any three consecutive "best years" over the last 13 years, whichever is higher. For the sake of modelling simplicity, we have made the assumption that pensionable salary is the salary in the very last year of a member's employment, which will be true for a member with no unusual fluctuations in salary in the last few years prior to retirement. The annual pension is increased in line with RPI every year.

Although the scheme allows for both early and late retirement, we have not modelled these explicitly, but have assumed a modelled retirement age of 62 for both males and females which is consistent with 2008 actuarial valuation report assumptions.

In addition to salary inflation, an explicit age-based promotional salary increase scale is assumed in the USS 2008 valuation, as shown in Table F.1.

Table 4.2: Key USS 2008 valuation assumptions.

	Salary scale		Withdrawal rates		Proportion married	
Age	Male	Female	Male	Female	Male	Female
25	–	–	14.42%	19.28%	34%	56%
35	3.8%	3.1%	9.19%	11.40%	81%	84%
45	2.0%	1.8%	3.79%	3.83%	92%	93%
55	1.1%	1.4%	–	–	–	–

For members who have withdrawn from the scheme, deferred RPI linked pension benefits are provided based on accrued service on withdrawal. RPI indexation of salaries between the date of leaving and retirement is provided. Annual scheme withdrawal rates, as extracted from the 2008 valuation report, are reproduced in Table F.1.

Apart from pension benefits, USS also provide benefits on death of a member. Scheme death benefits are as follows:

- For active members, death in service benefits comprise a lump sum payment of three times annual salary and a spouse's pension of half the pension the member would have received if the member had survived until normal retirement.
- On the death of a deferred pensioner, a lump sum equal to the present value of the deferred lump sum payable at normal retirement age is provided along with a spouse's pension of half the amount of the deferred pension at date of death.
- On the death of a pensioner, a spouse's pension equal to half the member's pension is paid to the surviving spouse.

The 2008 valuation report assumes that wives are, on average, three years younger than their husbands. Assumed proportions of married members are provided in Table F.1, again extracted from USS scheme data.

The benefits payable to members' spouses or dependents after death are known as dependants' pensions. We have modelled these as well. However, the amount of dependants' pensions is relatively low compared to benefits for active members, deferred members and pensioners group.

4.2.2 Contributions

USS is a contributory scheme, with the 2008 actuarial valuation report recommending an employers' contribution of 16% and members' contribution of 6.35% of annual salary.

In our modelling work, where we model future contributions, we assume that these are constant. In practice, future contributions will tend to vary in line with actuarial advice, as it is received.

4.2.3 Investment

Given the relatively young membership profile of the scheme, with a low proportion of pensioners, USS currently pursues a fairly expansive investment strategy, with a high proportion of equity investment. Table 4.3 provides a summary of the USS current investment mix, as extracted from the USS Annual Reports and Accounts for 2008 and 2009.

Table 4.3: USS Investment Mix.

	2008		2009	
Assets	Actual	Benchmark	Actual	Benchmark
UK equities	36%	38%	32%	35%
Overseas equities	42%	38%	38%	35%
Alternative assets	4%	4%	9%	10%
Property	6%	10%	6%	10%
Total real	88%	90%	85%	90%
Fixed interest	9%	10%	10%	10%
Cash	3%	0%	5%	0%
Total fixed	12%	10%	15%	10%

From Table 4.3, it can be seen that a 90:10 asset split between real and fixed interest type investments is being followed and we will use this as our base assumption in our modelling work. For UK DB pension sector as a whole, the average investment in equity was around 50% at that time.

4.2.4 Expenses

We have assumed a per member administrative expense of £60 per annum increasing in line with RPI. The investment expenses are assumed to be 0.1% p.a. of the fund under management. These figures are consistent with the expenses reported in the USS Annual Reports and Accounts.

4.3 Assumptions

The membership profile used in our model is estimated from USS valuation report 2008. The USS has used deterministic discount rates for different memberships. They have also assumed future withdrawal rate, salary increase, mortality rates and so on, our assumptions are broadly consistent with USS valuation report 2008 in reproducing the membership profile. Valuation assumptions used in the USS valuation report 2008 can be found in Appendix F. Members are divided in four groups: active members, deferred members, pensioners and dependants.

We have represented the active member group using 4 model points as shown in Table 4.4. For simplicity, we have assumed a uniform distribution for active members across ages for the age groups 25–35, 36–45, 46–55 and 56–62 represented by ages 30, 40, 50 and 60 respectively.

Table 4.4: Model points representing USS active members.

			Annual salary	
Age	Number of members	Past service	Male	Female
30	35,257	5	£24,685	£23,069
40	35,257	9	£35,225	£30,912
50	35,257	13	£43,700	£37,515
60	24,680	17	£49,405	£43,366

The deferred members, pensioners and dependents groups are represented by single model points of ages 44, 70 and 73 respectively as shown in Table 4.5.

We have assumed a 50:50 split between males and females for all model points in our model.

Tables 4.5 and 4.6 compare the fit of the model points to the USS scheme and it can be seen from these tables that it is very good. In Table 4.6, accrued benefit PUM liabilities are calculated on the USS 2008 valuation basis. Dependants are not included in Table 4.6 as there is no USS data to compare our model point results against.

Table 4.5: Comparison of model points data with USS 2008 valuation data.

		Model points	USS 2008
Active members	Number	130,451	130,450
	Total pensionable salaries (£p.a.)	£4,872.2m	£4,950.3m
	Average pensionable salaries (£p.a.)	£37,350	£37,947
	Average age	43.8	43.7
	Average past service (years)	10.5	10.5
Deferred members	Number	76,104	76,104
	Total deferred pension (£p.a.)	£155.5m	£155.5m
	Average deferred pension (£p.a.)	£2,044	£2,044
	Average age	44	43.7
Pensioners	Number	40,945	40,945
	Total pension payable (£p.a.)	£709.5m	£709.5m
	Average pension (£p.a)	£17,329	£17,329
	Average age	70	69.8
Dependants	Number	8,057	8,057
	Total pension payable (£p.a.)	£73.5m	£73.5m
	Average pension (£p.a)	£9,117	£9,117
	Average age	73	72.5

4.4 Results

In this section, we quantify the economic capital requirement for USS under various scenarios. We follow the economic capital calculation method described in Chapter 2 together with the economic and demographic models

Table 4.6: Comparison of accrued benefit PUM liabilities between model points and USS valuation report 2008 on the USS 2008 valuation basis.

	Model points	USS 2008
Active members	£15,159.1m	£14,774.6m
Deferred members	£2,312.5m	£2,229.3m
Pensioners	£11,064.8m	£11,131.4m
Total	£28,536.4m	£28,135.3m

from Chapter 3 to produce results which are shown in a series of graphs for different scenarios. Unless otherwise stated, we value accrued benefits up to the valuation date only (the liability curves shows the liability level accrued up to the corresponding date).

4.4.1 Base Case

Using the assumptions set out before, we produce the economic capitals and liabilities for different model points starting from year 2008. We refer to the results in this subsection as the base case results.

Figure 4.1 shows economic capital amounts and best-estimate liabilities, for the four model points in the active members' group with different ages and for the deferred members' and pensioners' groups.

Figure 4.2 shows economic capitals and the best-estimate liability for the full USS model, aggregated for all USS model points.

We have not presented the results for the dependants' model point separately as they are relatively small compared to other model points. However, the results for the aggregated model points case as shown in Figure 4.2 include the dependants' model point.

The liability curves represent the mean best-estimated liabilities across all simulations. For example, the liability level at duration 20 for the age-

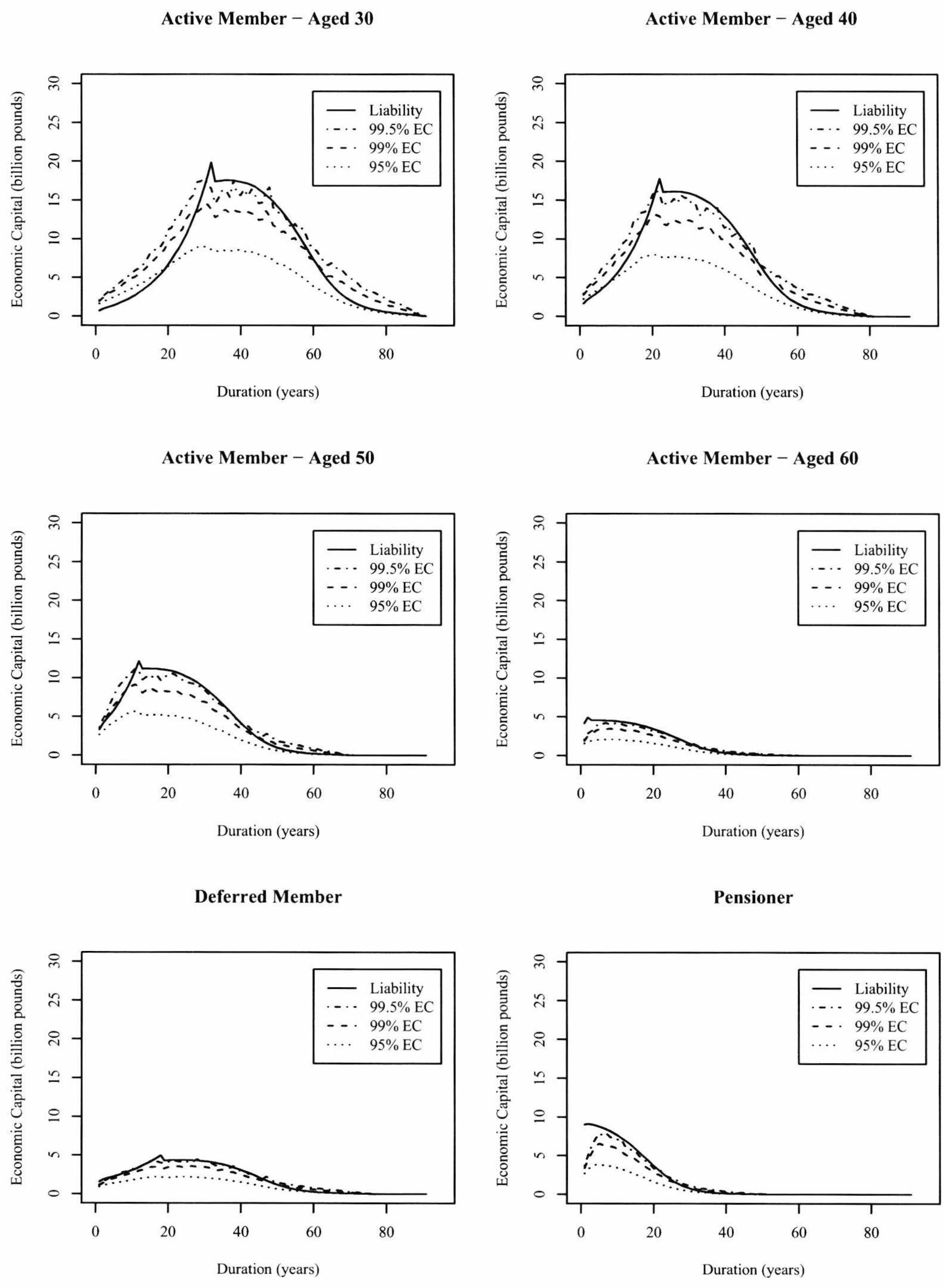

Figure 4.1: Base Scenario: Liability and economic capital for different member groups.

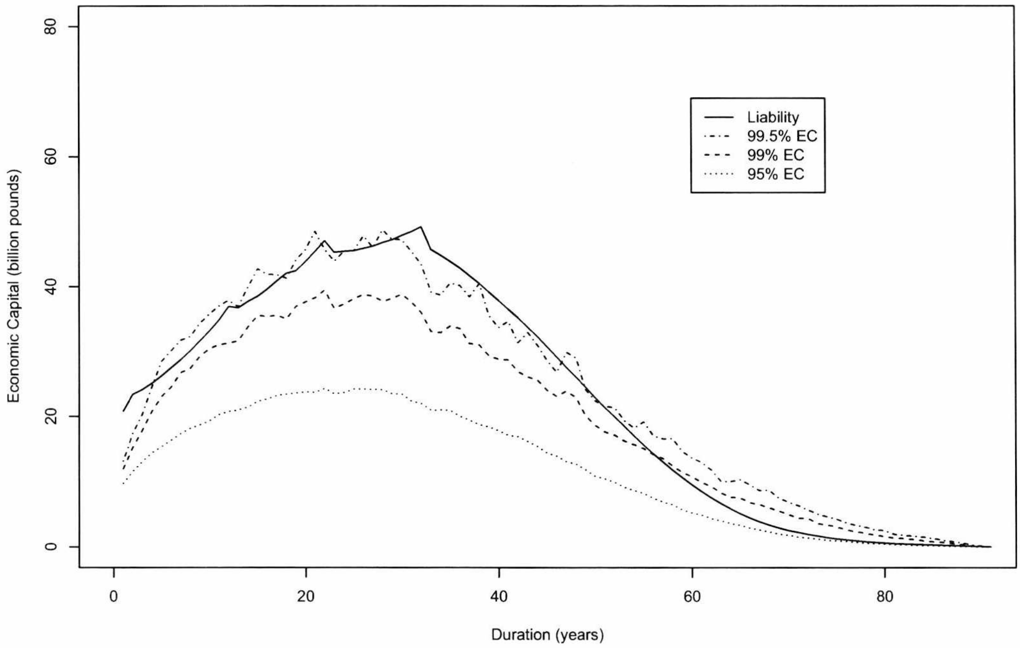

Figure 4.2: Base Scenario: Liability and economic capital for the full scheme.

group 30 represents the average liability level across simulations which have been accrued by members in this group by year 2028. Duration 0 corresponds to year 2008 and we use projections until the death of the last member.

We can see from these graphs that the liabilities of all active members initially increase with age as members accrue benefits till retirement. As active members become older, they build up their past service entitlements and the liabilities increase accordingly. Active members can also become deferred members or die. The liabilities for these members is also included. We can see from these graphs that the liability level reaches maximum value at retirement age where we value full accrued benefit levels at the retirement age. Note that the spikes in the best-estimate liability curves correspond to the cash lump sum paid on retirement.

The level of economic capital requirement at any time represents the level of risk for USS at that time. The economic capitals reach their maximum values around retirement age as the USS is liable to pension entitlements of all past services from this time onward. Contributions before retirement age and discount factors make the economic capital requirements at earlier durations lower. The economic capital amounts and best-estimate liabilities tail off to zero because the aggregate member benefit reduces over time as each member ages and eventually dies.

We can see from these results that for younger members, the economic capital requirements are relatively large compare to older members. This is due to the following reasons:

- The benefits for younger members have longer duration which results in a higher degree of uncertainty both for future asset returns and mortality improvements.
- They have more variation in salary growth.
- They have more uncertainty in inflation rates applicable on their pensions.

From graphs shown in Figure 4.1, it can be seen that economic capital for each group is large relative to the corresponding best-estimate liability. In other words, the amount of capital that is required to back these risks is considerable.

These graphs also show that the economic capital requirements for active members and deferred members are relatively higher than pensioners. It is because that the model points used for active and deferred members being younger than the model points for pensioners, the risks are higher due to greater uncertainty in future investment return, inflation, salary growth and mortality improvement.

Comparing active members against deferred members, the active members have potential to achieve high salary increases while deferred members have their benefit entitlement increasing only with RPI from the date of withdrawal.

The greater fluctuation in salary growth results in a higher economic capital requirement for active members. On the other hand, the contributions receivable on behalf of active members bring down the economic capital requirements. On balance the economic capital requirements for active members and deferred members are both significant compared to their liability levels.

From the aggregated economic capital and liability results it can be seen that USS economic capital is extremely large, starting at approximately to £13 billion, for 99.5th percentile economic capital, and peaking close to £48 billion. This is relative to best-estimate liabilities that start at around £21 billion and which peak at just over £49 billion. This aggregate economic capital is lower than the sum of economic capital requirement for each individual member groups which is around £15 billion. We can see a diversification benefit by providing economic capital for the scheme as a whole.

The main conclusion that can be drawn from these base case results, therefore, is that the amount of economic capital required to protect USS members is very large indeed.

4.4.2 100% Investment in Bonds

In this subsection we recalculate the base case results on the assumption that all USS assets are invested in government bonds. Throughout this thesis we always assume that the scheme invests only in 15 year government bonds and that the bond portfolio is sold and reinvested each month to preserve the 15 year duration assumption.

Results for each individual model point are shown in Figure 4.3. The main observations that we can make from Figure 4.3, relative to base case results, are that best-estimate liabilities increase fairly materially, but have broadly the same shape, whereas the economic capital results look very different.

Liabilities increase because they are discounted at a lower discount rate relative to the base case results, reflecting the lack of equity investment, and so increasing best-estimate liabilities. The lower discount rate reflects the fact that the mean returns generated from 100% bond investment are lower than these achieved for the investment mix of 90% equity and 10% bond.

The main differences in the economic capital results are that for active and deferred members, especially for younger ages, economic capital is much higher at the shorter durations and has a flatter shape, relative to the base case results. For active and deferred members this pattern is explained by the 15 year bonds being too short to match liabilities in the early years, and so increasing economic capital. For pensioners with shorter liabilities, the bonds are less volatile than equities, so reducing economic capital. Pensioners' economic capital is generally lower, but with the same shape as the base case because the term of this investment is similar to the pensioner's liability.

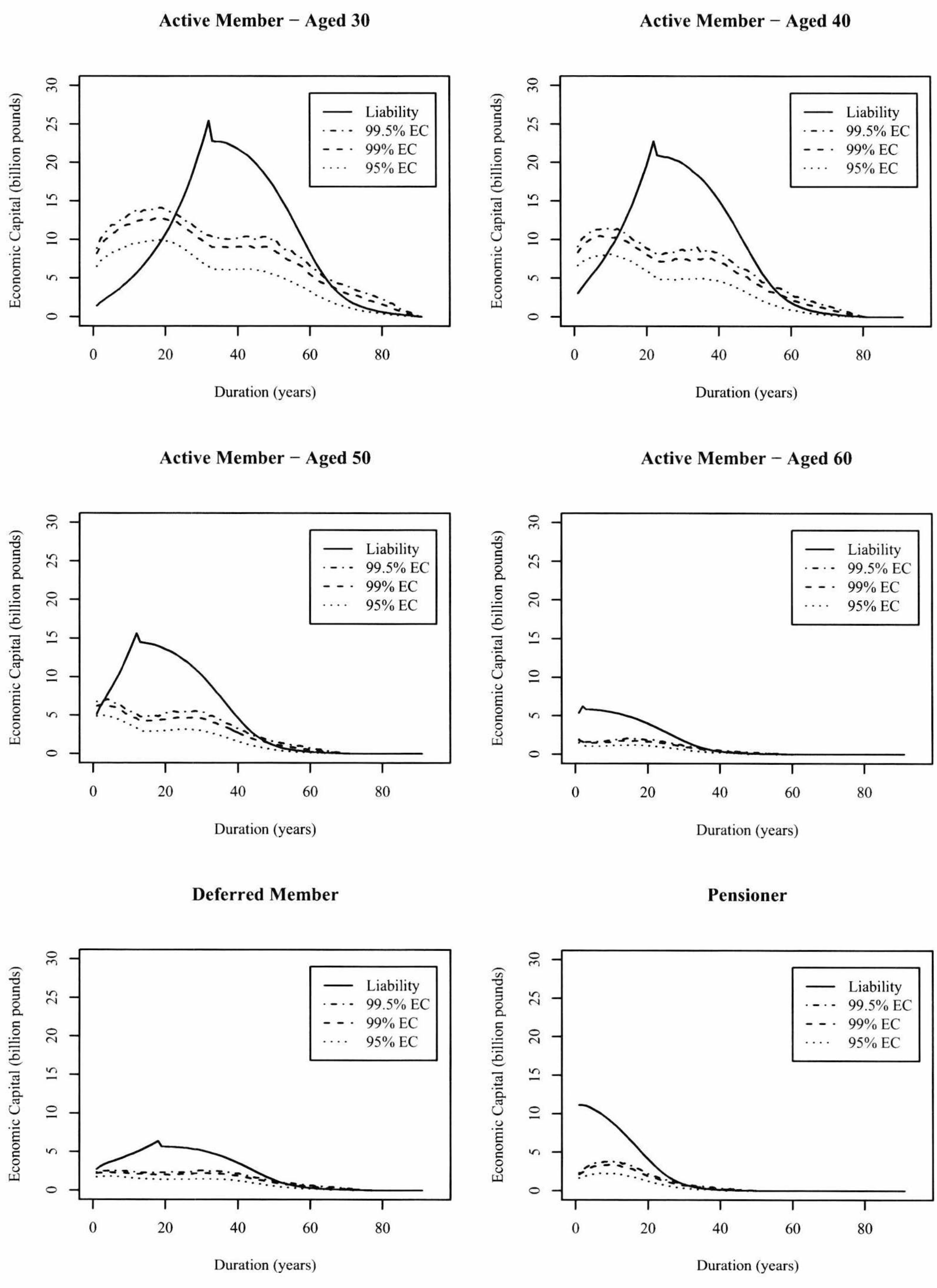

Figure 4.3: 100% investment in bonds: Liability and economic capital for different member groups.

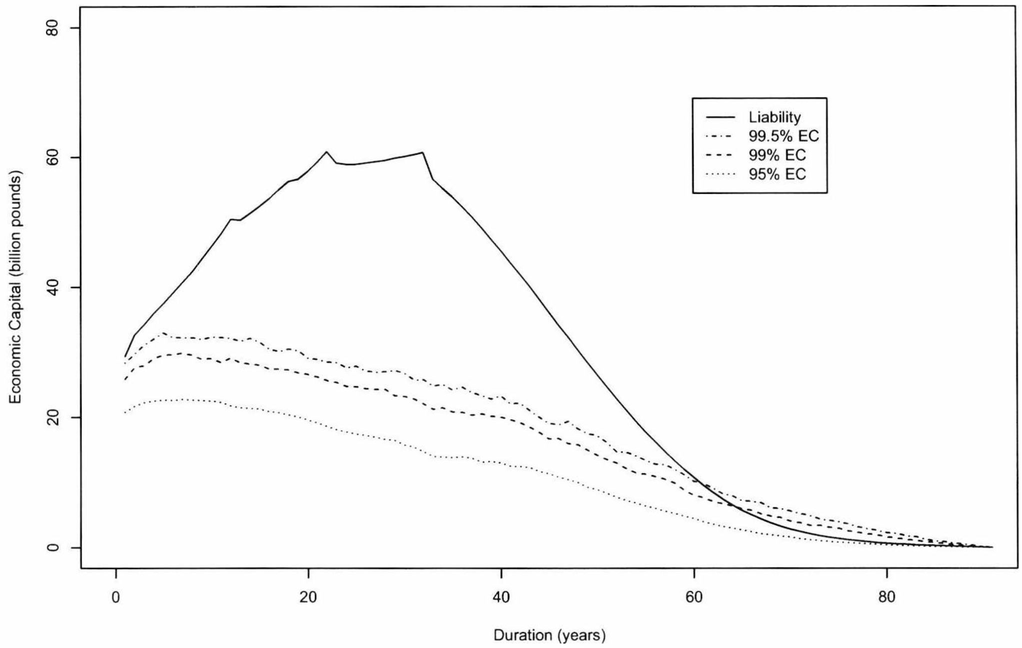

Figure 4.4: 100% investment in bonds: Liability and economic capital for the full scheme.

However, as can be seen from Figure 4.4, which shows results for the whole scheme, it remains the case that the economic capital amounts required to protect USS members are extremely large.

4.4.3 Sensitivity to Investment Strategy

In this subsection, we have recalculated the base case results by assuming that assets will be invested equally in equity and bonds with rebalancing at the end of each year. The discount rate used for future liability calculations is set accordingly. The results are shown in Figure 4.5 and 4.6.

These figures show that the liabilities are higher than the liabilities in base case but lower than the liabilities for the case where all assets were invested in bonds. This is expected as the discount rate used lies between

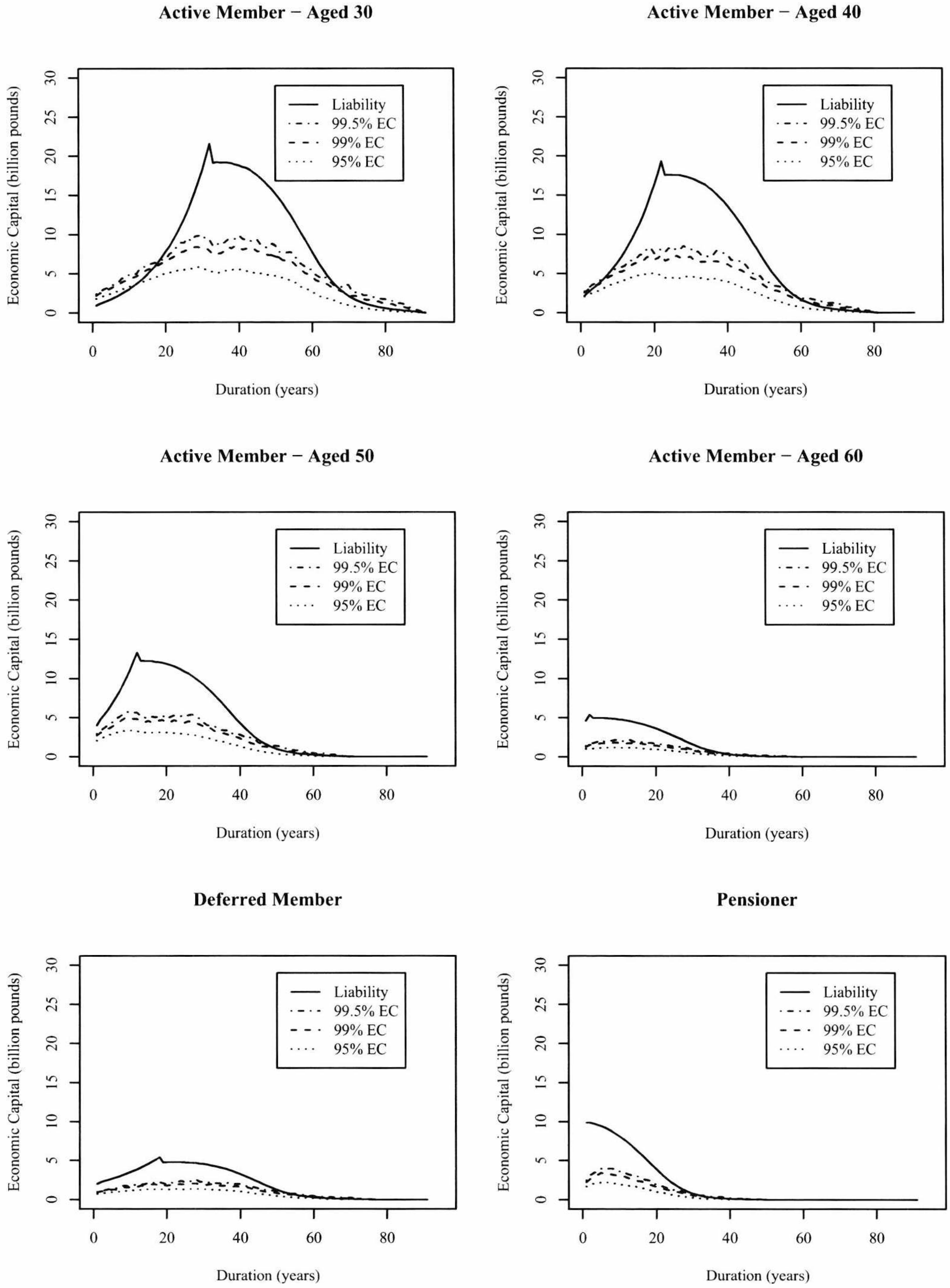

Figure 4.5: Investment strategy of 50% in equity and 50% in long-term government bond: Liability and economic capital for different member groups.

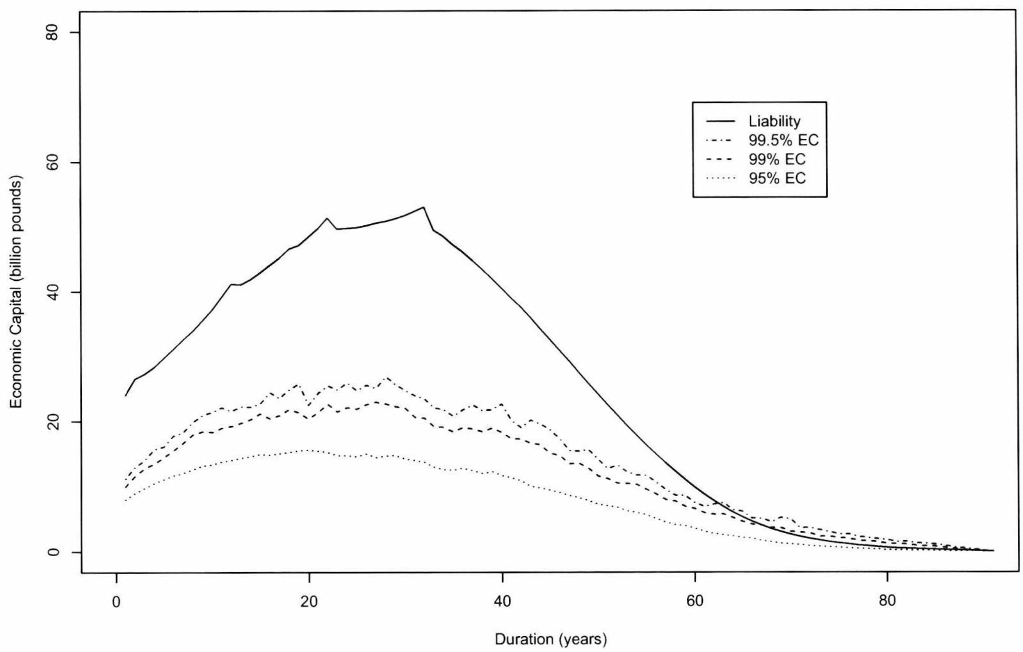

Figure 4.6: Investment strategy of 50% in equity and 50% in long-term government bond: Liability and economic capital for the full scheme.

the discount rates used in those cases.

The economic capital on the other hand, takes the general shape of the base case but lower for all durations. One reason is that the reserves for this is higher than the base case. Moreover, a 50-50 split generates a higher diversification benefits and bring down the overall risks of the pension scheme. However, the total economic capital requirements remains significant.

In our analysis, we have considered a passive investment strategy as, traditionally, UK DB pension schemes have followed this approach in conjunction with relatively high exposures to equities. A more dynamic investment strategy, although not typical of current practise, might reduce a DB scheme's economic capital requirement further.

4.4.4 Sensitivity to Accrual Rates

In this subsection we recalculate the base case results on the assumption that the accrual rate for active members is reduced from 1/80th to 1/120th for both past and future benefits. However, we have not altered the contribution rates in this subsection.

Relative to the base case results, the deferred member and pensioners' best-estimate liabilities and economic capital amounts are unaltered as the accrual rate assumption does not affect the benefits of these classes of scheme members. For active members, both best-estimate liabilities and economic capital requirements fall, relative to the base case results, because the value of their benefits fall due to the reduced accrual rate assumption. Again, this is as expected. The results are shown in Figure 4.7.

The main differences in these figures, relative to base case results, are that both liabilities and economic capitals for active members fall by approximately a-third.

However, as can be seen from Figure 4.8, which shows results for the whole scheme, although best-estimate liabilities and economic capital fall materially from the base case results, the amount of economic capital required to protect USS members, compared to best-estimate liabilities and also in absolute terms, remains significant.

4.4.5 Sensitivity to Retirement Age

In this subsection we recalculate the base case results on the assumption that the retirement age is increased to 70. Results for different model points are shown in Figure 4.9.

Relative to the base case results, the pensioners' best-estimate liabilities

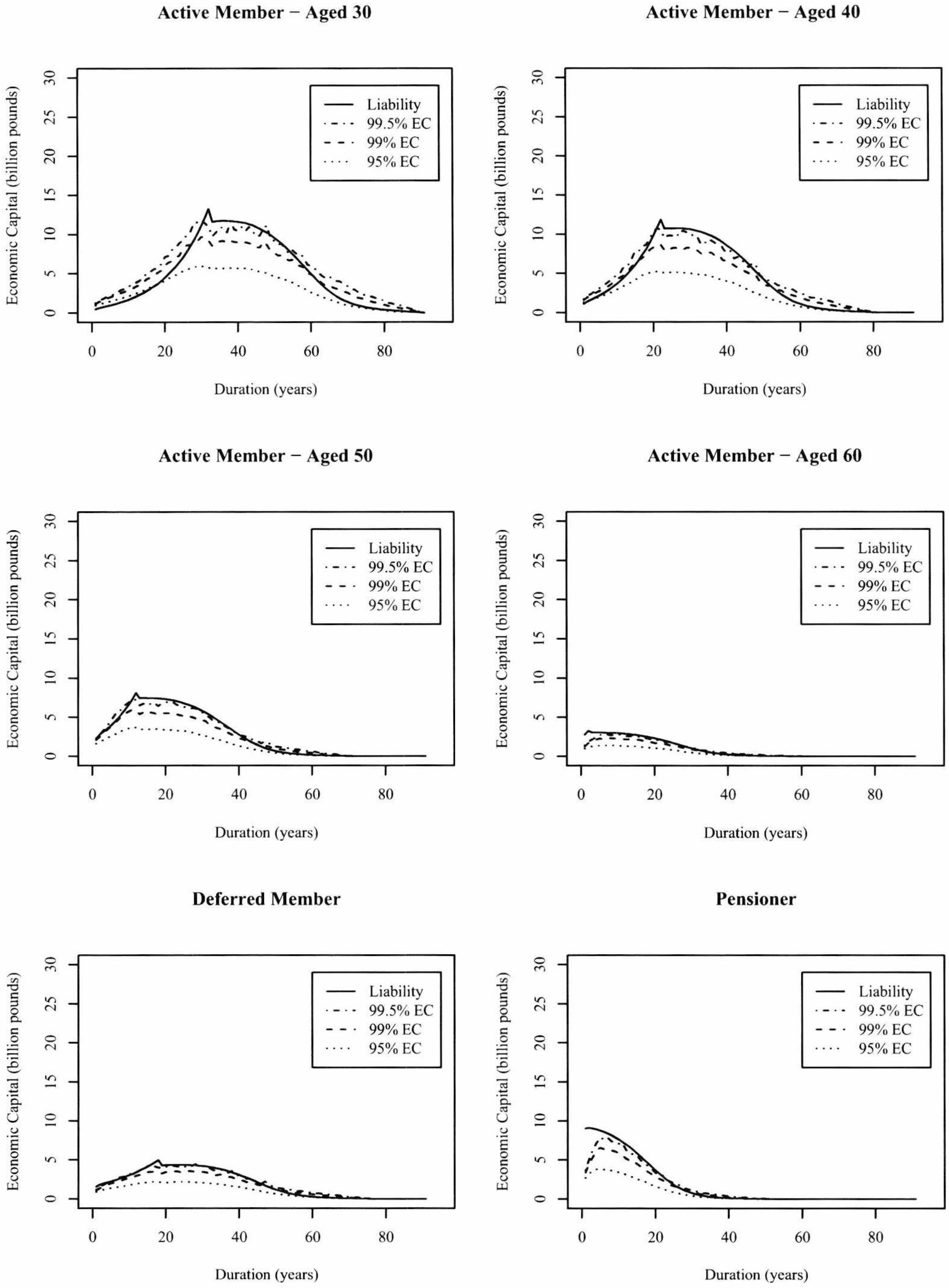

Figure 4.7: Accrual rate reduced to 1/120th: Liability and economic capital for different member groups.

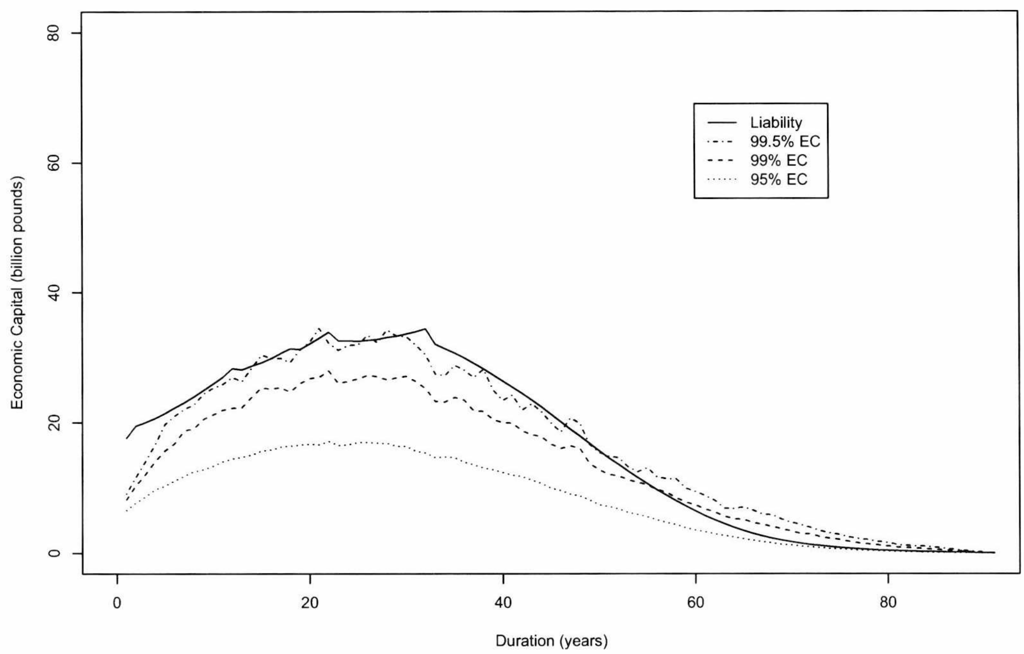

Figure 4.8: Accrual rate reduced to 1/120th: Liability and economic capital for the full scheme.

and economic capital amounts are unaltered. This is as expected as the increased retirement age assumption does not affect the benefits of this class of scheme members.

For deferred members, both best-estimate liabilities and economic capital amounts decrease because members have to wait longer to receive their benefits, which are unaltered, and their benefits are not adequately protected in deferment to preserve the value of these benefits. As a consequence, scheme risks fall.

For active members, both best-estimate liabilities and economic capital commence lower than base case results, before growing relatively larger. This is because the increased retirement age allows active members to accrue larger benefits, although these are paid later from the higher age and the duration of pension payments are reduced.

At the early durations, the increased retirement age reduces best-estimate liabilities and economic capital because of the delay in receiving the benefits. At the later durations, best-estimate liabilities and economic capital increase because the higher accrued benefits are worth more once they start being paid.

Figure 4.10, shows a similar pattern of results as for the active members. In particular, it can be seen that increasing the scheme retirement age does not in general reduce scheme economic capital requirements. In fact, at later durations, economic capital requirements actually increase.

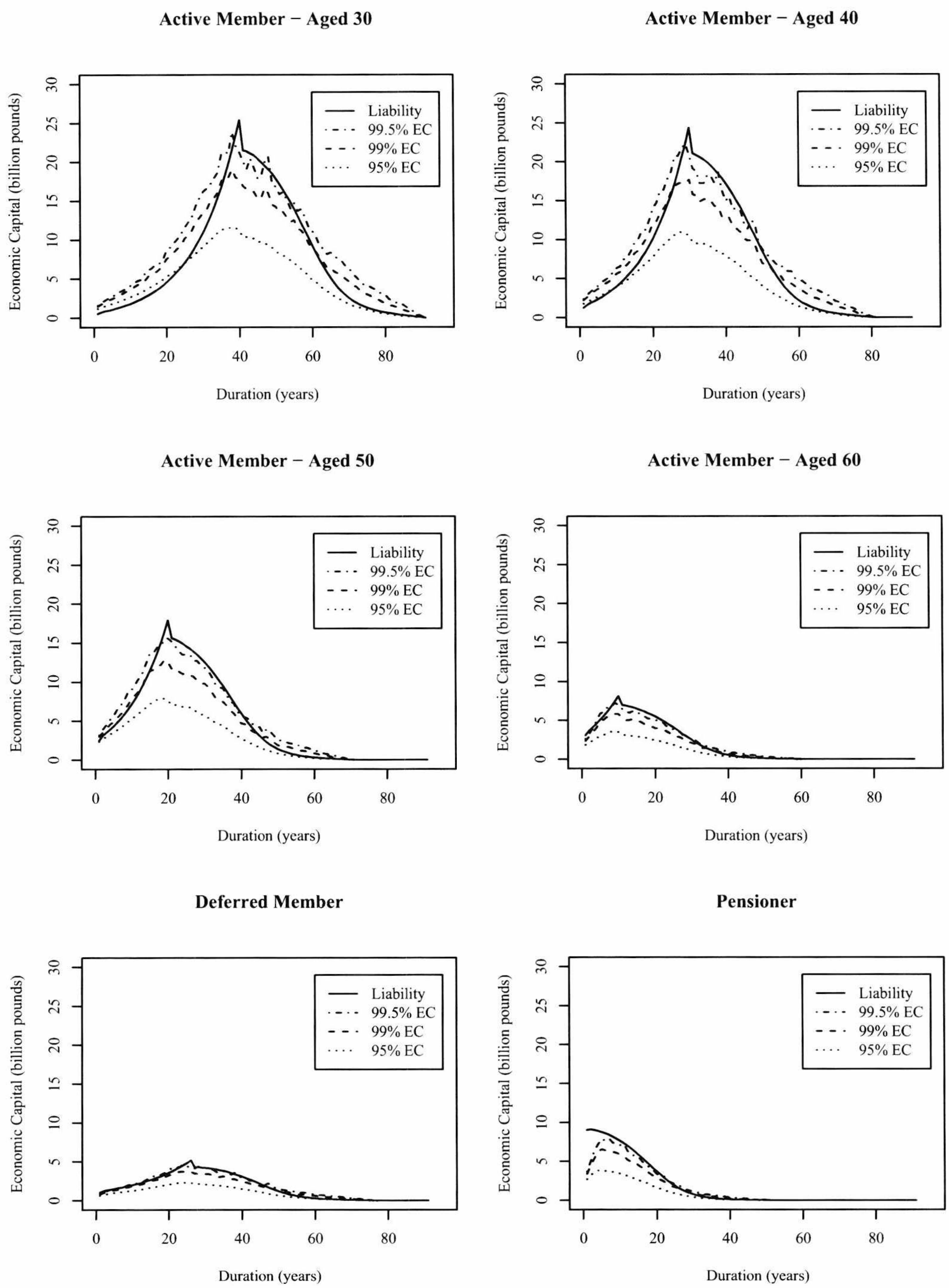

Figure 4.9: Retirement age increased to 70: Liability and economic capital for different member groups.

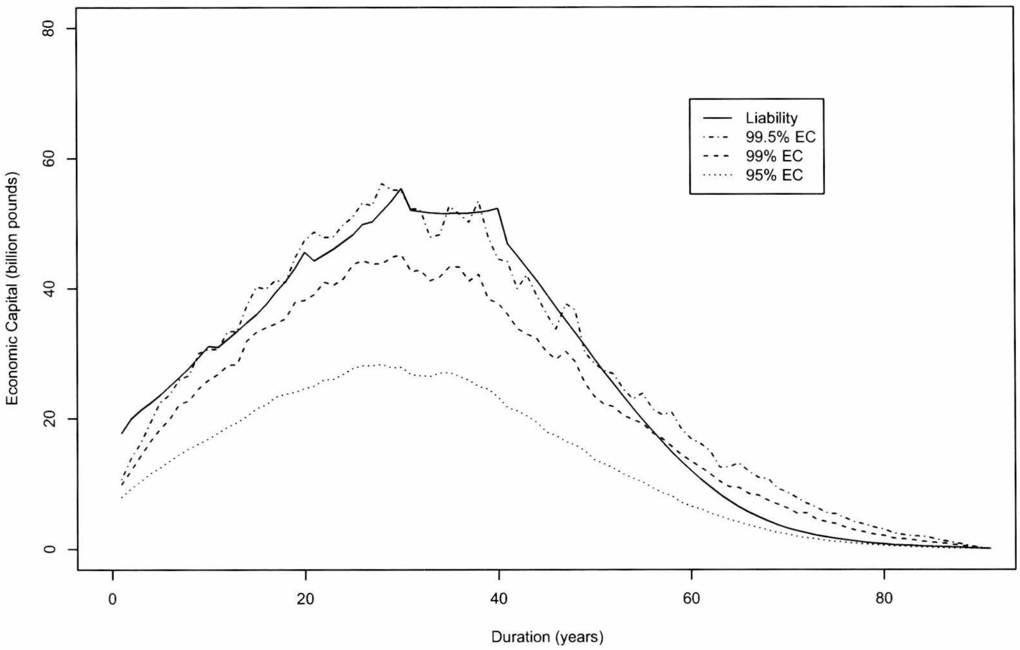

Figure 4.10: Retirement age increased to 70: Liability and economic capital for the full scheme.

4.4.6 Sensitivity to Time Horizon

In this subsection, we recalculate the base case results on the assumption that the time horizon used to calculate economic capital is reduced to one year, rather than the expected future lifetime of each member. With reference to the economic capital calculations set out in Section 2.3.2, we set the assessment horizon to be one year reduced from full run-off.

The results are shown in Figures 4.11 and 4.12. Generally speaking, best-estimate liabilities are unaltered and economic capital falls slightly at time 0, relative to the base case results. Economic capital falls because capital requirements are considered over a shorter time period and so are smaller as a consequence. The capital requirement at time 0 to cover a one-year period at 99.5th percentile level falls to £10 billion from £13 billion in the base case. The reduction in economic capital for one year case is not substantial in this case as we have not changed the investment pattern. The economic capital requirement resulted from asset-liability mismatching is still large as we invest 90% in equities. We have tested the one year time horizon with 100% investment in bond, the economic capital can reduce by 56% compared with 90% investment in equities.

An interesting point to note from Figures 4.11 and 4.12 is that the figures appear broadly similar to the base case results beyond the first few years. This is a feature of our choice of economic capital calculation formula.

As discussed in Section 2.3.2, based a single realisation of the future, the run-off capital requirement at time t is defined as:

$$C_t = \max\Big[- \min_{s=t}^{T} V_s D_{t,s}, 0\Big] = \max\Big[- V_\tau D_{t,\tau}, 0\Big],$$

where $\min_{s=t}^{T} V_s D_{t,s}$ occurs at time τ. We have also seen that over $(t, \tau]$, by definition, $C_t I_{(t,t+1)} = C_{t+1}$. Hence:

$$C_{\tau-1} = \max\big(- V_\tau D_{(\tau-1,\tau)}, 0\big).$$

However, for a 1-year assessment horizon, this is exactly the same expression for capital requirement at time $(\tau - 1)$:

$$C_{\tau-1} = \max\Big[- \min_{s=\tau-1}^{\tau} V_s D_{t,s}, 0\Big] = \max\Big[- V_\tau D_{t,\tau}, 0\Big].$$

Hence, Figures 4.11 and 4.12 coincides with the base case results beyond the first few years.

However, it needs to be pointed out that the one year assessment horizon figures can be slightly misleading, as unlike the full run-off cases, for shorter time horizons, it is expected that fresh capital calculation will be carried out at the end of the each assessment horizon.

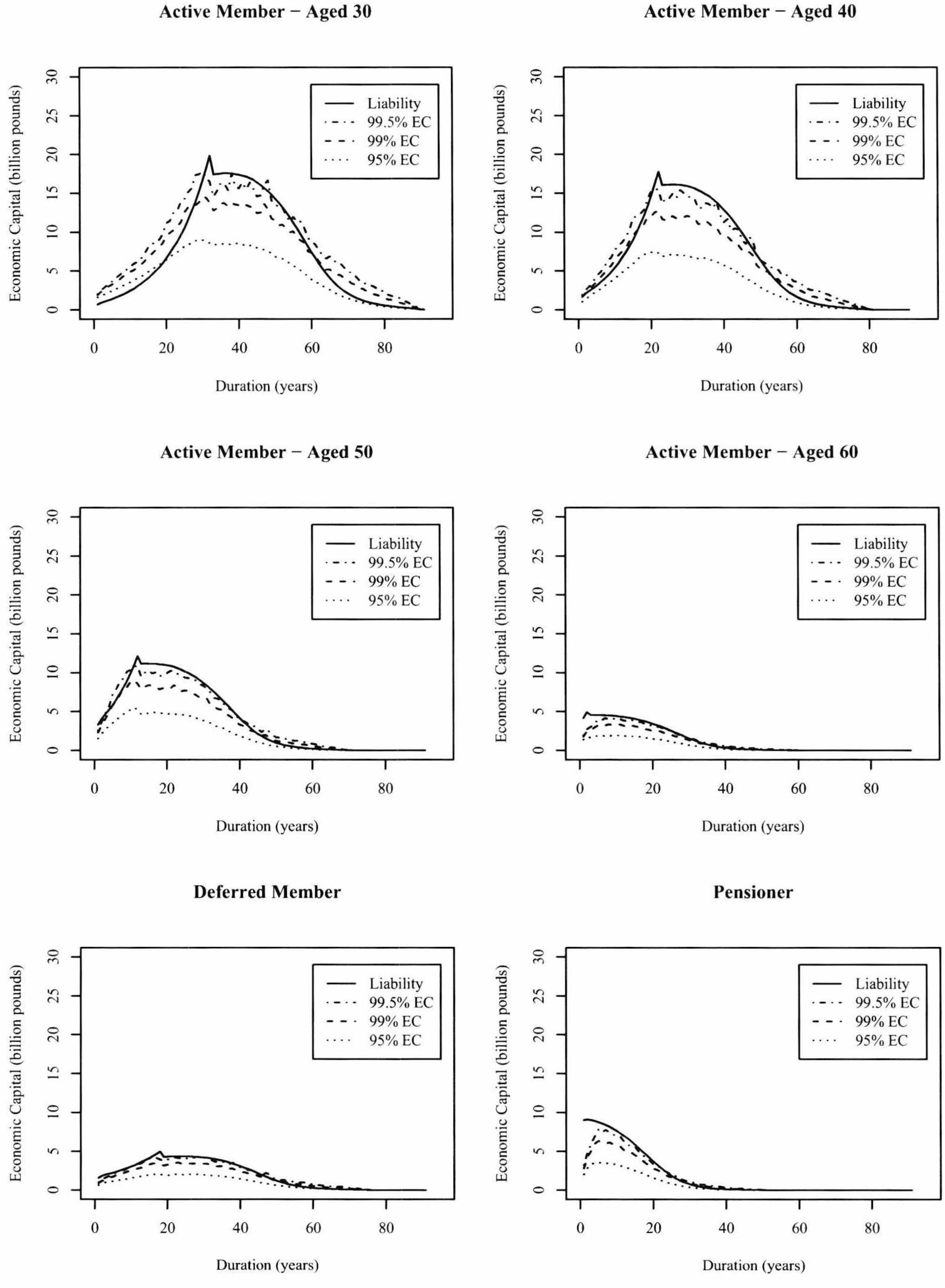

Figure 4.11: 1-year time horizon: Liability and economic capital for different member groups.

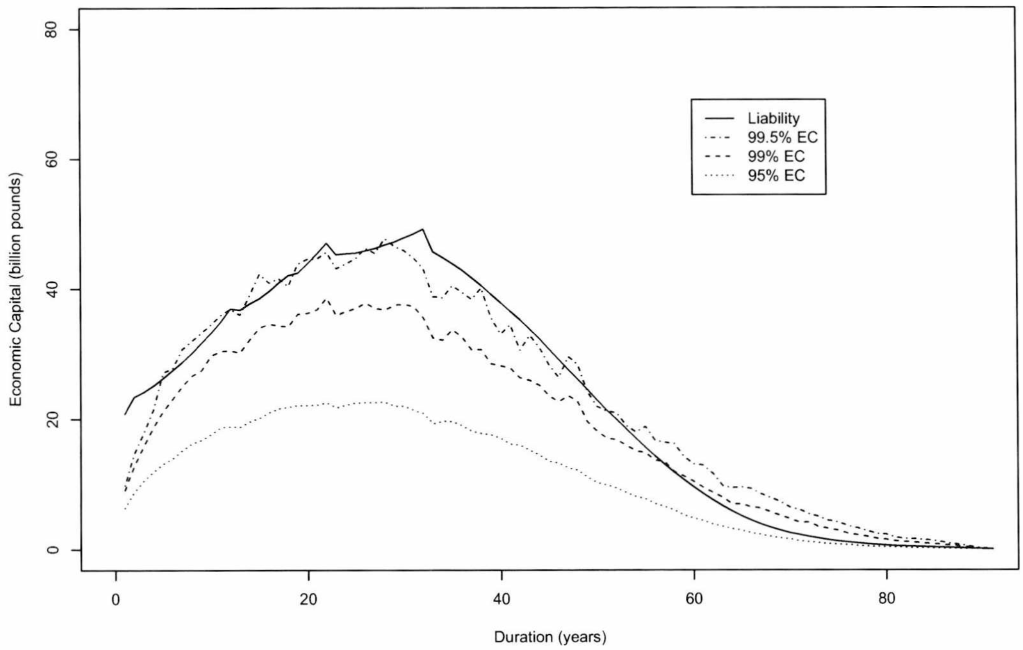

Figure 4.12: 1-year time horizon: Liability and economic capital for the full scheme.

4.4.7 Sensitivity to Contribution Rate

In this subsection, we recalculate the base case by increasing the contribution rate by 3% every year, i.e employee and employer together contribute 25.35% of annual salary into the scheme every year. As the liability is calculated using the PUM which does not take future contribution rate into account, the liabilities remain unaltered. The economic capital on the other hand, reduces slightly. By increasing the contribution rate, more surplus might arise in shorter duration for active members before retirement. Post retirement liability is not affected by the contribution rate which makes the capital requirement close to base case. The results for this case are not presented here as they are very similar but slightly lower than the base case results.

4.4.8 Sensitivity to Benefit Calculation Formula

In this subsection, we recalculate the base case results assuming that the benefit level of USS is based on career average salary instead of final salary. The results are shown in Figure 4.13 and Figure 4.14.

Based on this assumption, the level of benefits is reduced because it is now related to career average salary which is usually much lower than the final salary. Main observations from these figures are that the liabilities and economic capital requirements for active members are reduced by around 20%. This is a significant relief on the capital requirement for the scheme. The main reason is that under this assumption, the scheme benefits have reduced significantly while having the same level of contributions.

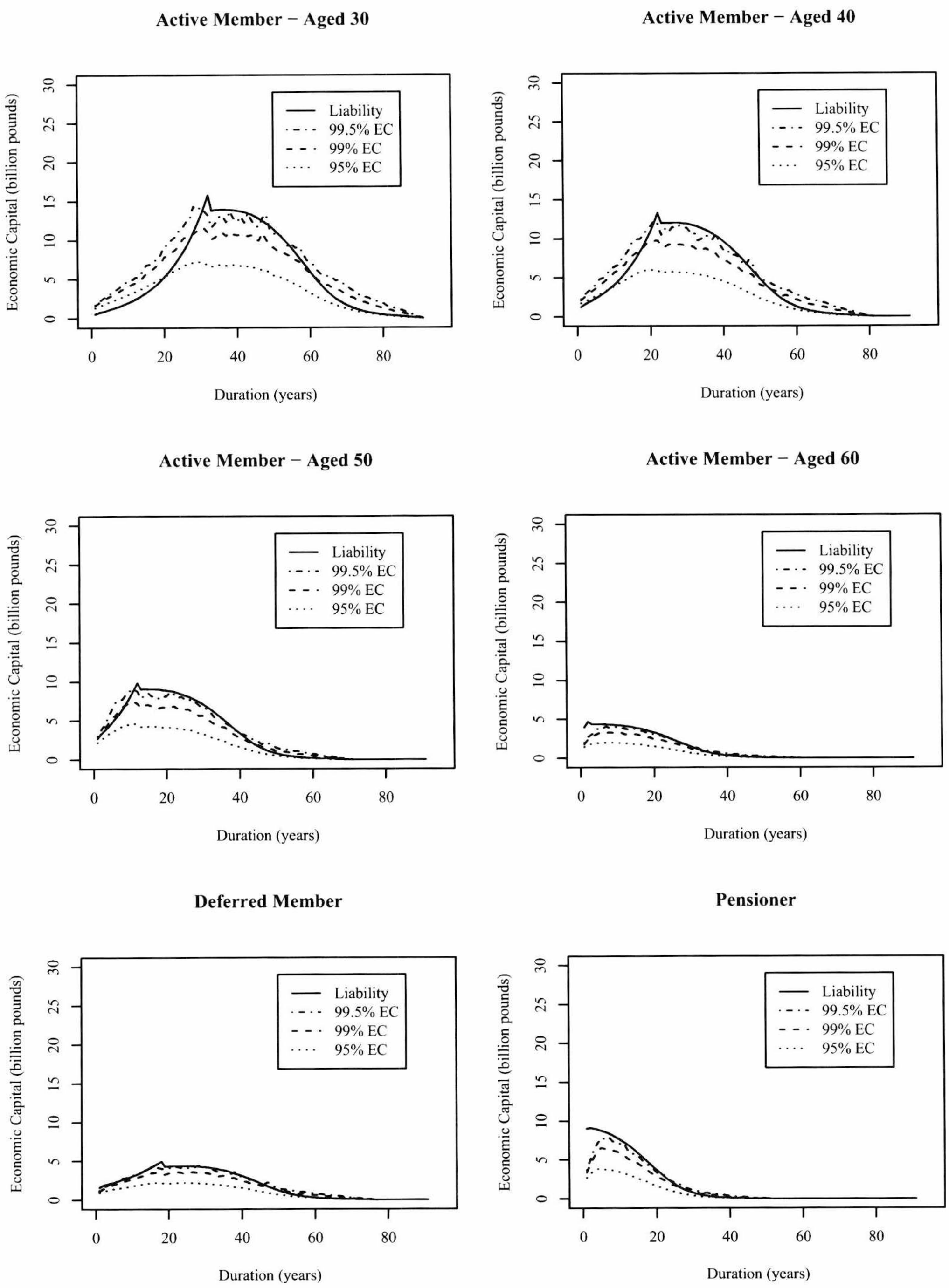

Figure 4.13: Career average benefit: Liability and economic capital for different member groups.

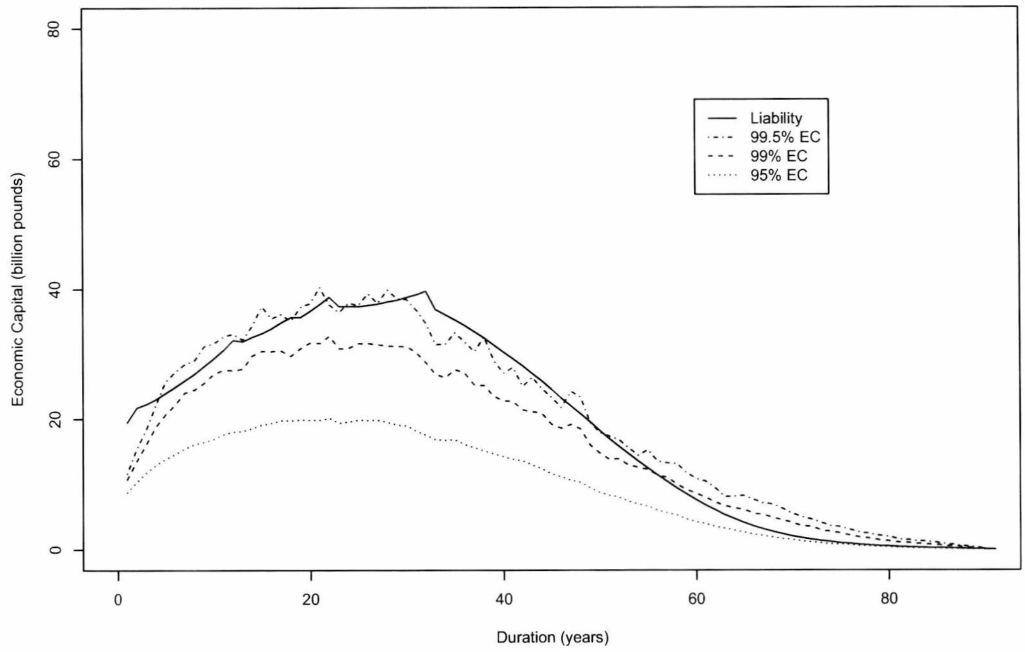

Figure 4.14: Career average benefit: Liability and economic capital for the full scheme.

4.4.9 Fully Prospective Best-Estimate Liability

In this subsection, we recalculate the base case results using a more traditional life insurance approach to estimating scheme best-estimate liabilities, rather than the projected unit method. In what we call the fully prospective liability method, we estimate scheme best-estimate liabilities by discounting the value of all scheme future cashflows, taking into account all future benefits, as well as accrued benefits, and all future contributions. Results are shown in Figure 4.15 and Figure 4.16.

The main observation is that it is only the active member groups results that are much different from the base case results. At the shorter durations the fully prospective best-estimate liability tends to be higher than the projected unit method best-estimate accrued benefit liability, because

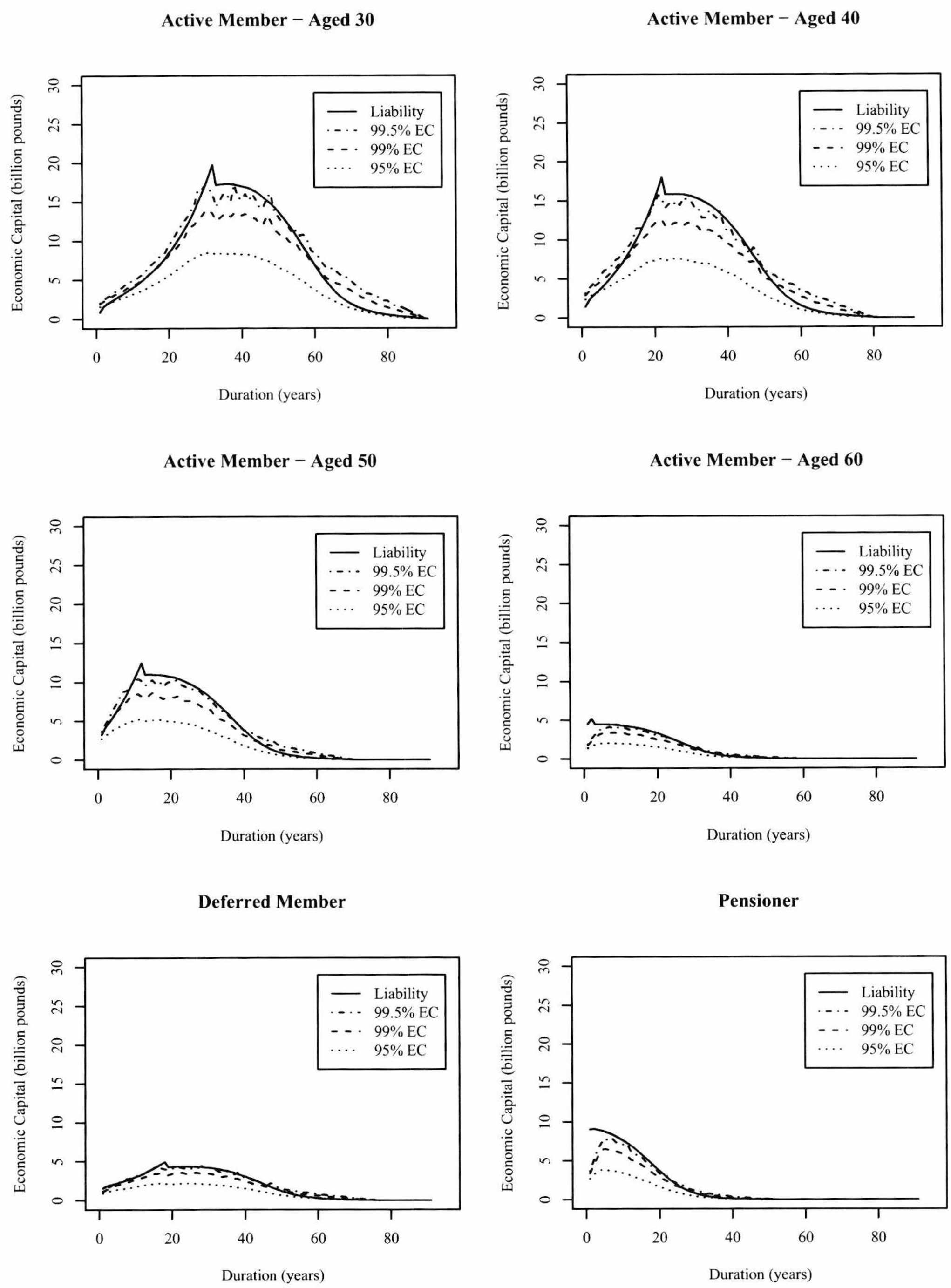

Figure 4.15: Fully prospective liability: Liability and economic capital for different member groups.

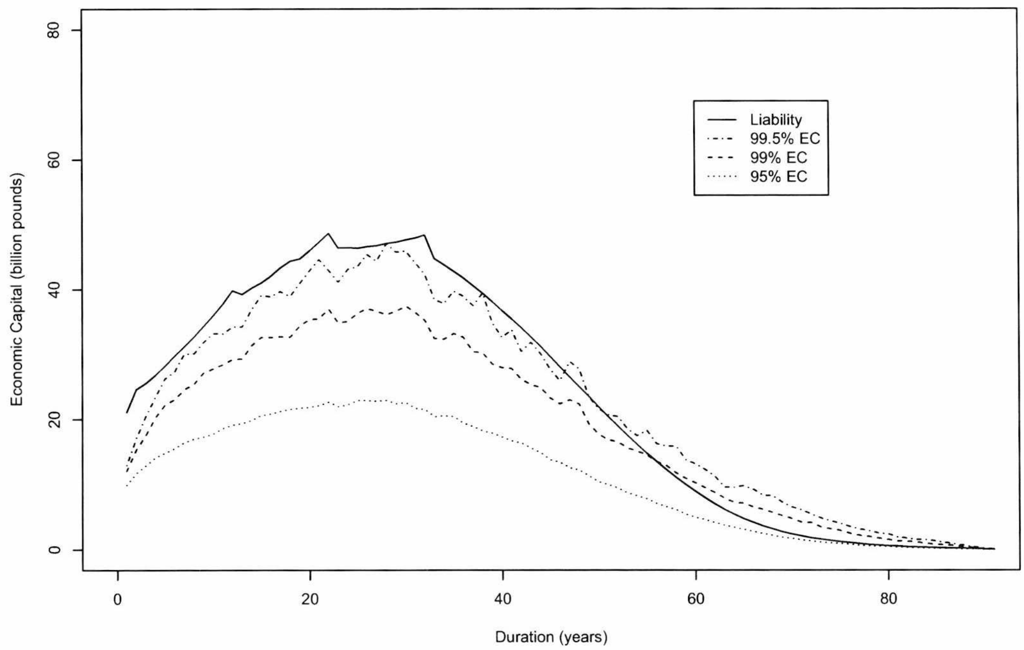

Figure 4.16: Fully prospective liability: Liability and economic capital for the full scheme.

future contributions are slightly too low to pay for future benefits, but with economic capital amounts generally fairly similar.

For the USS scheme in total, both best-estimate liabilities and economic capital are very similar to base case results. In other words, the assumed future contribution rate is broadly adequate to pay for future benefits, but not economic capital requirements.

4.4.10 Sensitivity to Contribution Increases on a Fully Prospective Best-Estimate Liability Basis

In this subsection, we investigate best-estimate liability results on the assumption that the total contribution amount is increased by 3% to 25.35% p.a. Results are shown in Figures 4.17 and 4.18.

We found that, at the earlier durations, before benefits become payable, active member best-estimate liabilities and economic capital fall relative to the base case fully prospective best-estimate liabilities scenario. This is as expected because the future contribution rate has increased. Once benefits are deferred, or are in payment, the contribution increase makes no difference to our results, again as expected.

Once again, the economic capital requirements of the USS scheme remain substantial.

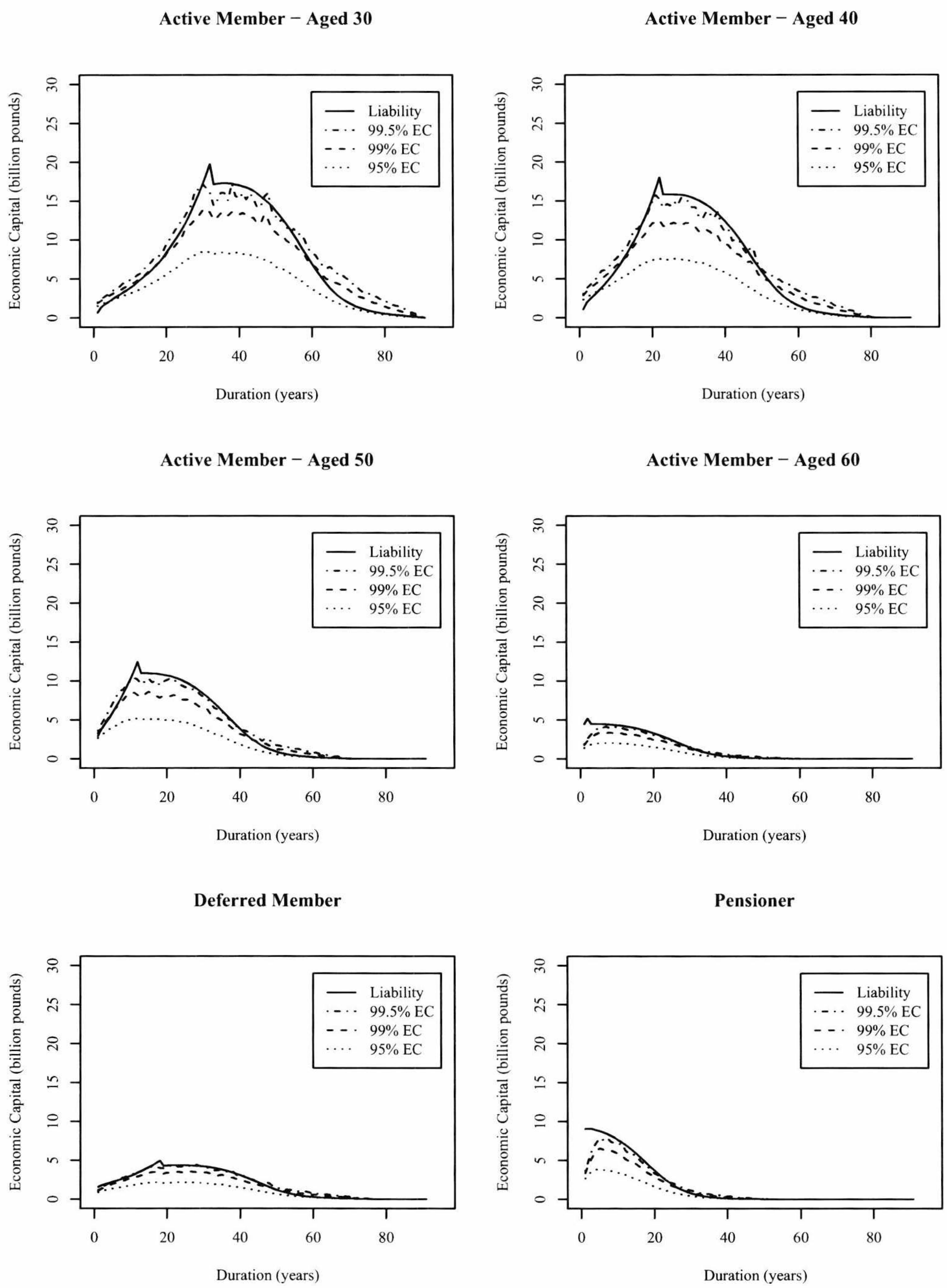

Figure 4.17: Fully prospective liability with contribution rate increased by 3%: Liability and economic capital for different member groups.

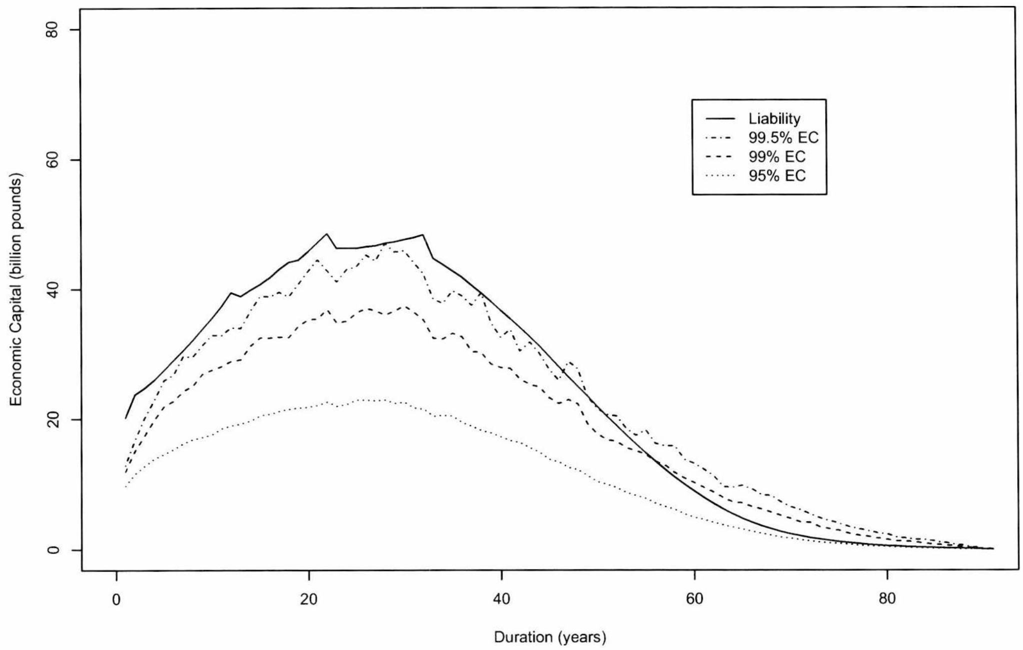

Figure 4.18: Fully prospective liability with contribution rate increased by 3%: Liability and economic capital for the full scheme.

4.4.11 Sensitivity to Longevity Stress

In Figures 4.19 and 4.20, we show the impact of doubling the size of the volatility, or standard deviation, parameter in our stochastic mortality model. As expected, economic capital increases everywhere, especially at the later durations, and is very large relative to best-estimate liabilities. This is especially concerning given the lack of success that actuaries and others have had in estimating future improvements in longevity. Best-estimate liabilities also increase very slightly, although this is a feature of the stochastic mortality model that we have used, where increasing volatility causes the distribution of mortality rates to become more negatively skewed.

In Figure 4.21, we increase the volatility of our stochastic mortality

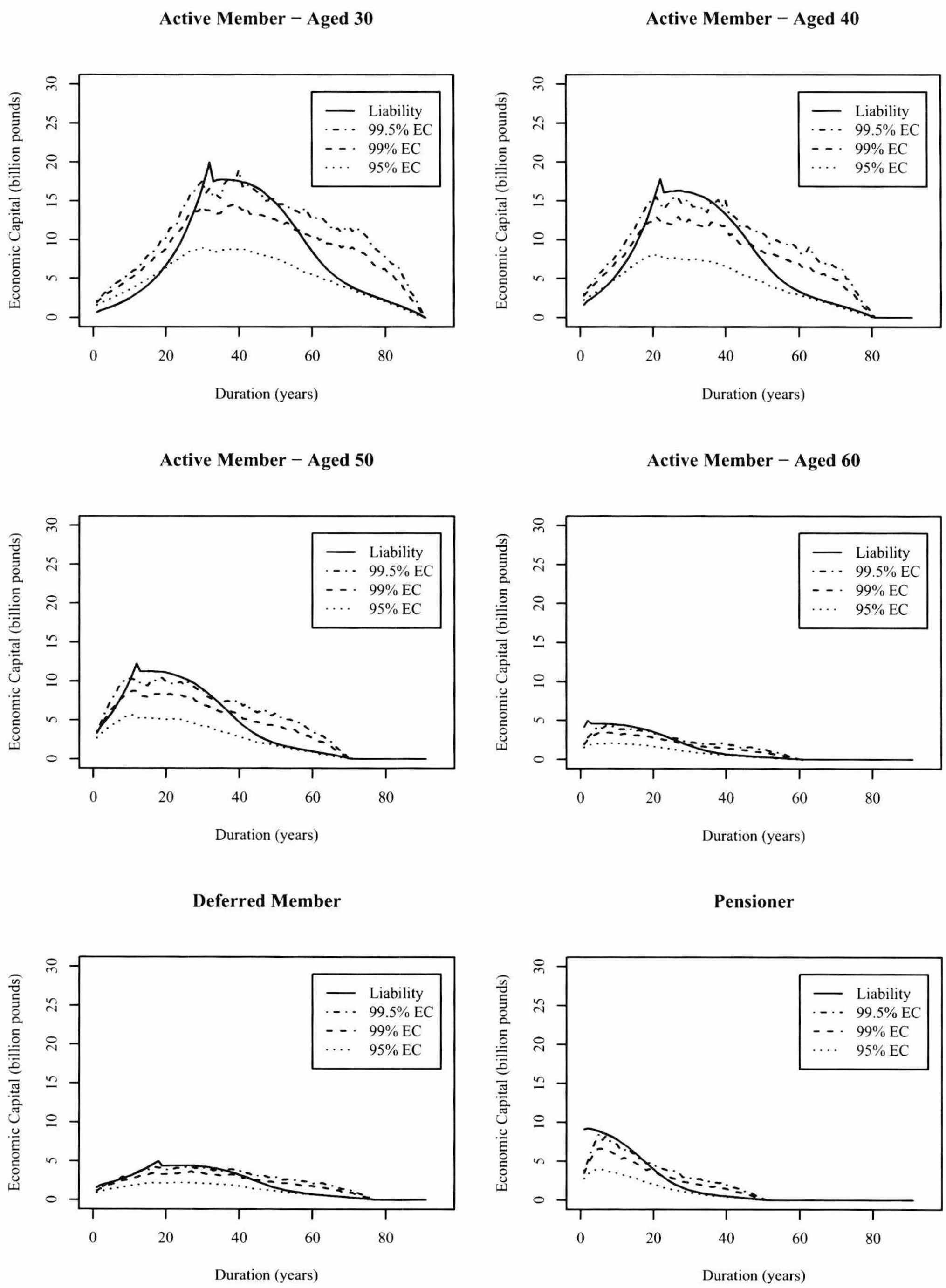

Figure 4.19: Longevity stress at twice the base scenario volatility: Liability and economic capital for different member groups.

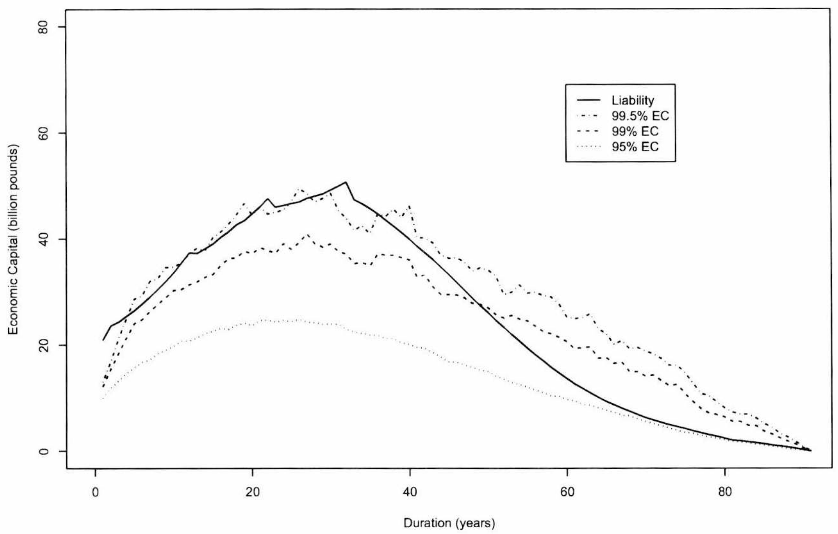

Figure 4.20: Longevity stress at twice the base scenario volatility: Liability and economic capital for the full scheme.

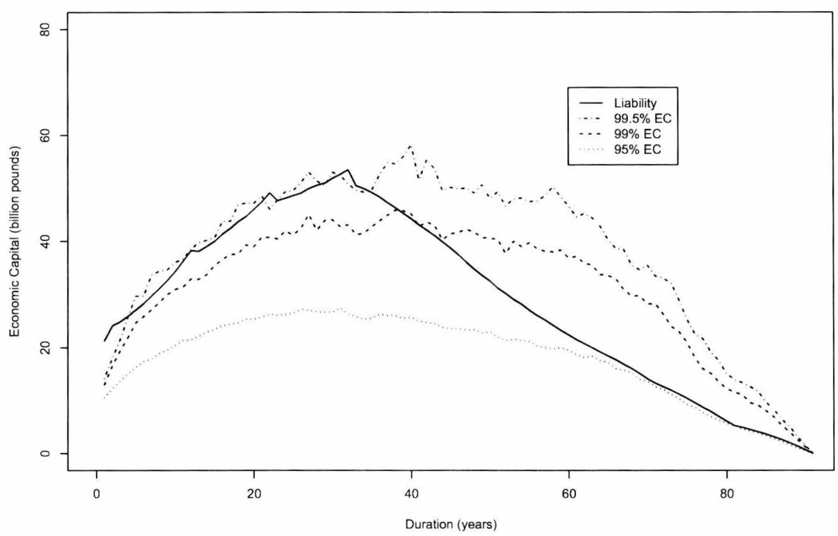

Figure 4.21: Longevity stress at five times the base senario volatility: Liability and economic capital for the full scheme.

model to be five times the original value. The economic capital increased even further especially for later durations.

4.4.12 Open Scheme

In previous subsections, we considered economic capital ignoring future entrants to the scheme i.e only existing members were considered. In this section, we allow new members to join the USS and model USS on an ongoing basis.

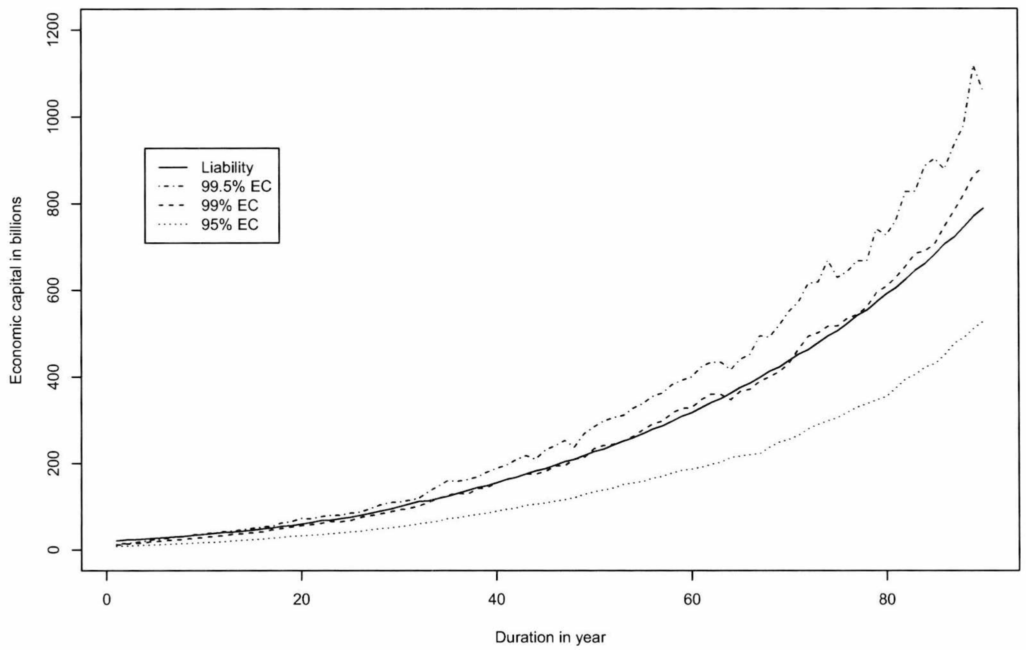

Figure 4.22: Open scheme with stable membership results: Liability and economic capital for the full scheme.

Figure 4.22 shows best-estimate liabilities and economic capital for the USS scheme on the assumption that new members join at a rate that is sufficient to maintain scheme active members at current levels, with current deferred, pensioner and dependant members allowed to run-off. As discussed before, USS is a relatively young scheme. If new members join at a rate to maintain the current active member profile, the number of deferred members, dependants and pensioners will increase until the membership profile stabilises. The membership profile will reach a stable position where the number of members exiting the system is equal to the number of members joining. However, the value of liabilities and economic capital will increase with salary inflation. We can see from Figure 4.22 that in long term, the economic capital at 99.5th percentile level is higher than the level of liabilities. As expected, economic capital reaches extremely high levels and also takes many years to stabilise.

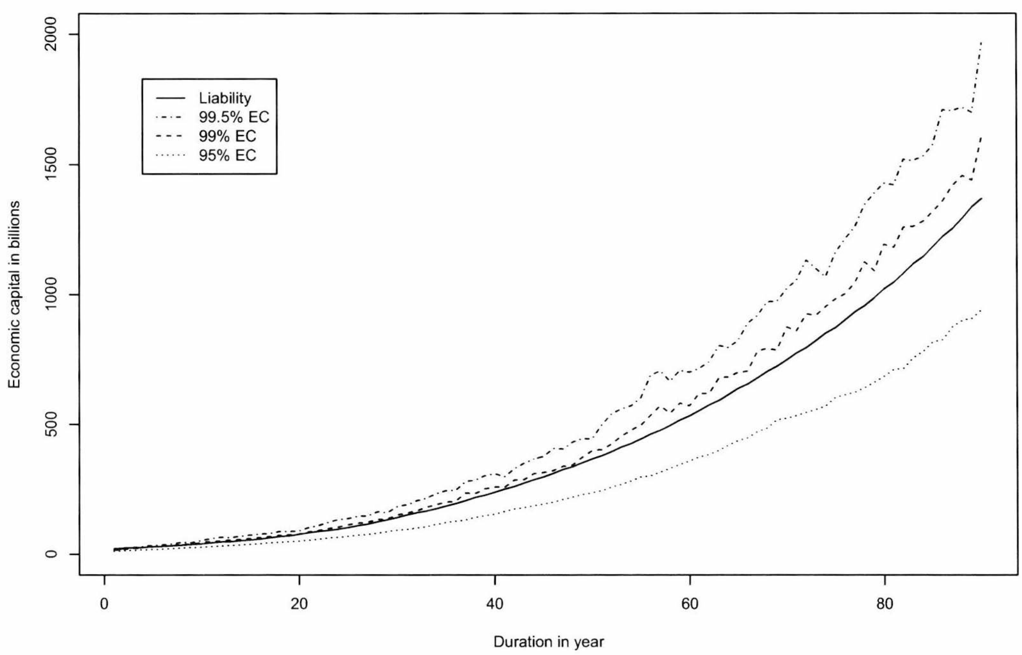

Figure 4.23: Open scheme with increasing membership results: Liability and economic capital for the full scheme.

Figure 4.23 shows the case where active members are assumed to increase at 5% p.a. from current levels. It can be seen, as expected, that economic capital increases on a rising trend to reach alarmingly high levels.

4.4.13 Solvency Level

In this subsection, we summarise the economic capital results obtained and present them in terms of a percentage of best-estimate liability. Table 4.7 shows the amount of economic capital required as a percentage of best-estimate liabilities at time zero, for different scenarios.

Table 4.7: Ratio of economic capital to best-estimate liabilities at time zero.

	Economic capital percentile levels		
Scenario	95th	99th	99.5th
Base case	47%	57%	60%
100% investment in bonds	71%	90%	98%
50% equity 50% bond investment	33%	42%	46%
Accrual rate reduced to 1/120th	37%	46%	49%
Retirement age increased to 70	44%	55%	59%
1-year time horizon	30%	43%	47%
Contribution rate increased to 25.25%	45%	56%	59%
Career average benefit	45%	55%	60%
Fully prospective liability	47%	57%	61%
Fully prospective liability (+3% contribution)	46%	56%	60%
Longevity stress twice variability	48%	58%	63%
Longevity stress five times variability	50%	63%	70%

It can be seen from Table 4.7 that economic capital requirements are very large indeed compared to the level of liabilities.

In Table 4.8, we compare USS scheme assets at time zero to the sum of scheme best-estimate liabilities and economic capital for each of the scenarios considered.

Based on 99.5th percentile economic capital, for example, it can be seen that the USS might be considered to be in reasonable health only if:

- Retirement age increased to 70;
- Accrual rate reduced to 1/120th;
- Using career average benefit calculation formula.

Table 4.8: Ratio of USS scheme assets at 2008 actuarial valuation (£28,842.6m) to the sum of scheme best-estimate liabilities and economic capital at time zero.

	Economic capital percentile levels		
Scenario	95th	99th	99.5th
Base case	94%	88%	86%
100% investment in bonds	58%	52%	50%
50% equity 50% bond investment	90%	85%	93%
Accrual rate reduced to 1/120th	119%	112%	110%
Retirement age increased to 70	112%	104%	102%
1-year time horizon	106%	97%	94%
Contribution rate increased to 25.25%	96%	90%	87%
Career average benefit	96%	90%	87%
Fully prospective liability	92%	86%	84%
Fully prospective liability (+3% contribution)	95%	89%	87%
Longevity stress twice variability	94%	88%	85%
Longevity stress five times variability	92%	85%	82%

This is clearly not a good outcome, especially as the situation still deteriorates at later durations, as was seen from the figures presented earlier in this section.

We can see that it is important to find a balance between the benefits provided and the risks associated with them. Ideally, a satisfactory level of security should be provided to members of occupational pension schemes under an affordable funding requirement.

4.4.14 Solvency Level Based on Retained Profit

Table 4.9 summarises the amount of economic capital required as a percentage of best-estimate liabilities at time zero assuming USS retain all profits for different scenarios. Here the economic capital is calculated using the steps outlined in Section 2.3.2.

As expected, retained profit assumption produced relatively lower economic capital requirements for all cases except 1-year time horizon case where we only consider the economic capital to cover 1-year solvency. In

Table 4.9: Retained profit cases: Ratio of economic capital to best-estimate liabilities at time zero.

	Economic capital percentile levels		
Scenario	95th	99th	99.5th
Base case	33%	46%	50%
100% investment in bonds	69%	89%	97%
50% equity 50% bond investment	28%	39%	42%
Accrual rate reduced to 1/120th	15%	22%	23%
Retirement age increased to 70	19%	31%	34%
1-year time horizon	30%	43%	47%
Contribution rate increased to 25.25%	32%	46%	50%
Career average benefit	25%	34%	38%
Fully prospective liability	32%	45%	49%
Fully prospective liability (+3% contribution)	32%	44%	48%
Longevity stress twice variability	36%	46%	57%
Longevity stress five times variability	49%	60%	67%

addition, economic capital falls to zero much more quickly as retained profits are built up and reduce capital requirement.

Comparing with the results in Table 4.7, increasing retirement age to 70 and decreasing accrual rate to 1/120th produce relatively larger drops in economic capital. This is because by switching retirement age from 62 to 70, more profits can be accumulated before paying pension benefits. By reducing to 1/120th accrual rate while maintaining the same contribution rates along with retained profits also reduce economic capital significantly. However, economic capital is still relatively high compared to the level of liability.

As building up substantial surplus within a pension scheme without providing any contribution relief to the sponsor has not been proved possible historically, we do not consider this case further.

4.5 Summary

In this chapter, we have determined the amount of economic capital that a DB pension scheme needs to cover the risks that it is running, using an insurance firm balance sheet asset liability management approach, rather than a pension scheme funding level adequacy approach. As expected, economic capital requirements are very large, about 60% of the best-estimate liability at the 99.5th percentile level for the base scenario. This reflects the risks inherent in providing such generous, guaranteed benefits whilst, at the same time, backing the associated liabilities with the volatile assets expected to generate the returns needed to support these benefits.

We also saw that, apart from explicitly hedging scheme risks such as longevity risk, the most effective short term measures that schemes can adopt to improve their positions are to reduce benefits, either by increasing retirement ages, or by reducing the benefits provided (by reducing accrual rates or using career average benefit calculation formula). However, such measures are only effective in the shorter term because, as time goes by, scheme risks still accumulate faster than assets leading to future economic capital deficits. Reducing scheme benefits will also obviously be extremely unpopular with scheme members.

USS proposed some new changes on October 2010, including the following main changes:

- Increase the normal pension age to age 65;
- Increase member's contribution rates from 6.35% to 6.5% of salary;
- Use a career average salary instead of final salary to value the pension benefits.

These changes will only apply to new USS members who join after 1 April 2011. However, the retirement age and contribution increases have already been imposed to existing members since 1 Oct 2011 (the member's contribution rate has been increased to 7.5% of salary).

From results shown in Section 4.4, increasing retirement age to 65 and increasing contribution rate have limited impact on economic capital. We have tested (not shown here) that based on USS 2008 profile, applying these three changes together at 99.5th percentile level, the economic capital is still as much as 56% of the best-estimated liability. However, compared to the base case results shown in Section 4.4.1, liabilities and economic capital requirements for new active members have been reduced by around a-third. This is a significant relief on the capital requirement for the scheme. However, it is obviously detrimental to members to have their benefits reduced while paying higher level of contributions. Moreover, the level of economic capital still remain significant.

Based on year 2008 data, the economic capital requirement are so large that it would not be credible, nor sustainable, for scheme sponsors to set capital aside to match economic capital. These resources are simply not available and they would, in any case, force many firm sponsors out of business and damage already fragile economies. The only practical choices on the table appear to be to reduce scheme benefits and de-risk DB pension schemes using explicit hedging tools.

In the next chapter, we are going to test the effect of hybrid pension design on the amount of economic capital requirement. As it is difficult for the pension provider to find resources to provide adequate security to a pension scheme, we argue that it might be more practical to share part of these risks with scheme members. By adopting a hybrid pension design, scheme members get exposure to the risks consequently can receive potentially higher benefits. On the other hand, the risks to the pension provider, is reduced as some of the risks are transferred to scheme members.

Chapter 5

Hybrid Pension Schemes

UK has seen a lot of DB schemes switched to DC schemes recently due to the employers' desire to reduce risks. Hybrid pension schemes could also help employers to de-risk their pension schemes. However, hybrid pension design is not popular compared to DB or DC schemes and the number of hybrid schemes is relatively small compared to DB or DC schemes right now.

It is worth noting that unlike DB and DC pension schemes where either the pension providers or the scheme members bear all risks, hybrid pension schemes can provide a more even risk allocation between employers and employees. By using a hybrid structure, the risks for employers can be reduced while retaining attractive features of DB pension schemes preferred by employees. Having this advantage, hybrid pension scheme design does have good growth potential.

Hybrid schemes can have varied designs which make them much more flexible than pure DB or DC pension designs. By mixing different pension features, hybrid schemes can be used to serve different purposes. They can provide DB and DC benefits at the same time which will be explained using the underpin arrangement later. It can also offer DC benefits for younger members gradually moving towards DB benefits at older ages. For employees, a DC benefit at younger ages look attractive as it can transfer benefits while switching jobs. From the perspective of employers, DB for older ages is helpful in retaining experienced and loyal workers. Hybrid pension schemes can also provide benefits calculated using various formulae which enable tailored benefit packages and pension features to be beneficial for both employees and employers.

As mentioned in Chapter 1, there are many different types of hybrid pension schemes. Among all forms of hybrids, we will focus on the underpin arrangement as it shares the advantages of DB and DC schemes while providing a relatively straightforward comparison to the risk of a final salary DB pension scheme. Other types of hybrids are not considered in this thesis.

We consider a DC scheme with DB underpin which pays a higher of DB and DC benefit in this thesis. This type of hybrid has the following features:

- Members can benefit from favourable market movements from the DC part of the arrangement.
- Members are protected from poor investment performances due to a DB underpin guaranteeing a minimum pension benefit.
- This arrangement is simple enough to be understood by both employers and scheme members which makes the communication between them effective.
- The scheme design is transparent and relatively easy to administer.
- The risks of a hybrid structure from the perspective of employer is usually lower than final salary DB pension depending on the scheme

design while still providing adequate pension benefits to scheme members.

Evidently hybrid pension design has some advantages compared to both DB and DC pension designs. However, there has been very little research carried out on hybrid pension risk.

In this chapter, we are going to address the question: how much capital relief can a hybrid pension design bring to a DB pension provider? Again, economic capital principles will be used to quantify the amount of risks.

We will focus on the implications of using hybrid schemes as an alternative for moving to full DC schemes while de-risking DB schemes. The risk level for different hybrid underpins are compared with pure DB design to show that hybrid scheme designs can provide an alternative way of reducing risk while remaining attractive to scheme members.

The structure of this chapter is as follows. In Section 5.1, we provide a literature review related to hybrid pension scheme risks. In Section 5.2, we set out the model assumptions for our hybrid pension model. We present our results in Section 5.3 and in Section 5.4, we draw our conclusions.

5.1 Literature Review

Wesbroom and Reay (2005) looked into factors leading to pension sponsors' adoption of DB, DC or hybrid schemes, including a study of relevant regulations. Different kinds of hybrid schemes are discussed in this paper including their features, risk characteristics, histories and market practises. Regulatory, theoretical and practical issues of hybrid schemes are also included in this paper. The authors concluded that the growth of hybrid schemes is unlikely to be as dramatic as DC schemes. This is because the move to DC schemes is part of a global trend that sponsors are using to control both the volatility and the cost of DB schemes. They are reluctant to move back to a hybrid scheme where the risks still remain with them. However, members' and unions' actions, interference and concern from the regulators regarding the volatility in pension benefits are all good reasons to persuade sponsors to move away from pure DB or DC scheme design and adopt a hybrid structure instead.

Cooper (2005) used different replacement ratios of the level of pension benefits to the level of salary as indicators to compare different pension designs including final salary DB, DC, career average, cash balance and DC top-up pension schemes. The author compares the results based on fixed and stochastic financial assumptions using both deterministic and stochastic approaches. The expected replacement ratios and the volatility of the replacement ratios of different types of pension schemes are discussed in this paper. The author concluded that there is no "best" pension design as those designs which produce the highest replacement ratios also come with the greatest variability. However, he also stated that some form of risk sharing would seem a good compromise between risks and returns. Hybrid schemes can be a good choice in terms of risk sharing and adequate returns in some circumstances. Provider of a hybrid scheme needs to find a balance between returns and risks associated with them. However, the risks of a pension sponsor going insolvent and the risks of members receiving inadequate benefits are not discussed in this paper.

McCarthy (2005) analysed the optimal allocation of pension risk between employers and employees. The trade-off between risk and return of employers and employees was considered under an incomplete market set-up. They created a model to assess the risk sharing between workers and pension providers aiming to minimise the overall risk. The effects of forms of pension and different hybrid pension designs are discussed. The author mainly focused on investment, individual mortality, cohort mortality, salary and job tenure risks in this paper. The author concluded that a hybrid design has an advantage as it has a better balance of risk and return than pure DB or DC schemes.

In this thesis, we do not consider job tenure risk which represent the risk that an individual's actual tenure in jobs may be longer or shorter than anticipated. We used the actual rate of withdrawal from scheme per year and an average retirement age to represents member's tenure in jobs.

Chen and Hardy (2009) used financial option methodology to value a DB underpin pension arrangement. They combined a financial engineering simulation method with pension funding principles to analyse the risks. By calculating the volatility and confidence intervals of contributions required under different assumptions, they estimated the risk levels of a DB underpin. Their findings indicate that increasing the contribution rate, applying a salary cap or adjusting the accrual rate can significantly reduce the level of risk. The authors have also analysed the effect of different funding methods in this paper including the entry age normal method, projected unit credit method and traditional unit credit funding methods. We have only adopted the projected unit method in this chapter as the projected unit method satisfies pension valuation requirement in the UK, and is consistent with the latest USS Actuarial Valuation (a brief discussion of different funding methods is provided in Appendix B).

McCarthy and Neuberger (2009) discussed the economics of pension and pension regulations. They also analysed the economics of risk sharing between employers and employees as well as from inter-generational smoothing. The regulations for insurance companies and pension schemes were compared in this paper and they argued that the principles of insurance products should also apply to pension products to bring them under an equal footing. From the perspective of pension regulation, they stated that the solvency of DC schemes is not a major concern as the liability equals the value of assets by definition. The only risks underlying DC schemes are fraud, theft and incompetence. For DB schemes however, current pension regulation allows them to build up deficit and remain in deficit over many years. Schemes are also allowed to mismatch their assets and liabilities and allow new entrants even if they are already in deficit. As the risks associated with DB schemes are significant, they concluded that stronger regulations should be introduced to bring the regulation for pension schemes more in line with insurance products.

Following on from the risk assessment of a pure DB pension scheme as demonstrated in Chapter 4, we analyse the effect of adopting a hybrid structure on the level of economic capital. As mentioned by a number of researchers above, hybrid schemes do provides a good trade off between risks and returns in some circumstances compared to both pure DB and pure DC pension schemes. We expect to find hybrid pension design to be more attractive to scheme members and have a lower risk level in terms of economic capital to the pension providers compared to a pure DB scheme.

5.2 A Hypothetical Hybrid Structure for USS

In this section, we will set out a hypothetical hybrid pension design for the USS which will provide us a direct comparison of risk levels of a hybrid pension scheme against a pure DB scheme. We have not considered regulatory issues of implying the hybrid structure in this thesis.

As mentioned earlier, in this chapter we will focus on underpin hybrid pension arrangements. In an underpin arrangement, a member's benefit after retirement could be calculated using many scales at the same time. For example, a hybrid pension scheme could apply a final salary scale, a career average scale based on a higher accrual rate and a DC scale simultaneously and give the highest pension among these three scales.

We will focus on a particular underpin arrangement with two scales using both DB and DC approach in the rest of the chapter. However, more benefit calculation scales could be used and in general providing more pension guarantee will result in a higher risk for the pension provider.

As members' benefits are calculated using both DC and DB scales, it can be considered as a DC guarantee with a DB underpin. When pension benefits become payable, the benefits calculated using the DC approach will be compared with the DB benefits and the higher of the two will then become payable to scheme members.

The amount of DC benefit at retirement is determined by the accumulated value of contributions as well as the price of buying a lifetime annuity. The DC fund for any year before retirement age would be the DC fund value in the previous year increasing with investment plus the contributions made this year. At retirement age the amount of pension is determined as the total fund value over the price of buying a life annuity.

If the fund value is £100 at retirement age and the price of buying a life annuity is £20 one-off payment for every £1 annuity increasing with inflation. The pensioner will get a life time annuity of £5 increasing with inflation.

The price of the annuity is determined by discounting future annuity payments back to the retirement age using the applicable discount rate projected for that particular simulation at retirement age.

The accumulated contributions is built up using investment returns on the contributions. The price for converting the DC fund into a life time annuity is determined using projected interest and mortality rates starting from the retirement age. After the crystallisation of benefits, the pension will be provided until the death of the member.

The amount of benefit from DB underpin is calculated from the duration of members' pensionable service and their final salary. Based on the amount of DB and DC benefit, the hybrid scheme will pay the higher of the two till the member dies.

In Chapter 4 we have already found that the current 1/80th final salary DB set-up results in a significant amount of economic capital requirement. We expect that the economic capital requirement would be reduced by sharing some of risks with the scheme members using an underpin structure. The economic capital requirements for the original 1/80th final salary DB pension design will be compared to hybrid scheme designs using DC benefits with both 1/80th and 1/120th DB underpins.

As we are assuming a hypothetical hybrid design for the USS, we use the same membership profile, investment strategy, demographic and investment model to provide a direct comparison.

Most assumptions directly follow from Chapter 4. The only differences between the hybrid model and the final salary pension scheme model are listed below:

- We have excluded the model points for pensioners, dependants and deferred members whose pension benefits are already in payment or determined by the final salary structure.

- We have excluded the benefits active members have already accrued before year 2008. By doing so, we only model active members assuming that they start accruing a hybrid benefit from year 2008 onwards which enables us to isolate the effect of a hybrid pension design.

- The liabilities and benefits for the hybrid pension scheme are calculated as a maximum of both DC and DB scales.

The results for the hypothetical hybrid scheme are then compared with same membership profile continuing to contribute to a final salary DB pension scheme from 2008 with no past service to see the effect of the underpin arrangement.

5.3 Results

We first produce results for USS scheme members using the original 1/80th final salary pension scheme ignoring past service, followed by the hypothetical hybrid pension set-up.

Recall from Chapter 4, that the fund under USS is invested 90% in equity and 10% in long-term government bond. We will assume that this investment strategy will also be continued under the hybrid structure. We will consider different scenarios of DC guarantees, DB underpins and investment strategies.

Four cases of DC guarantees will be considered as follows:

- DC Guarantee A: DC fund will accumulate in line with the actual fund investment.

- DC Guarantee B: DC fund will accumulate at a flat rate of 4% per year.

- DC Guarantee C: DC fund will accumulate in line with the long-term government bond index.

- DC Guarantee D: DC fund will accumulate at a flat rate of 8% per year.

We also consider two different levels of DB underpins:

- DB underpin A: 1/80th accrual rate which is the same as the USS current final salary DB guarantee.

- DB underpin B: a reduced 1/120th accrual rate.

In general, if the DC fund is invested in the same asset as the DC guarantee, the risks from the DC part can be minimised because the asset value will be the same as the value of liability at any time point. Otherwise, additional capital might be needed to back the asset-liability mismatch risk.

As we are aiming to find the economic capital relief for a hybrid pension design, we will try to minimise the effect of other factors on the level of economic capital. So in this chapter, we will also quantify economic capital in the case where on retirement risk is transferred to an insurance company by purchasing annuities. If the pension benefits are paid from the pension fund itself, the scheme still needs economic capital to back the risks of not meeting these pension benefits. Removing this effect can help in isolating the risk of the hybrid guarantee.

In this chapter, we will first compare the economic capital of final salary pension design and the hybrid pension design based on the assumption that pension benefits are paid from the scheme which is referred to as the base case. We then produce results based on the assumption that annuities are bought from an insurance company on retirement which we refer to as the buy-out case.

5.3.1 Base Case

In this section, we produce economic capital requirements assuming pension benefits are paid from the scheme itself.

First, we show the results for the 1/80th final salary DB pension in Figure 5.1. It can be seen that the shape of liability follows the same shape as in the figures given in Chapter 4 except that the value of liability here starts from 0 and peaks at a lower value, as we have excluded the accrued benefits till 2008. We can see that the liability peaks after 32 years when the youngest model point group currently aged 30 retires. We have also shown the liability level of the hybrid pension set up in this graph. It can be seen that by providing a hybrid benefit structure, on average, the cost of providing the benefit is higher than a pure DB structure.

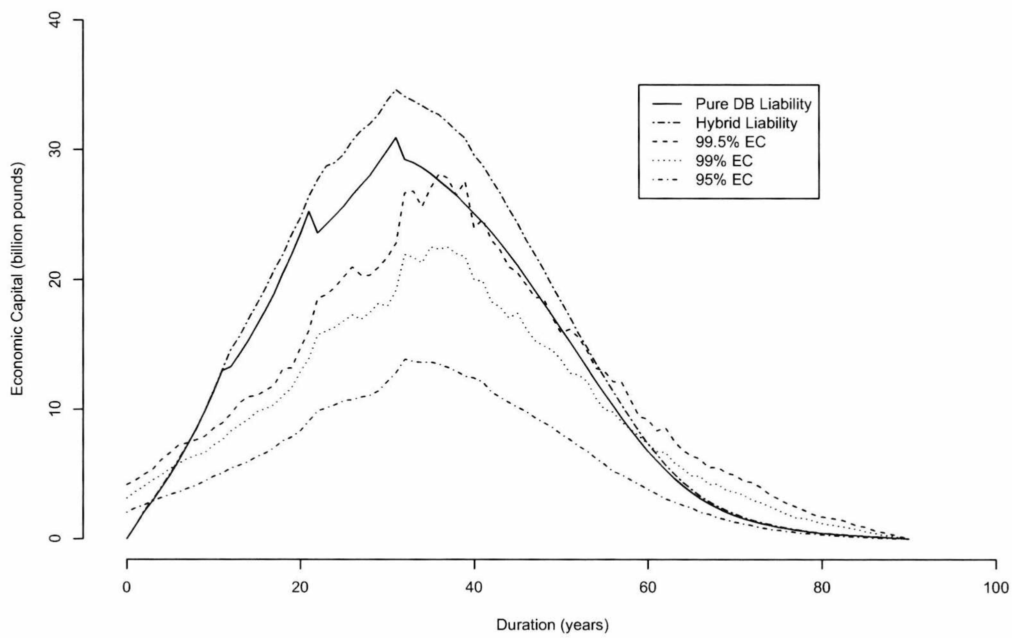

Figure 5.1: Liability and economic capital for 1/80th DB final salary benefit.

The level of economic capitals are also lower compared to the results shown in Chapter 4 which included accrued benefits. At 99.5th percentile level economic capital starts from £4.17 billion in year 2008 and peaks around £28 billion after 35 years.

We then quantify economic capital at 99.5th percentile levels for the hypothetical hybrid pension scheme for different scenarios at time 0 which is year 2008. The numbers are produced in Table 5.1.

Table 5.1: The economic capital requirements at 99.5th percentile level in year 2008 in billions pounds for different hybrid scheme structure.

	DC guarantee			
	A	B	C	D
DB underpin A	4.02	3.73	3.91	4.57
DB underpin B	3.46	1.70	2.36	4.35

Comparing the economic capital of hybrid design having DC guarantee A and DB underpin A with the final salary DB case, we can see that the economic capital requirement actually decreases by £0.15 billion. The only difference between these two cases is that in the hybrid design, an additional DC guarantee is provided. The reason for having a lower economic capital where more guarantee is provided is that in the hybrid case, the pension provider is required to hold a liability which is the maximum of the DC guarantee and DB underpin. This has resulted in a higher liability value and consequently a lower economic capital.

The economic capital at 99.5th percentile levels for DC guarantee A with different DB underpins cases (the second column of Table 5.1) are shown in Figure 5.2.

We can see from this graph that the shape of economic capital is spiky. This is the effect of paying pension benefits from the scheme after retirement for the three active member model points aged 30, 40 and 50 respectively. As the DC guarantee A is based on 90% investment in equity and 10% in

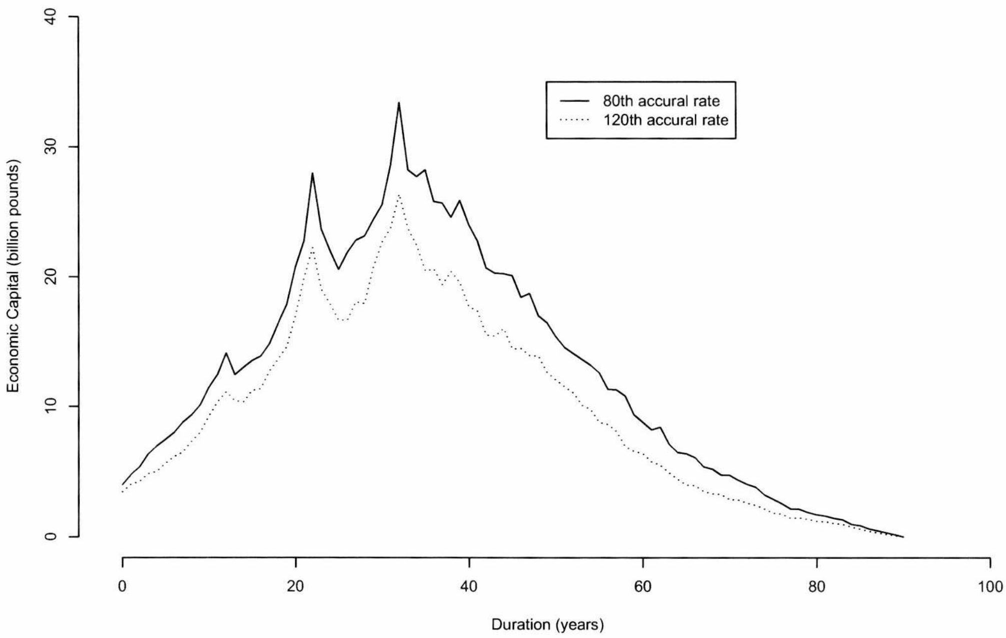

Figure 5.2: Economic capital at 99.5th percentile levels for DC guarantee A with different DB underpins.

bond, very large pension payments are possible if investment returns are good. A significant economic capital is then needed to back these pension payments.

We can also see from Figure 5.2 that by reducing the DB underpin from 1/80th to 1/120th did not reduce the economic capital requirement by much. This is because the economic capital in these cases is mainly dominated by the DC guarantee rather than the DB underpin. We will remove the effect of pension guarantees after retirement in the next section.

Next, we show the economic capital at 99.5th percentile level for the DC guarantee B (4% fixed annual return) with different DB underpins (third column of Table 5.1) in Figure 5.3.

Comparing Figure 5.3 with Figure 5.2, we can see that the economic

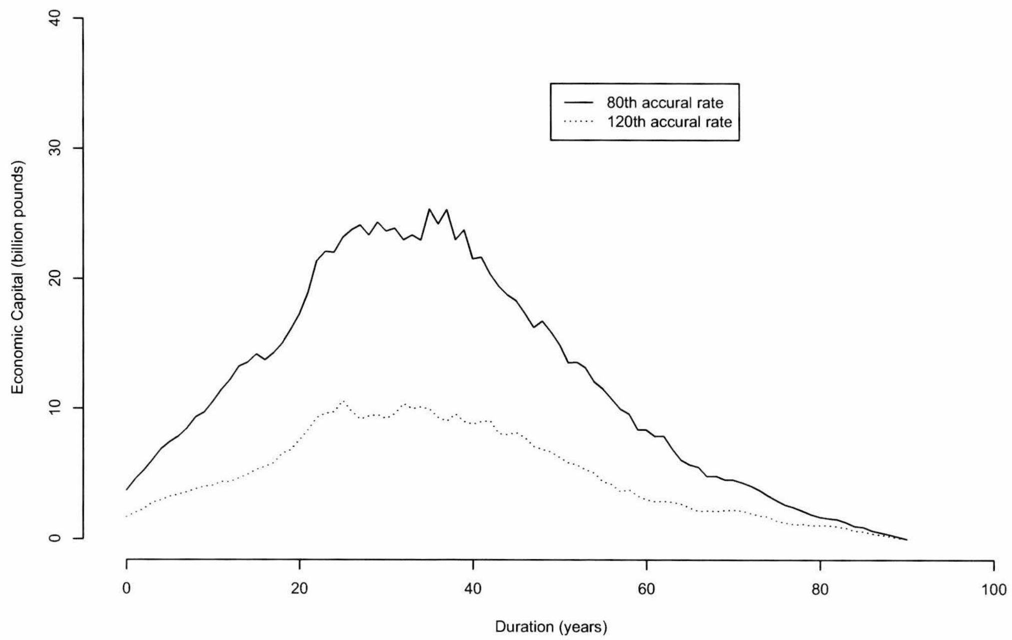

Figure 5.3: Economic capital at 99.5th percentile levels for DC guarantee B (4% fixed annual return) with different DB underpins.

capital curves in these two figures have different shapes. This is because for DC guarantee B, the economic capital is no longer dominated by the high DC guarantee. The economic capital in this case mainly reflects the risk that the accumulated DC fund is not enough to meet the DB underpin at retirement age. More economic capital is needed to support pensions based on a higher DB underpin. We can also see from Figure 5.3 where DC benefit does not dominate the benefit payments after retirement, by reducing the DB underpin, the economic capital drops significantly.

We have also checked (not shown here) that for the DC guarantees C (long-term government bond return) and D (8% fixed return), the economic capitals take the same shape as the DC guarantee B (4% fixed annual return case) but with higher economic capital values.

We then look at the effect of different DC guarantees when the DB underpin is fixed. Taking the DB underpin B (1/120th accrual rate, last row of Table 5.1) as an example, we show the economic capital at 99.5th percentile levels for all durations in Figure 5.4.

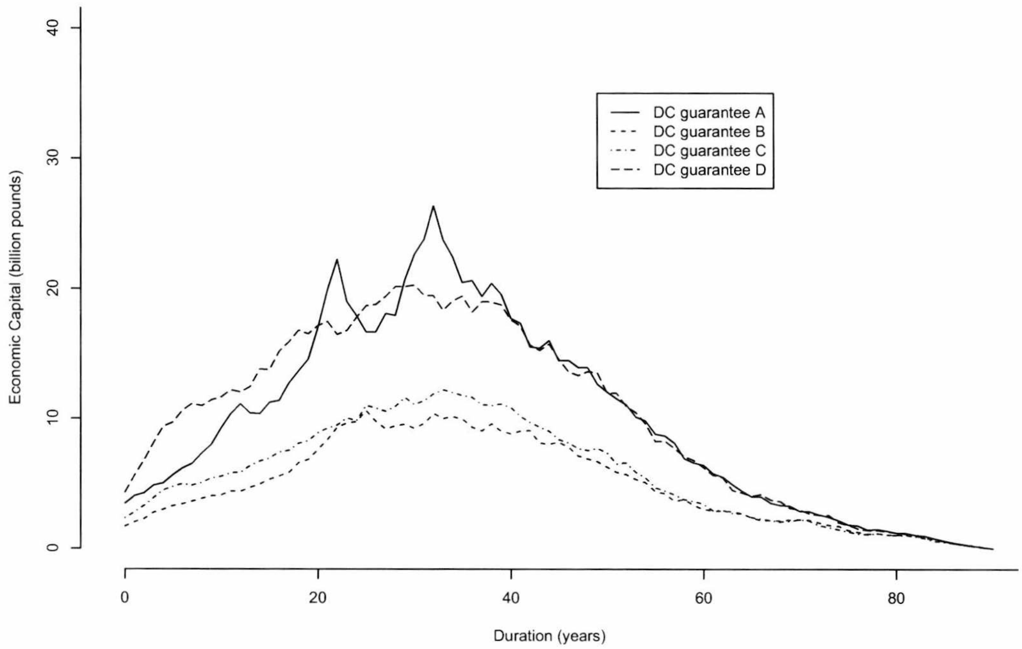

Figure 5.4: Economic capital at 99.5th percentile levels for DB underpin B (1/120th accrual rate) with different DC guarantees.

It can be seen from Figure 5.4 that by having the same DB underpin, lower DC guarantee requires lower economic capital backing as expected. In addition, the DC guarantee A is the only case having a spiky economic capital curve because of possible high annuity payments caused by DC guarantee after retirement.

5.3.2 Buy-out Case

In the previous subsection, we have produced economic capital requirements for a hybrid scheme paying pensions from within the fund itself. However, as pointed out earlier, substantial economic capital requirement can still arise due to the risk of paying pension benefits from own fund.

In this subsection, we remove the risks of pension payments by assuming that annuities are bought from an insurance company at retirement age. We assume that the price charged by an insurance company to take over the liability is equal to the amount of liability.

As a result, these buy-out cases will eliminate the need to hold economic capital to back pension payments after retirement. For each member, the economic capital requirement will fall to 0 immediately on retirement as the future risk has been transferred on to the insurance company. The economic capital requirements in the buy-out cases are therefore purely for the risks that the accumulated fund has fallen below the maximum of DB underpin and DC guarantee.

For the final salary DB pension scheme with buy-out assumption, the economic capital at 99.5th percentile level turns out to be £3.75 billion which is lower than the base case as expected. The comparable figures for the base case is £4.17 billion which is £0.42 billion higher.

The results for the buy-out cases for different DC guarantees and DB underpins are presented in Table 5.2.

Table 5.2: The economic capital requirements at 99.5th percentile level in year 2008 in billions pounds for buy-out cases.

	DC guarantee			
	A	B	C	D
DB guarantee A	3.65	3.20	3.42	3.97
DB guarantee B	0.95	0.85	1.29	3.14

Figure 5.5 shows the economic capital for all durations for DB underpin B (1/120th accrual rate) given in the third row of Table 5.2.

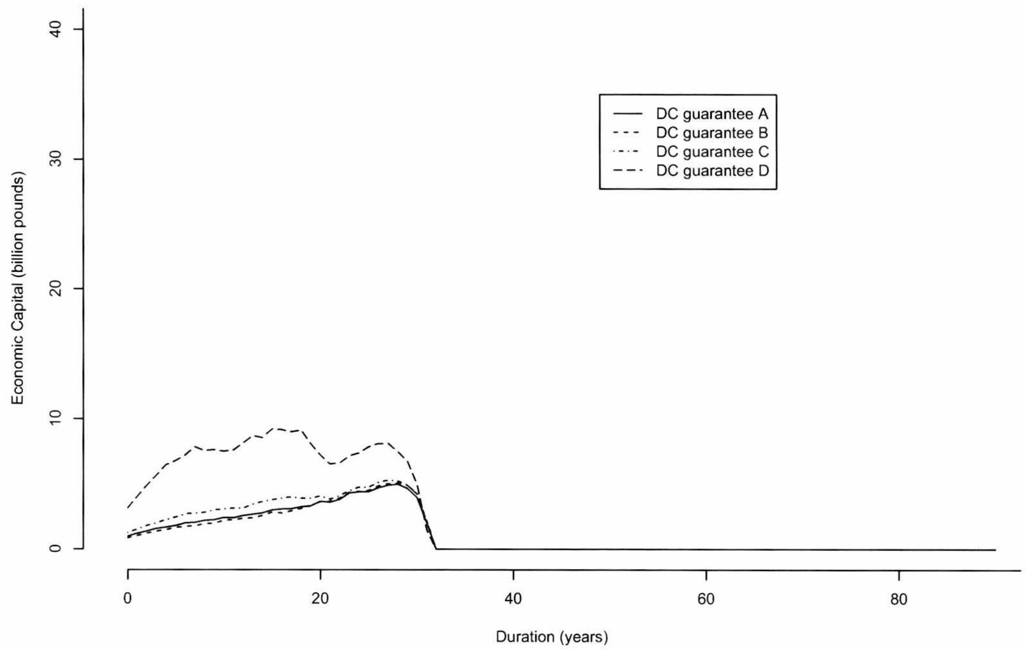

Figure 5.5: Buy-out case: economic capital at 99.5th percentile levels for underlying DC benefit with different DB accrual rates.

By comparing Figure 5.5 with Figure 5.4 we can see that the economic capital requirements are much lower in the buy-out cases especially for DC guarantee A. The DC guarantee A does not have a spiky shape anymore and produces a lower economic capital requirement as expected.

The levels of economic capital for buy-out cases are always lower than the base case. Moreover, the economic capital requirement falls to 0 after 32 years when the liabilities of the last group of members are transferred to insurance companies leaving no risks within the hybrid scheme.

Comparing the numbers in Table 5.1 and 5.2, more significant drops in economic capitals are observed when applying 1/120th DB guarantee together with the buy-out assumption. By providing 1/120th accrual rate in conjunction with DC guarantees A or B, the economic capital requirement falls below £1 billion.

However for DC guarantee D (8% fixed annual return) significant risk persists as the actual DC fund struggles to meet the guarantee provided. Reducing the DB underpin has limited effect in this case.

Overall, comparing with the pure DB final salary pension set-up, a significant reduction can be seen in economic capital requirement by adopting a hybrid pension design with a lower accrual rate for the DB underpin. Having pension payments transferred to an insurance company can also reduce the risk for the pension provider significantly. Of course, it is based on the assumption that an insurance firm will be willing to take on the liabilities at the desired price which may not be possible in reality.

5.4 Summary

In this chapter, we have used economic capital as a measure of risk for a hybrid underpin pension set-up. We have found significant reduction in economic capital if the USS adopts a hybrid structure using a lower accrual rate. We have shown that it is practical and effective to use hybrid scheme design to de-risk DB pension schemes.

We have also tested the effect of purchasing annuities at retirement from an insurance company. We have found that the risks arising due to payment of pension benefits from the scheme itself is substantial. Transferring some of these risks to insurance companies can reduce the risk level of a pension scheme significantly.

In summary, for the purpose of controlling DB pension risks, apart from reducing DB benefits, closing down DB schemes or switching to DC schemes, hybrid pension designs provides a viable alternative. We have found that risk sharing can play an important role in pension risk management. Risks can be shared between scheme providers and scheme members. It can also be shared between scheme providers and insurance companies.

The risks embedded in a pension scheme may at first seem unaffordable to pension provider. However, breaking down the risks into its constituent parts and sharing them between scheme provider, scheme member and insurance companies, can provide a suitable approach in managing pension risks.

Chapter 6

The Pension Protection Fund

In the previous two chapters, we have used the USS to illustrate the economic capital requirements for a pure DB and a hybrid pension scheme. We found that the economic capital requirements can be substantial for the pension provider and it may not be practical for every pension provider to fund the amount of economic capital required to back the underlying risks.

In this chapter, we will use a risk-based approach to examine the amount of economic capital required to cover the risks associated with the PPF which guarantees benefits of all eligible UK DB pension schemes.

We will adopt stochastic time series investment and longevity models to quantify the aggregate amount of risks for the PPF using economic capital. We will analyse different ways of de-risking schemes covered by the PPF and the PPF itself. In addition, we will also test the capital requirement for individual schemes and compare with the PPF's economic capital requirement.

The rest of the chapter is organised as follows. In Section 6.1, we provide an overview of the PPF. A literature review of relevant research is included in Section 6.2. Section 6.3 provides background information for the PPF. Section 6.4 outlines our modelling assumptions. The results and sensitivity tests are discussed in Section 6.5. In Section 6.6, we draw our conclusions.

6.1 Overview

Following the death of Robert Maxwell who had embezzled a large amount of money from the pension fund of Mirror Group Newspapers, The Pensions Act 1995 was introduced to protect the benefits of pension scheme members. The Occupational Pensions Regulatory Authority (OPRA) was established by the Pension Act 1995 to regulate work-based pension schemes in the UK.

The Pensions Regulator replaced OPRA on 6 April 2005 after the enactment of The Pensions Act 2004, with wider powers than OPRA. The Pension Regulator created the PPF which is a statutory fund starting from 6 April 2005. The PPF is empowered to collect levies from all eligible schemes and provide pension benefits for schemes if their sponsors become insolvent. It effectively acts like an insurer for the UK DB pension industry.

According to the Purple Book 2010 (The Pension Protection Fund and The Pensions Regulator (2010d)), by March 2010, there were around 6,600 schemes with liabilities amounting to £888 billion covered by the PPF. The memberships in total were around 12 million. As the PPF guarantees most part of the deficit of these pension schemes, the future solvency of the PPF is a concern for the UK DB pension industry.

A similar protection fund, USA's Pension Benefit Guaranty Corporation formed in 1974 and after having many years of low claims, faced some very large claims since year 2000 due to adverse equity market performance. It had a deficit of $23 billion in 2004 ($63 billion liability), $22 billion in 2009 ($92 billion liability) and reported a projected median deficit of $25 billion in 2019 according to its Annual Report 2009 (Pension Benefit Guaranty Corporation (2009)). Among other issues, as schemes covered by the UK's PPF have significant amount of risk exposure to the equity market, if a large number of eligible schemes become insolvent, it is quite possible that the PPF will also face similar problems in the future.

It is possible that by holding an additional capital on top of the liability, PPF can survive adverse circumstances without recourse to tax payers' money or imposing additional levy from surviving schemes. Our objective is to quantify the amount of capital PPF would need to hold in order to maintain a low insolvency rate with regard to PPF's funding position. We employ a full stochastic time series model with an economic capital approach to estimate the capital requirement for the PPF.

6.2 Literature review

A number of research papers have focused on the risk associated with the PPF. The PPF has been compared with other similar pension protection funds and insurance products. The risk level of the PPF has been tested in various ways and most of the literature suggests that the PPF faces significant risk. A number of ways of de-risking the PPF have also been suggested in these papers.

Blake *et al.* (2007) draws lessons from other government-sponsored insurance schemes such as US Pension Benefit Guaranty Corporation. They commented that insurance works less well if the risks assumed are correlated. Considering the PPF as insurance for all UK eligible schemes, it faces systemic risks as well as insolvency risks. The PPF has also chosen a highly conservative investment strategy with more than 60% of its assets invested in bonds. The authors conclude that the PPF faces substantial risks while the current levels of capital backing the PPF's risks is relatively low. In conclusion, a formal capital requirement, as for life assurance products, are recommended for adoption by pension schemes to improve the level of security for scheme members.

McCarthy and Neuberger (2005) provides more evidence in support of this opinion. They have mentioned that insolvencies are cyclical and underfunding risk is most when the insolvency probability peaks. This is because UK pension schemes are heavily invested in equities and equity under-performance is positively correlated with insolvency rates. They have adopted a simulation based approach to examine the risk associated with the PPF where they assumed an infinite number of small, identical firms with independent insolvency risk modelled as a Poisson process. In this set-up, all firms have the same asset split between equities and bonds (two-thirds of the pension fund invested in equities), schemes have a 10-years amortisation period subject to a maximum funding cap of 120%. By calculating the fair value premium for the PPF, they have found that the PPF is likely to have many years of small claims with rare and unpredictable periods of exceedingly large claims which might result in the PPF becoming insolvent. They have argued that the claim sizes of the PPF will vary so much, just like the USA's Pension Benefit Guaranty Corporation, that the surpluses in the good years are not enough to cover the deficits in the bad years. They have also argued that more strict capital requirement should be introduced for individual pension schemes and the PPF.

Sweeting (2006) focused on the impact of correlations, between pension scheme assets and firm values, on the levy charged by the PPF. The author recommends that the risk-based levy charged by the PPF should also consider the following factors:

- the value and volatility of pension scheme assets and liabilities;
- the value and volatility of the firm's value and its debt;
- the correlations between these items.

The author arrived at a levy which is significantly higher than the PPF's current levy and concluded that ignoring the correlations would result in a potentially serious underestimation of the PPF's levy.

Charmaille *et al.* (2012) discussed the application of Enterprise Risk Management principles and techniques for the PPF. They argue that holistic risk management techniques, which are widely used by banks and insurance companies, could also make sense for pension schemes. They compare the PPF long-term risk model with Solvency II financial risk management approach and conclude that financial risk management principles and practises can provide an effective and objective basis for decision making of the PPF.

The Institutions for Occupational Retirement Provision (IORP) Directive European Commission (2003) is the European prudential framework for IORP. Member states had to implement it by 23 September 2005. The UK government has implemented it through The Pension Act 2004.

The objective of IORP is to provide a cross-border prudential framework for pension funds. It enables schemes in different member states to be managed uniformly by a set standard. The latest document issued by the EIOPA (European Commission (2011a)) revealed an intention to move towards a supervisory system in which the financial position of a pension scheme will be assessed by a risk-based approach.

In summary, past research has highlighted that the amount of risk exposure of the PPF from the DB pension sector is large and may endanger the existence of the PPF itself. It has also emerged that the PPF's levy together with its asset holding is not enough to provide sufficient protection for the PPF and the eligible pension scheme members. As at 2010, DB pension schemes are not subject to regulatory capital requirement. The PPF also has no formal capital requirement to protect itself from the risk of insolvency. We argue that either at the scheme level or for the PPF, capital needs to be set aside to back the risks inherent in pension schemes.

6.3 Background

The PPF was established in 2005. It guarantees accrued benefits for members of eligible schemes when a qualifying insolvency event occurs. If there is insufficient asset in a pension plan to cover benefit payments when the pension sponsor becomes insolvent, the PPF will guarantee the members' accrued benefits up to the PPF compensation levels.

Most DB occupational pension schemes and DB elements of hybrid schemes in the UK are protected by the PPF. Schemes exempt from PPF are those schemes which are unfunded or covered by a crown guarantee (liabilities of these schemes are underwritten by the government). All eligible schemes are liable to a compulsory PPF levy payable annually.

Normally, in case of deficit where the sponsor is still solvent, the scheme trustees are simply required to agree a funding strategy with the sponsoring employer to remedy the deficit in due course. A recovery plan is triggered if the scheme funding falls below a certain level. A recovery plan can have a period of 10-15 years to allow the scheme to make up any deficit. If the sponsoring employer becomes insolvent and the associated DB pension scheme is still in deficit, the PFF guarantees 90% of pensions in deferment and 100% of pensions already in payment subject to compensation caps.

Table 6.1, extracted from Purple Book 2010 (The Pension Protection Fund and The Pensions Regulator (2010d)) shows that the recognition of the significant risk associated with DB schemes have led many schemes to shift to DC schemes as well as become closed to new members or future accruals. Evidently, schemes have already began to limit further exposure to risks.

Table 6.1: PPF eligible schemes distribution for 2008, 2009 and 2010.

	2008	2009	2010
Open	31%	27%	18%
Closed to new members	50%	52%	58%
Closed to future accruals	17%	19%	21%
Wound up	2%	2%	3%

However, a substantial amount of risk still remains due to the exposure to the equity market and sponsor insolvency. Even closed schemes have exposure to these risks arising out of benefits which have already been accrued. As reported by the Purple Books, the funding ratio, which is the level of assets over liabilities, of all PPF eligible schemes peaked at 121% in 2007 and troughed at 79% in 2009 which means a deficit of as much as £216.7 billion.

As there is no requirement for the PPF to hold additional capital on top of its liabilities, there is no guarantee that the PPF itself can stay solvent in the future. In this thesis, we have used an economic capital approach to estimate the risk level of the PPF and test how the amount of risk is affected under different circumstances.

6.4 Model Assumptions

In order to quantify economic capital, we use projections of future economic and demographic scenarios to calculate the amount of economic capital that should be held by PPF to ensure its long-term solvency.

The PPF has also developed its own long-term risk model (The Pension Protection Fund and The Pensions Regulator (2010c)) to estimate the PPF levy. Details of PPF's long-term risk model is enclosed in Appendix C. However, the PPF's long-term risk model focuses on solvency over a time horizon of 5 years while we adopt a run-off approach. According to PPF's long-term risk model, the deficit of the PPF after 5 years at 99th percentile level is as much as £11.7 billion.

The assumptions used in our model are discussed in the remainder of this section as follows:

- Eligible schemes' benefit structure.
- Membership profile.
- Levy assumptions.
- Liability valuation assumptions.
- Investment assumptions.
- Additional assumptions.

6.4.1 Eligible Schemes' Benefit Structure

In this subsection, we set out our assumptions for PPF eligible schemes' benefit structure. We assume that all schemes covered by the PPF take the same generic final salary DB pension structure where the normal retirement age is assumed to be 65 for both males and females and no allowance is made for early retirement as this option is usually cost-neutral.

Pensions and cash lump sum benefits on retirement is calculated using an accrual rate of 1/80th giving a pension of half the final salary after 40 years of service based on the following formulae:

$$\text{Annual pension} = \text{Accrual rate} \times \text{Pensionable service} \times \text{Pensionable salary};$$

$$\text{Lump sum payment} = 3 \times \text{Annual pension}.$$

Pensionable service denotes the duration of employment. Pensionable salary is the salary at the date of retirement. The annual pension is increased in line with RPI as generated by the economic model every year.

Scheme death benefits are as follows:

- For active members, death in service benefits comprise a lump sum payment of three times annual salary and a spouse's pension of half the pension the member would have received if the member had survived until normal retirement age.
- On the death of a deferred pensioner, a lump sum equal to the present value of the deferred lump sum payable at normal retirement age is provided along with a spouse's pension of half the amount of the deferred pension at date of death.
- On the death of a pensioner, a spouse's pension equal to half the member's pension is paid to the surviving spouse.

This benefit structure is broadly based on scheme design of the USS which is one of the largest eligible schemes in the PPF as outlined in Chapter 2.

For members who have withdrawn from the scheme, deferred RPI linked pension benefits are provided based on accrued service on withdrawal. RPI indexation of salaries between the date of leaving and retirement is provided.

PPF's compensation increase for pension service prior to 6 April 2009 is subject to a cap of 5% p.a. For pension service on or after 6 April 2009, the compensation increase is subject to a cap of 2.5% p.a. The compensation is also subjected to an overall annual cap of £29,897.42 at age 65 after applying the 90% compensation adjustment.

Assumptions for annual scheme withdrawal rates and the percentage married are displayed in Table 6.2. As industry average experience is not directly available, we have taken these rates from the data available for USS and we assume all schemes to follow the same rates. For intermediate ages, we use linear interpolations.

Table 6.2: Withdrawal rates and proportion married assumptions.

	Withdrawal Rates		Proportion married	
Age	Male	Female	Male	Female
25	14.42%	19.28%	34%	56%
35	9.19%	11.40%	81%	84%
45	3.79%	3.83%	92%	93%

The average salary for all members is assumed to be consistent with all UK population reported in National Statistics which states that the average salary per year was £26,510 p.a. in 2010 (http://www.statistics.gov.uk).

6.4.2 Membership Profile

We estimate the PPF's membership profile from the Purple Book 2010 (The Pension Protection Fund and The Pensions Regulator (2010d)). According to this document, by March 2010, there were around 6,600 schemes (excluding 341 schemes in the PPF assessment process) with 12.0 million memberships covered by the PPF including 5.2 million deferred memberships, 4.3 million pensioner memberships and 2.4 million active memberships (an individual can have multiple memberships). The total liability of the schemes covered by the PPF excluding schemes in the assessment process at March 2010 was £888 billion. By March 2010, there were already in total £2.5 billion liabilities has been transferred to the PPF. As a result, the PPF is in charge of paying benefits to schemes with a total liability of £2.5 billion and guarantees schemes with total liability of £888 billion which might be transferred to PPF if their sponsors went insolvent. As demonstrated in Figure 6.1, box A represents schemes which are paying a PPF levy but have not yet been transferred to the PPF (total liability of £888 billion), box B represents schemes which have already been transferred to the PPF after the insolvency of their sponsor (liability aggregating £2.5 billion). If a sponsor of a scheme in box A went insolvent with insufficient asset to cover its liability, it will be moved from box A to box B. If there is adequate asset to cover the liability of a scheme after the insolvency of the sponsor, the scheme will be moved outside the system (an insurance company will guarantee the scheme's benefit).

Schemes covered by the PPF can be classified into following four categories: open schemes (still running and accepting new members), schemes closed to new members (running but not accepting new members), schemes closed to future accrual (members can not accrue further benefits) and schemes wound up. The distribution of membership at 31 March 2010 is shown in Table 6.3.

We can see that active members only contribute 20% towards the total membership. Most members are deferred members and pensioners. It can also be seen that open schemes only contribute 34% to the total membership. As schemes are either closed to new members or future accruals. Without

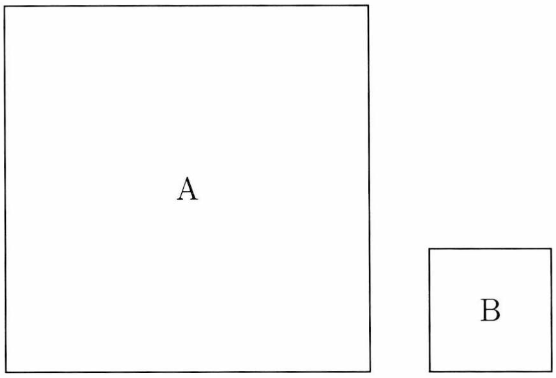

Figure 6.1: The structure of the PPF

Table 6.3: PPF membership distribution (in millions).

	Open	Closed to new members	Closed to future accruals	Winding up	Total
Active members	1.14	1.26	-	-	2.40
Deferred members	1.52	3.31	0.37	0.03	5.23
Pensioners	1.44	2.64	0.23	0.03	4.34
Total	4.10	7.20	0.61	0.06	11.97

new schemes joining the PPF database, the percentages of active members and open schemes are expected to shrink even further.

According to these data, we estimate the PPF's membership distribution for our model as follows. In total 11,967,334 members in 6,596 schemes covered by the PPF are divided into 7 groups by the size of memberships. We have divided schemes with over 10,000 members into 3 groups as E1, E2 and E3 to model the impact of insolvency of schemes with relatively large membership profile. We also assume that schemes within each group are identical and have same membership distributions. Following this assumption we calculate the average number of active members, deferred members and pensioners for each of the group as shown in Table 6.4.

Table 6.4: Average membership distribution estimated from Purple Book 2010.

Group	Schemes	Active	Deferred	Pensioner	Total
A	2,342	7	23	14	44
B	3,018	68	177	103	348
C	832	483	1,057	718	2,258
D	184	1,382	3,254	2,469	7,106
E1	170	2,859	5,709	5,384	13,952
E2	40	13,459	26,876	25,348	65,684
E3	10	53,836	107,506	101,393	262,734
Total	6,596	2,441,985	5,188,612	4,336,737	11,967,334

For modelling simplicity, we also use the following six model points to represent active members, deferred members and pensioners for all schemes as shown in Table 6.5. These model points are estimated from Purple Book 2010. The ages of these model points are the average age data taken from Purple Book 2010. Past service is calculated by matching the liability of each model point. The amount of accrued pension, pension payments and gender split are again taken from Purple Book 2010.

Table 6.5: PPF model points.

Membership	Sex	Age	Benefit
Active	Male	42	16 years past service
	Female	42	16 years past service
Deferred	Male	48	Accrued pension of £3,700 per year
	Female	48	Accrued pension of £2,000 per year
Pensioner	Male	67	Pension of £4,500 per year
	Female	67	Pension of £2,100 per year

The schemes within each group can also have different investment strategies. According to Purple Book 2010, out of the total of 6,596 schemes, around 1,500 schemes are investing 25% of their assets in equities while

75% is in bonds, 4,000 schemes are investing 50% in equities and 50% in bonds, 1,000 schemes are investing 25% in equities and 75% in bonds.

Based on this, we have assumed for each group of pension schemes, 25% of schemes invest 25% in equity, 60% of schemes invest 50% in equity and 15% of schemes invest 75% in equity. Remaining assets are assumed to be invested in bonds.

The data on funding levels for schemes in each group are taken from Purple Book 2010 and are shown in Table 6.6.

Table 6.6: Funding levels by size of scheme membership as at 31 March 2010 (Purple Book 2010).

Group	50%-75% funded	Funding levels 75%-100% funded	Over 100% funded	Actual Liability (£billion)	Estimated liability (£billion)
A	12%	36%	52%	10.2	10.0
B	17%	45%	38%	82.3	76.7
C	13%	50%	37%	138.1	129.8
D	9%	49%	42%	100.2	96.4
E	4%	34%	62%	557.2	571.1
Total				888.0	884.1

By using an average funding level of 63%, 88% and 113% to represent the 50%-75%, 75%-100% and over 100% funded groups respectively, we obtained the estimated liability as shown in Table 6.6. The 113% funding level for schemes which are over 100% funded is estimated by matching the liability level with PPF's data. The estimated values show a good match of the PPF's liabilities.

6.4.3 Levy Assumptions

The PPF's levy is related to the schemes' funding levels, insolvency probabilities and protected liability levels. The method used by the PPF to calculate its levy is provided in Appendix D.

Since it is not the purpose of this article to model each scheme's levy payment, we use a simplified approach to model the PPF levy by assuming that the aggregate levy charged for all schemes is a constant proportion c of the total liabilities of the schemes under cover, i.e schemes which have not yet been transferred to the PPF. If the total liability of schemes covered by the PPF is TL_t at time t, the PPF annual levy charged in year t would be $c * TL_t$.

The estimation of parameter c is based on the principle that the aggregate levy charged should be just enough to meet the total expected deficit transferred from insolvent schemes into the PPF. If an insolvent scheme's asset at time t when the insolvency event occurs is A_t and the liability is L_t, the deficit transferred to PPF is $\text{Max}(L_t - A_t, 0)$ at time t. As the PPF needs to meet this deficit from its levies to bring back the funding levels of these schemes back to 100%, the levy charged should be enough to meet these deficits.

We have simulated future deficits transferred to the PPF and future total liability of schemes covered by the PPF, by setting the expected net present value of PPF levy equal the expected net present value of future deficits. We found that the required value of c needs to be 0.067%, i.e the estimated average annual PPF levy for each scheme is 0.067% of their liabilities. This estimate is also close to the actual average levies charged by PPF which are 0.069%, 0.066% and 0.067% of the total liabilities for the years 2008, 2009 and 2010 respectively.

In all of our projections, we assume that the levy charged by the PPF in every future year is 0.067% of the total liability of schemes which have not yet been transferred to the PPF in that particular year.

6.4.4 Liability Valuation Assumptions

The liability calculation method we use is consistent with the Section 179 valuation method which is used by the PPF to estimate the funding levels. The PPF uses a combination of discount rates for different periods and membership status. The detailed rules are given in Appendix A. However, for our modelling purposes, we have adopted a simplified approach as outlined below.

As at 31st March 2010, according to the Section 179 valuation and applicable long-term government bond yields at that time, the following discount rate is calculated for different kinds of benefits.

- Compensations increasing in deferment accrued before 5 April 2010: 0.825%.
- Compensations increasing in deferment accrued after 5 April 2010: 2.03%.
- Compensations not increasing in deferment: 4.53%.
- Benefit already in payment which is increasing: 2.6%.
- Benefit already in payment which is not increasing: 5.1%.

By equating the liability of our model points with the PPF's data from Purple Book 2010 (The Pension Protection Fund and The Pensions Regulator (2010d)) and using all applicable discount rates listed above, we have estimated an average discount rate of 3% for all member groups in the PPF.

By using the estimated discount rate of 3% as at 31st March 2010 together with other assumptions introduced earlier, we obtain a good match with PPF's liability data as shown in Table 6.7.

Table 6.7: Total liability covered by the PPF in billion pounds as at 31st March 2010.

	Active and Deferred Members	Pensioners	Total
Purple book 2010	524	364	888
Our model	536	357	893

Next we link the discount rate to the long-term government bond yield in the economic model so that the discount rate can be projected forward consistently. At 31st March 2010, the long-term government bond yield was 4.63%, so the estimated discount rate of 3% is 1.63% less than the long-term government bond yield. We assume that this difference will stay constant over time. As our economic model generates long-term government bond yield over time with long-term mean value of 5.25% starting from 4.63% as at 31st March 2010, the discount rate will start at 3% on 31st March 2010 and vary over time with a long-term mean value of 3.62%.

For those schemes which have already been transferred to PPF as at 31st March 2010 and receiving a compensation from PPF, we have used the statistics extracted from Purple Book 2010 (The Pension Protection Fund and The Pensions Regulator (2010d)) as shown in Tables 6.8 and 6.9 to estimate the liability. The liability using our assumptions and the data displayed Table 6.8 and Table 6.9 is £2.59 billion which is close to the reported value of £2.45 billion in the PPF's annual report and accounts 2009/10 (The Pension Protection Fund and The Pensions Regulator (2010a)).

Table 6.8: PPF deferred membership data as at 31st March 2010.

Sex	Number	Age	Total Accrued Pension at 31st Mar 2010 (£000s pa)	Average deferred pension per member (£s pa)
Male	20,924	49	77,147	3,687
Female	5,134	47	10,406	2,027

Table 6.9: PPF pensioners membership data as at 31st March 2010.

Sex	Number	Age	Average pension as at 31st Mar 2010 (£000s pa)	Average pension per member per year (£s pa)
Male	14,325	68	64,814	4,525
Female	3,145	70	6,541	2,080

6.4.5 Investment

Table 6.10, extracted from Purple Book 2010, shows the investment pattern of schemes covered by the PPF.

Table 6.10: Asset allocation for all schemes.

	2006	2007	2008	2009	2010
Equities	61.1%	59.5%	53.6%	46.4%	42.0%
Gilts and fixed interest	28.3%	29.6%	32.9%	37.1%	40.4%
Insurance policies	0.9%	0.8%	1.1%	1.4%	1.4%
Cash and deposits	2.3%	2.3%	3.0%	3.9%	3.9%
Property	4.3%	5.2%	5.6%	5.2%	4.6%
Other investments	3.1%	2.5%	3.8%	6.0%	7.6%

It can be seen from this table that schemes have already started to de-risk themselves by moving towards less risky investment strategy. The percentage invested in equities dropped consistently since 2006 with increasing weightage on bonds. In 2010, around 50% of the investment are real assets (properties, equities and overseas equities), 50% of the investment are fixed assets.

The PPF itself has also chosen a highly conservative investment strategy. The PPF's assets include those assets from schemes transferred to PPF and levy payments. The PPF is aiming an asset allocation of 70% in cash and bonds, 10% in equities and 20% alternatives including property.

For the PPF, we assume a 70% of asset investment in long-term government bond and 30% in equities because The Purple Book 2010 indicates an investment split of 70% fixed and 30% real.

6.4.6 Additional Assumptions

We project the future economic and demographic scenarios using the model described in Chapter 3. The membership of pension schemes are projected into the future which enables us to calculate each scheme's asset and liability movements over time.

Each scheme's asset is allowed to grow subject to a funding cap which is set to be a percentage of the level of liability. This limit is imposed to prevent the pension schemes to be used as a tax avoidance device. This assumption is also consistent with McCarthy (2005). If the assets exceeds this funding cap, the surplus is assumed to be released. If assets falls below the level of liability, schemes are required to make up these deficits over a period of 10 years.

We then simulate insolvency events of all PPF eligible schemes. The assets and liabilities of schemes becoming insolvent are transferred to the PPF if the value of assets is less than that of liability at the time of the insolvency event.

The average insolvency probabilities for schemes with different sizes are taken from the Purple Book 2010 (The Pension Protection Fund and The Pensions Regulator (2010d)) and are given in Table 6.11. We have assumed that the number of annual defaults within each group follow a Poisson distribution with the parameters given in Table 6.11. So, each year, for a scheme in group A, it will have a probability of going insolvent which is a Poisson variable with mean value of 1.60%. We assume the probability of insolvency for each scheme is independent from each other and from year to year.

Table 6.11: Average annual insolvency probability for 2009/10.

Group	Annual insolvency rate
A	1.60%
B	1.40%
C	0.97%
D	0.40%
E	0.25%

By using the simulated timing and amount of liabilities and assets transferred to PPF, we further calculate PPF's own balance sheet. The PPF's assets consist of assets transferred to PPF from insolvent schemes and the levies collected less any compensation paid. The economic capital requirement, as discussed in Chapter 2, is the amount of capital needed on top of the value of assets to ensure that the value of economic capital plus the value of assets is always greater than the value of liabilities. For each particular scenario, we calculate the economic capital requirement for PPF using steps outlined in Section 2.3.2.

Additional assumptions used in our model are listed below:

- The maximum funding cap is set at 120% following McCarthy and Neuberger (2005) which means a maximum funding ratio of 120% for all pension schemes. If the funding level of a scheme exceeds 120% by any reason, we assume the excess is released from the scheme fund to restore the funding level back to 120%.
- The model is based on current membership profile and no new entrants into this system is considered.
- The total contribution rate is assumed to be 22.35% of member's

annual salary, which is the standard contribution rate estimated from our model points of active members using PUM.

- All schemes and their sponsors are independent from each other (multi-employer schemes are not considered in this thesis).

- Administration expenses, scheme transfer costs and taxation are not considered in our analysis.

- Schemes have an amortisation period of 10 years where they are required to make up any deficit in that period. If a scheme has a deficit of £10 in year 2010, it is required to eliminate this deficit by year 2020 by contribution £1 into the scheme every year ignoring any interest.

6.5 Results

In this section, we will present the results based on the assumptions set out in Sections 6.4. We will perform sensitivity analysis of the effects of:

- 4-year amortisation period.

- 150% maximum funding.

- PPF takes over all schemes.

- Sensitivity to investment strategy.

These results are discussed in detail in the following subsections.

6.5.1 Base Case

The base case results is shown in Figure 6.2 where the solid line represents the economic capital at 99.5th percentile level.

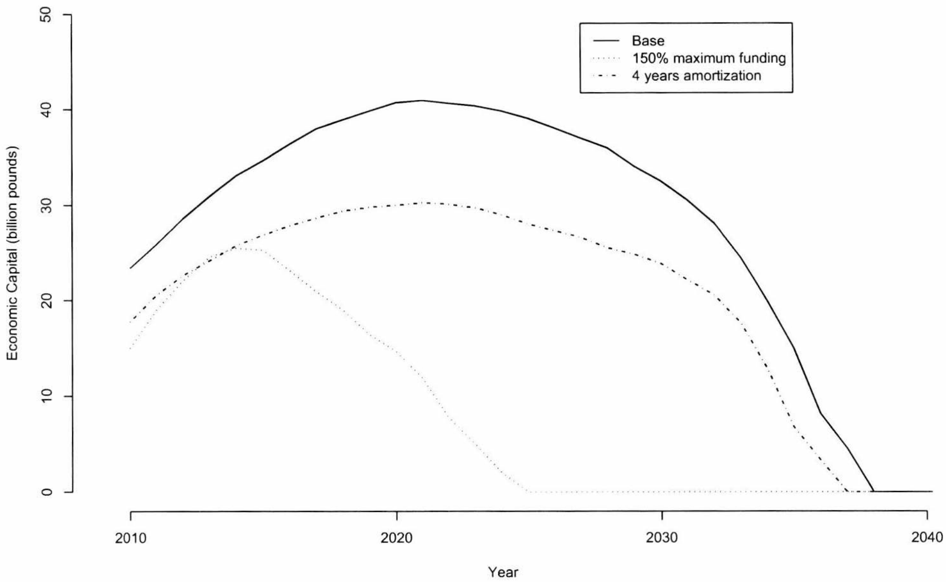

Figure 6.2: Economic capital for the PPF at 99.5th percentile level.

Economic capital, starts from £23 billion in year 2010 before increasing to around £40 billion in year 2022 and subsequently falling to zero by 2038. This particular shape is mainly due to the risks of the PPF being most significant in shorter durations. As we assume that the PPF will not release any surplus, the asset of the PPF will build up and exceed the liability in the long run, which eventually will result in a zero economic capital requirement. However, for earlier durations, significant amount of economic capital is needed to cover the uncertainty in investment returns, insolvency event of schemes and PPF compensations.

It is important to note that the asset level of the PPF in 2010 was £4.6 billion as reported in the PPF Annual Report and Accounts 2009/10 The Pension Protection Fund and The Pensions Regulator (2010a). The corresponding liability was £2.5 giving an excess asset of only £2.1 billion. However, our result suggests a capital buffer of £23 billion, on top of liabilities, is required to ensure that the PPF will stay solvent with a probability of 99.5%. This is indeed very large compared to PPF's own liability. However, an economic capital of £23 billion appears plausible when compared with the total amount of liability under PPF's protection which is £888 billion. In essence, the economic capital needed at 99.5% confidence level is only 2.6% of the total amount of liability under cover.

6.5.2 Sensitivity to Maximum Funding Ratio

The results for 150% maximum funding cap is obtained by recalculating the economic capital requirement by increasing the maximum funding ratio so that individual schemes are allowed to build up their assets to 150% (up from 120% used in the base case) of their liabilities before any surplus is released.

As shown in Figure 6.2, by having a higher funding cap, the economic capital requirement for 99.5% confidence level is reduced to £15 billion which is a reduction of £8 billion from the base case results. This reduction in economic capital is due to the fact that the schemes are able to build up their assets when market returns are favourable and stay at a high funding levels thereafter.

As the schemes are assumed to be able to hold additional capital in their funds, these surpluses can be used to absorb losses when experiences are adverse. Consequently, the chance of a scheme winding up with insufficient asset to cover Section 179 accrued benefit liability is low, i.e. the probability of a scheme to be transferred to the PPF is reduced. In addition, the amount of deficit of those schemes when insolvency events do occur is lower, i.e. the amount of the deficit transferred to the PPF is lower. The overall effect is that the PPF's economic capital requirements are significantly lower than the base case. Under this assumption, the economic capital requirement for the PPF falls to zero within 15 years which is much shorter than for the base case scenario.

6.5.3 Sensitivity to Amortisation Period

The 4-year amortisation period result is obtained by recalculating the base case results by reducing the amortisation period from 10 years to 4 years. Based on this assumption, the sponsors of pension schemes are required to make up any deficit in their pension schemes within 4 years. As a result, the probability of schemes being transferred to PPF will be reduced and the amount of deficit transferred will be lower than the base case. It can be seen from Figure 6.2 that the economic capital value at 99.5% percentile level in 2010 is £18 billion which is around £5 billion lower than the base case. The economic capital requirement also falls to zero slightly earlier than the base case results.

6.5.4 Sensitivity to Investment Strategy

We have also produced results based on different investment strategies of the PPF itself. In the base case, the PPF is assumed to be investing 30% in equities and 70% in bond. Here we test the cases where 100% of assets is invested in bonds and where 50% is in bonds and 50% is in equities.

The results are shown in Figure 6.3. Note that, the investment strategy of each individual pension scheme remains unchanged at 50%/50% investment in bonds and equities.

We can see from Figure 6.3 that the economic capital for the PPF investing 100% in bond at 99.5% confidence level is £12 billion which is £11 billion less than the base case value. By investing 50% in equity and 50% in bond, the economic capital increased by £6 billion from base case. These

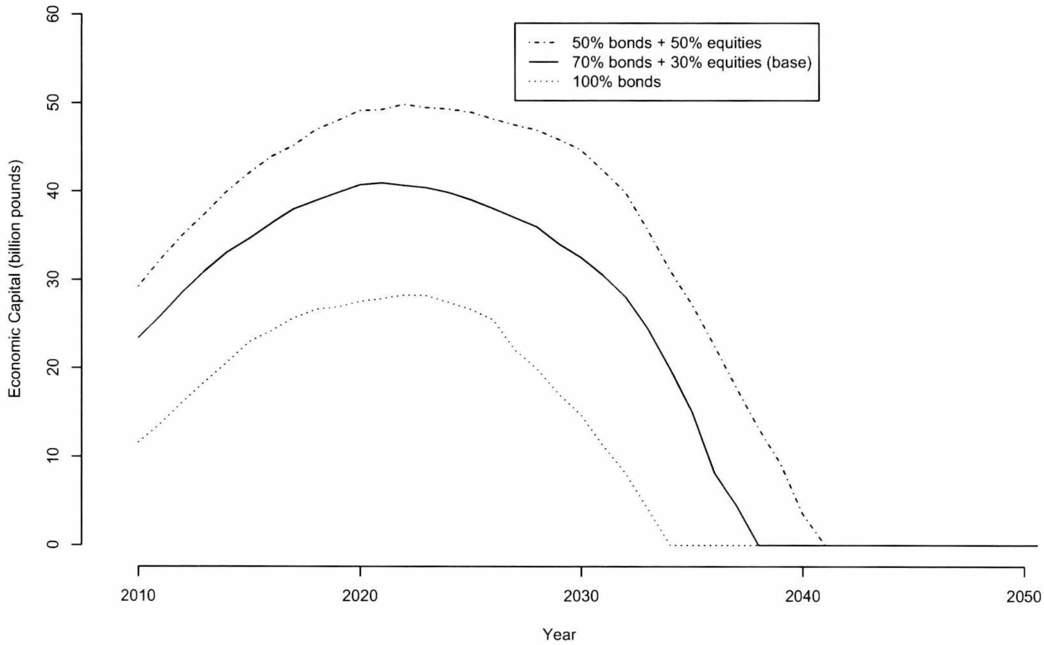

Figure 6.3: Economic capital for the PPF at 99.5th percentile level for different investment mix.

result suggest that if the PPF adopt a more conservative investment strategy, less economic capital is needed to meet future risks. This is because by investing in bonds, volatility in asset value is much smaller than the base case. Less economic capital is needed as the chances for heavy investment losses are reduced. In addition, bond type of investment provides a good match for deferred and immediate annuities which are the form of benefits guaranteed by the PPF.

6.5.5 Absorbing All Insolvent Schemes

Currently the PPF only takes over insolvent schemes which do not have sufficient assets to cover their level of liabilities. However, even for a scheme which is 100% funded today, there is no guarantee that member's benefits can be met in future.

In this subsection, we test the effect of PPF taking over all insolvent schemes regardless of their funding level. In other words, we assume the PPF also takes over the liabilities of insolvent schemes with over 100% funding level. We argue that even these schemes run some risks and taking over all schemes can potentially increase PPF's economic capital requirement.

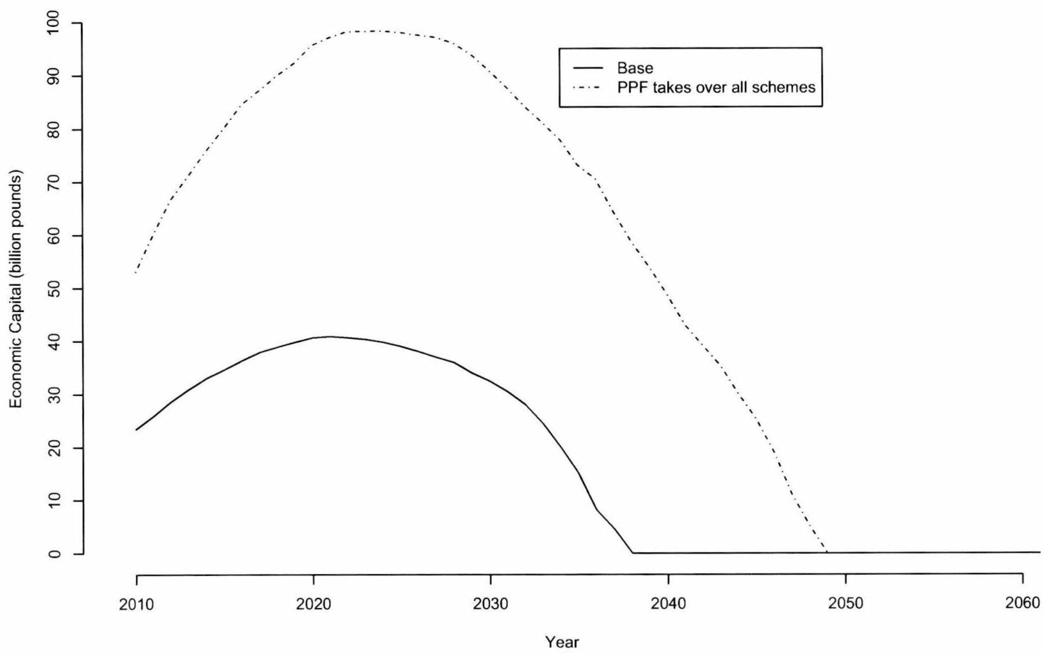

Figure 6.4: Economic capital for the PPF at 99.5th percentile level (PPF takes over all schemes case).

As shown in Figure 6.4, as the PPF takes over all insolvent schemes, the economic capital requirement is significantly higher than the base case. Firstly more schemes will be transferred into the PPF. Moreover, the amount of potential risk is larger. In 2010, the economic capital requirement at 99.5% confidence level for this case is £53 billion which is £30 billion more than the base case. This result suggests that taking over schemes which are even in surplus will significantly increase the risk level of the PPF itself. It also shows that the true measure of the risks is not captured by the 100% funding target.

6.5.6 Higher Funding Target for Schemes

In this subsection, we will quantify the economic capital for the PPF if each individual pension schemes have additional funding requirement. We will recalculate the economic capital requirement based on each individual PPF eligible schemes having a higher funding target $(100 + x)\%$ to meet instead of 100% in the base case.

We assume if scheme's asset falls below $(100 + x)\%$ of its liability, it is required to amortise the shortfall over 10 years subject to a funding cap of $1.2 * (100 + x)\%$ (We adjust the funding cap so that the 120% funding cap will not influence the result of those higher funding target cases).

First, we test the effect of additional level of funding target for individual schemes on the PPF's economic capital. The economic capital of the PPF for 99.5% confidence level is shown in Figure 6.5 with respect to individual have a funding target of 100% (base case), 125% and 150%.

It can be seen from Figure 6.5 that increasing the schemes' funding target substantially reduces the PPF's risk level. The economic capital requirement comes down from £23 billion in the base case to £15 billion and £12 billion for the 125% and 150% funding target levels respectively. However, the short-term capital requirements are significant as schemes still need some time to increase the current funding level to the required funding target.

We have also checked the effect of having a higher funding target as well as a reduced amortisation period of 4 years. The shape of economic capitals in this case follows the 10-year amortisation period case but with a lower

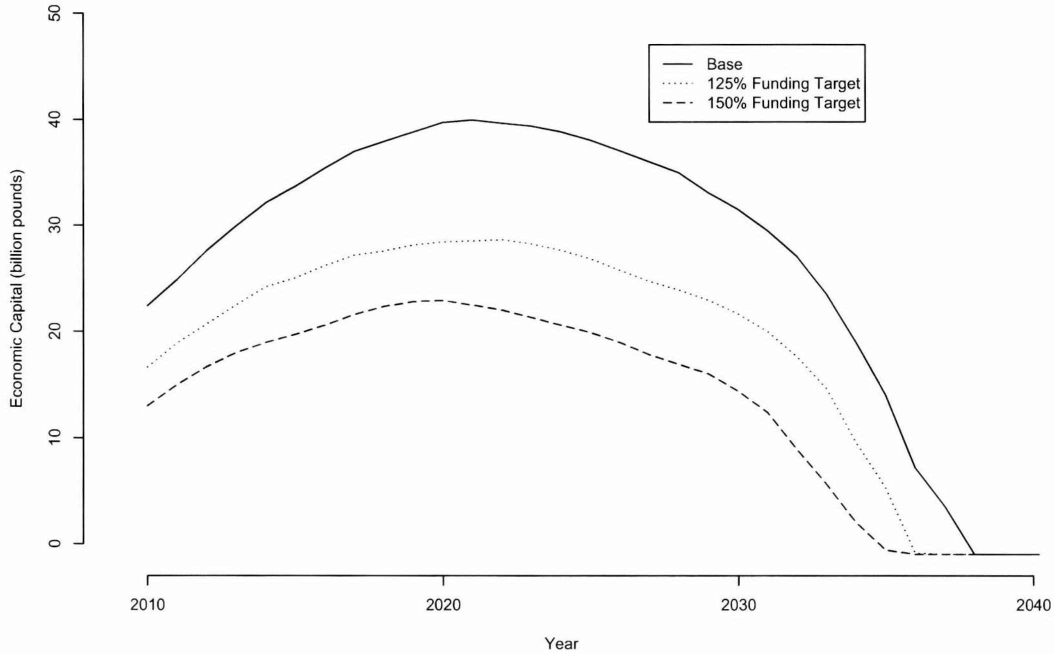

Figure 6.5: Economic capital of PPF at 99.5% confidence levels if schemes have higher funding targets.

economic capital. These economic capital requirements at 99.5% confidence level for year 2010 are shown in Table 6.12.

Table 6.12: Economic capital of the PPF at 99.5% confidence level with respect to higher funding targets (in billion pounds).

	Amortisation Period	
Funding target	10 year	4 year
100%	23.4	17.8
125%	17.8	10.2
150%	13.2	6.9

The result suggests that by requiring schemes to achieve a higher funding target sooner, as demonstrated in the 4-years amortisation period cases, significantly reduces the risk level of the PPF.

6.5.7 Schemes Holding Individual Economic Capital

In this subsection, we calculate economic capital requirement for the PPF by assuming that each individual scheme is required to hold economic capital to cover its own risks in year 2010.

The individual pension scheme's capital requirement are calculated following the steps from Section 2.3.1. The economic capital requirement for the USS at 99.5% confidence level was around 60% of the best-estimated liability. However, based on the PPF schemes' membership profiles, funding levels and investment strategies, the economic capital requirements for each group is shown in Table 6.13.

Table 6.13: Economic capitals at 99.5th percentile in 2010 as a percentage of liabilities for PPF schemes.

Group	Funding level	Investment Strategy		
		25% in bond	50% in bond	75% in bond
A	63% funded	67%	64%	73%
	88% funded	42%	39%	48%
	113% funded	17%	14%	23%
B	63% funded	71%	70%	80%
	88% funded	46%	45%	55%
	113% funded	21%	20%	30%
C	63% funded	72%	72%	82%
	88% funded	47%	47%	57%
	113% funded	22%	22%	32%
D	63% funded	70%	69%	78%
	88% funded	45%	44%	53%
	113% funded	20%	19%	28%
E	63% funded	71%	70%	79%
	88% funded	46%	45%	54%
	113% funded	21%	20%	29%

By summing up all economic capital requirement of individual pension schemes, the total economic capital requirement at 99.5% confidence level of all PPF eligible scheme is around 35% of its Section 179 liability of

£888 billion which gives an aggregate economic capital requirement of £319 billion.

It can be seen that the total economic capital requirement is significant if each individual scheme is required to hold capital buffers. However, by pooling all those schemes together through PPF, the amount of capital required to cover this risk is only around £23 billion in the base case at 99.5% confidence level which is less than 3% of the amount of total liability under protection.

We can see that there exists a significant amount of diversification benefit by managing the risks for all pension schemes together through the PPF.

6.6 Summary

In this chapter, we modelled the PPF and used a risk-based economic capital approach to calculate the economic capital requirement for the PPF. We illustrate the extent of risk the PPF is facing and how economic capital can be used as a risk management tool for pension funds and the PPF.

The results suggest that the risks undertaken by the PPF is significant at least in the short term. Without government support, there is a possibility that under adverse market conditions the PPF will be unable to meet the benefits guaranteed. Although the PPF has the right to change the levy, it is still not conceivable to recover all losses from a severe crisis by changing only the levy structure.

We have also tested the economic capital requirement resulting from the variability in insolvency rate of schemes. The results suggested that by applying deterministic insolvency rates (no Poisson insolvency rates), the economic capital at 99.5th percentile level will drop by 6% compared to the base case. We can see that most of the risks are resulted from the investment and mortality part rather than the variability in solvency rates.

Under the current situation, the risk of the PPF is significant as schemes have large exposure to equity market as well as insolvency risks. The funding and capital requirements for schemes are not strict enough to control the risks involved.

We have seen that possible ways to reducing the risk levels of the PPF are to:

- encourage schemes to maintain a higher funding ratio and
- shorten the amortisation period.

It is a demonstration of how economic capital can be used as a risk management tool to ascertain the risk levels under different circumstances. The result for any other scenarios or combination of scenarios can easily be obtained using this approach.

We have also compared the PPF's economic capital against a requirement that each individual scheme should hold their own economic capital. We found that by pooling risks through a central fund like the PPF, huge amount of diversification benefit could be achieved in terms of economic capital.

In summary, the risks inherent in the PPF guarantees provided for the UK DB pension sector is very large. It would be beneficial to share some of these risks with sponsors of pension schemes by encouraging them to maintain a high funding level. In addition, the PPF needs to build up its own assets to cover possible large deficits in future.

Chapter 7

Conclusions

7.1 Summary

The objective of this thesis is to quantify the risks for pension schemes using the concept of economic capital. In Chapter 4, we used USS, which is a final salary DB pension scheme, to illustrate the economic capital requirement for an individual pension scheme. The economic capital requirement for a DB pension scheme turns out to be very large. As it is not practical for the pension providers to fund for such high economic capital, the risk levels of individual DB pension schemes need to be managed and mitigated using a mixture of alternative approaches. We have found that the effective ways to reduce the amount of risks are by reducing accrual rates or increasing retirement age. However, these actions are extremely unpopular with scheme members.

Concerns about the extent of pension scheme risks have led to a trend of switching DB to DC schemes which shifts all pension risks to scheme members. We argue that the problem lies in understanding the risks and providing sufficient protection for the level of benefits guaranteed. Some pension providers still have the desire to provide DB pension features for members due to paternalistic approach to scheme members or for the purpose of recruiting and retaining productive employees.

In Chapter 5, we calculate the risk level to the pension provider of a hybrid scheme with both DB and DC elements. As expected, the risk levels for hybrid schemes are relatively low compared to pure DB schemes. A hybrid pension structure with appropriate benefit design can be a suitable alternative to a move towards pure DC scheme design.

In Chapter 6, we quantified the economic capital requirement for the PPF. The results suggest that DB pension risks can be managed more effectively on a group basis. However, the risks for the PPF remains significant and the PPF faces a potential default risk itself. However, a more rigorous funding requirement both for individual schemes and also the PPF should be introduced to protect the PPF itself.

We have shown that the concept of economic capital which is being adopted for insurance companies and banks can also be used for pension schemes. Even if it is not practical to set aside economic capital for pension schemes, it can still provide useful insights for an adequate understanding of the issues involved and aid in managing and mitigating pension risks.

In summary, although the improved understanding of DB pension scheme risks that can be gained through the economic capital lens may seem like bad news for DB pension schemes and their members, the good news is that we now have much greater clarity of the embedded risks and costs of these schemes. What matters most going forward is that we use a risk sensitive economic capital framework, as illustrated in this thesis, to help manage DB pension schemes, in a transparent manner. This will help to ensure that benefits provided are not unrealistic and that schemes are not taking inappropriate levels of risk that could hurt their members.

We believe that there will be significant de-risking of DB pension schemes in future years and the economic capital approach will be of great assistance in ensuring that this activity is as effective as possible.

7.2 Future Research

In this section, we summarise the shortcomings in our research and discuss possible avenues for future research.

For individual schemes:

- Our research could be extended to pension schemes in different industries which have different characteristics e.g. different salary scales, employee turnover rates etc.
- We have only considered the PUM method together with best-estimated liability. However, different funding and reserving methods could be considered to check how these approaches affect economic capital of a DB pension scheme.
- We have only considered the underpin arrangement for the alternative hybrid design for USS. In fact, more types of hybrid structure need to be investigated to assess the suitability and extent of risk reduction for particular pension schemes.
- Our analysis is based on USS's membership profile, the effect of a different membership distribution could be further investigated.
- The prerogative of the pension provider to alter pension benefit, retirement age and contribution rate in times of stress could be taken into account in the economic capital calculation.

For the PPF:

- We have not considered possible default correlations between pension schemes through industrial classifications in this thesis. However, we can expect a correlation between their insolvency rates and market movements. If this is true, when market crashes, the insolvency rates for schemes should also rise. In addition, it is more likely that many schemes in the same market sector could go insolvent at the same time. A larger economic capital requirement would be required if we consider a positive correlation.

- In Chapter 6, we have used a simple model for insolvency rates which could be improved with possible implementation of dynamic insolvency rates which change with each firm's financial strength.

- We have not considered multi-employer schemes which are having a slightly different levy structure and risks.

Other possible improvement includes:

- Throughout the thesis, for modelling simplicity, we have assumed relatively simple investment strategies. We have not really considered dynamic investment strategies. More sophisticated investment strategies can be studied in future including possibilities of introducing reinsurance, longevity swaps and other hedging strategies.

- In this thesis, we did not include a risk margin in economic capital calculation. Our economic capital measure, therefore, assesses the amount of surplus assets required to ensure that best estimate liabilities in respect of accrued benefits, rather than market consistent liabilities in respect of accrued benefits, can be covered following a stress event. A risk margin can, however, be easily included, if deemed appropriate.

- We have used model points to represents the membership profile of pension schemes, more detailed data from a real scheme could be used to improve the accuracy of our results and also to check the sensitivity of economic capital calculation in presence of outliers e.g. high benefits of senior managers.

- Different mortality model (CBD models) and economic model (Wilkie 1995 model) could be employed. The results could also be improved if we assume that the actual model employed can have its parameters updated over time.

- Different approaches for economic capital calculations can be considered. In this thesis, our results are based on Porteous and Tapadar (2005) and Olivieri and Pitacco (2003). However, economic capital definitions proposed by Desmedt and Walhin (2004) or Diers (2011) which are differently defined could also be used.

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Appendices

Appendix A

Section 179 Valuation

The Section 179 valuation is the guidance to determine the funding level of pension schemes given in Section 179 of Pensions Act 2004 as updated on 8 October 2009. The Section 179 valuation is used for schemes covered by the PPF to calculate the funding level and the pension protection levy.

In order to apply Section 179 valuation, the following adjustment should be made to the members' benefits:

- Applying caps to benefits of members under normal retirement age.
- Reducing the benefit of members under normal retirement age by 10%.
- Disregarding any indexation on benefits in respect of pre 6 April 1997 service.
- Allowing for indexation up to RPI but capped at 2.5% on benefits in respect of service from 6 April 1997.

After applying these adjustments, the Section 179 valuation then assumes that an active member will become a deferred pensioner immediately before the valuation date. The liabilities are calculated as the net present values of expected future benefit payments of all accrued benefits.

In addition, the Section 179 valuation also set out the discount rates to be used for the valuation. The discount rates used for Section 179 valuation is determined by referring to the following yields:

- Yield A: The average of FTSE Actuaries Government Securities Index-Linked annualised Real Yields over 15 years assuming 5% inflation and 0% inflation;
- Yield B: The annualised yield on the FTSE Actuaries Government 20 year Fixed Interest Index;
- Yield C: The annualised yield on the FTSE Actuaries Government 15 year fixed Interest Index;
- Yield D: The average of FTSE Actuaries Government Securities Index-Linked annualised Real Yields over 5 years assuming 5% inflation and 0% inflation.

Different types of benefits are valued by discounting future cash flows by a combination of yields introduced above:

- For compensations increase in deferment accrued before 5 April 2009, the liability for the period of deferment should be calculated by discounting the benefits from the normal pension age at the discount rate Yield A minus 0.3%.
- For compensations increasing in deferment accrued after 5 April 2009, the discount rate used should be the higher of Yield A minus 0.3% and Yield B minus 2.6%.

- For compensations not increasing in deferment, the discount rate used should be Yield B minus 0.1%.
- For benefits already in payment and if the benefit is not increasing, the discount rate applicable should be Yield C plus 0.6%.
- For increasing benefits already in payment, the discount rate used should be the higher of Yield D plus 0.1% and Yield C minus 1.9%.

If the scheme's asset is lower than the calculated liability, then the scheme is underfunded and a recovery plan is triggered.

Appendix B

Funding Methods

Funding methods are used by the pension provider to determine the amount of contributions to be made to the pension fund. The contribution method will have an impact on the overall cost as earlier contributions can earn more investment returns.

The four main funding methods are: Attained Age funding method, Entry Age funding method, Projected Unit funding method and Current Unit funding method.

We define the following notations:

- R = Assumed retirement age.
- x = Age of the member at the valuation date.
- S = Salary at the valuation date.
- A = Rate of pension accrual.
- i = Discount rate.
- e = Assumed annual earnings growth.

- P = Past service at the valuation date.
- $F = R - x$ = Future service.
- E = Assumed entry age.
- $a_R^{'}$ = Value of an annuity payable from age R (allowing for any contingent spouse's pension and pension increases).
- $a_{\overline{R-x}|}$ = Value of an annuity to determine the present value of all future earnings (allowing for the timing of contributions and salary increases).

B.1 Attained Age Method

The Standard Contribution Rate (SCR) and Actual Liability (AL) are calculated as follows:

$$SCR = \frac{\frac{(R-x)\cdot S}{A} \cdot (\frac{1+e}{1+i})^{R-x} \cdot a_R^{'}}{S \cdot a_{\overline{R-x}|}}$$

$$AL = \frac{(P+F)\cdot S}{A} \cdot (\frac{1+e}{1+i})^{R-x} \cdot a_R^{'} - SCR \cdot S \cdot a_{\overline{R-x}|}$$

The SCR in this case is the discounted total future benefits divided by the discounted total earnings. The AL is the difference between the discounted total expected liabilities and contributions.

B.2 Entry Age Method

The SCR in this case is calculated similar to the Attained Age method except that benefits and contributions are calculated over the full duration of the membership of the pension.

$$SCR = \frac{\frac{(R-E)\cdot S}{A} \cdot (\frac{1+e}{1+i})^{R-E} \cdot a_R^{'}}{S \cdot a_{\overline{R-E}|}}$$

$$AL = \frac{(P+F)\cdot S}{A} \cdot (\frac{1+e}{1+i})^{R-x} \cdot a_R^{'} - SCR \cdot S \cdot a_{\overline{R-x}|}$$

The SCR in this case is the discounted total future benefits at the assumed entry date divided by the discounted total expected earnings at the assumed entry date. The AL formula is exactly the same as the Attained Age method.

B.3 Projected Unit Method

The Projected Unit method calculates the SCR from year to year, which can then be adjusted to match with actual experiences. The SCR can be expressed as the discounted benefit in the following year of the valuation date divided by the expected present value of earning in that year. The AL is the accrued benefits from past service before the valuation date.

$$SCR = \frac{\frac{1\cdot S}{A} \cdot (\frac{1+e}{1+i})^{R-x} \cdot a_R^{'}}{S \cdot a_{\overline{1}|}}$$

$$AL = \frac{P\cdot S}{A} \cdot (\frac{1+e}{1+i})^{R-x} \cdot a_R^{'}$$

B.4 Current Unit Method

This method is similar to the Projected Unit method except that salary growth is only allowed for only one year after the valuation date. No future salary growth is allowed.

$$AL = \frac{P\cdot S}{A} \cdot (\frac{1}{1+i})^{R-x} \cdot a_R^{'}$$

$$SCR = \frac{\frac{1\cdot S\cdot(1+e)}{A} \cdot (\frac{1}{1+i})^{R-x} \cdot a_R^{'} + (AL \cdot e)}{S \cdot a_{\overline{1}|}}$$

Appendix C

PPF's Long Term Risk Model

The PPF has developed a stochastic model to estimate the amount of levy to be collected every year. The PPF has published Modelling uncertainty: an introduction to the PPF Long Term Risk Model (LTRM) in August 2007 (The Pension Protection Fund and The Pensions Regulator (2007)). This model is used to determine the level of funds which is required to meet future potential liabilities for the PPF in long term. The PPF is aiming to meet the funding target of self-sufficiency by year 2030. The modelling result of current levy level will result in an 85% probability of meeting funding target by 2030.

The PPF did not consider the traditional approach to forecasting future cost from past experience using a deterministic model to be satisfactory any more. This is because the insolvency event occurs with a fairly low probability and it is correlated with underfunding through economic condition, i.e. a generalised economic downturn might cause a rise in insolvency probability and the underfunding level. As a result, the PPF preferred a stochastic approach with embedded correlations between parameters.

The stochastic framework used by the PPF for its LTRM is shown in

Figure C.1. It can be seen from this figure that the whole modelling process contains 5 parts as discussed below.

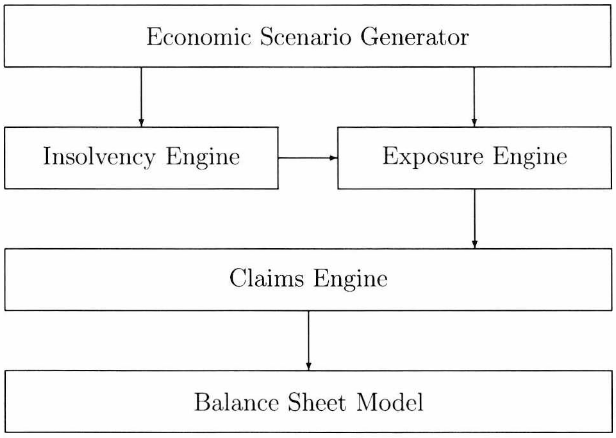

Figure C.1: Components of the LTRM used by the PPF.

The Economic Scenario Generator, which is the fundamental part, is provided by Barrie and Hibbert (*http : //www.barrhibb.com*). It produces stochastic economic variables from Mote Carlo simulations using a random number generator. Returns and yields for asset classes and random numbers which determine the insolvency events are all generated here. These numbers are fed into insolvency engine and exposure engine.

Some key output from the Economic Scenario Generator are follows:

- Nominal gilt yield: around 4.75% on average over 30 years.
- Inflation rate: around 3% on average over 30 years.
- Mean total equity returns: average 9.46% p.a.
- Mean short rate yield: around 2.5% p.a on average over 30 years.

The Insolvency Engine generates the probability of companies becoming insolvent. The insolvency probability is modelled by a six rating transition matrix which enable a dynamic feature of insolvency. The Insolvency

Engine takes Credit Risk Factor from Economic Scenario Generator to determine how the rating of a firm can move between different risk bands. The Credit Risk Factors for each firm are both scheme-wise and industry-wise correlated, they are also correlated to the equity and property returns. According to the PPF's Long Term Risk Model (LTRM) The Pension Protection Fund and The Pensions Regulator (2007), the correlations between the sectors and equity returns are around 50%, the correlations between sectors are around 60% to 80%. For the largest 479 schemes, the insolvency is modelled individually for each simulation. For smaller schemes, a pooled approach is adopted.

By generating events of insolvency and economic scenarios, the Exposure Engine can output the deficit of pension schemes in the event of insolvency. This is done by rolling forward the scheme's asset and liability to the time of failure. The demographic profile of a pension scheme is also used to fulfil this goal.

A split between different types of memberships (active member, deferred member and pensioners) is used to reflect the maturity process of a scheme more accurately. In the LTRM, the PPF has used 9 elementary pension schemes to represent different pension schemes. These 9 elementary pension schemes are: an active member, a deferred member and a pensioner for each of: open schemes, schemes closed to new entrants and schemes closed to new accruals. Each pension scheme is modelled by combining appropriate proportions of the elementary pension schemes.

The Claims Engine then takes all available information to calculate the assets and liabilities transferred to the PPF after an insolvency event. It translates insolvency events into claims to the PPF by adjusting the asset and liability values. Any contingent assets held by the pension scheme and recoveries of Section 75 debts from the scheme's sponsor are also taken into account. The Section 75 debt is the debt due from the employer to the trustee under the cessation of a defined benefit scheme. It is the employer's share of deficit followed by an insolvency event. The contingent asset is held by sponsor to reduce the risk associated with their pension schemes. There are in total three types of contingent assets recognised by the PPF:

- Type A: Group company guarantee where the parent of the pension scheme's sponsor guarantees part or all of the liability.
- Type B: Securities over the asset holding which can help to hedge or reduce the risk.
- Type C: Letters of credit or bank guarantees to cover part or all of the pension scheme's deficit.

The Claim Engine calculates the effect of the contingent assets in the event of claim.

The Balance Sheet Model then applies the techniques used for schemes to project PPF's own balance sheet. As the PPF follows a Liability Driven Investment strategy, this feature makes the sensitivity of asset to interest rates and inflation rates same as the sensitivity of liability and makes the accumulation of liability follow a money market index.

The LTRM employed by the PPF focusses on a time period of 5 years as the Board of the PPF considers 5 years to be long enough to capture any significant change in economic conditions without losing accuracy in modelling.

The modelling results from the LTRM shows that distribution of claim amount is significantly positively skewed where large claims are many times more than the average claim level as shown in Table C.1.

Table C.1: PPF deficit after 5 years (in billion pounds).

	90th percentile	95th percentile	99th percentile
PPF's deficit	£-2.6	£-5.05	£-11.7

Note that the PPF's total asset holding was around £4.6 billion at 31 March 2010 (Annual Report & Accounts 2009/10). It is almost equal to the level of deficit at 95th percentile level. In other word, if we apply a 99.5% solvency probability requirement for the same period, the asset held by the PPF is far too low compared to the level of liabilities.

Appendix D

PPF Levy

The PPF charges a compulsory annual levy from all eligible schemes. The levy is estimated to meet PPF's long term funding target which is to be self-sufficient (i.e. fully funded, with zero exposure to market, inflation and interest rate risk and protection against claims and longevity risk) by 2030. The current levy is estimated so that there is an 83% probability to meet this funding target. The levy charged for year 2010 was £592 million compared with a total liability of £888 billion. On average, the PPF levy was £0.67 for every £1,000 liability covered. The total levy is split among all eligible schemes according to a levy formulae.

The annual levy from all eligible schemes is composed of a scheme-based levy (SBL) and a risk-based levy (RBL). The SBL is proportional to the size of schemes i.e. the liability calculated under Section 179 valuation. The RBL is based on probability of insolvency and the expected amount of deficit. The PPF is aiming to a weighting of 20% contribution from the SBL and 80% contribution from RBL.

Since 2006, the SBL is calculated using the following formula:

$$SBL = L * h$$

where:

- L = The scheme's liability based on Section 179 valuation.
- h = The scheme based multiplier, which is estimated on yearly basis.

The scheme based multiplier is estimated annually to ensure that the total SBL contributes approximately 20% of the total pension protection levy.

The RBL is calculated as:

$$RBL = U * P * 0.8 * c$$

where:

- U = Underfunding risk.
- P = Probability of insolvency.
- 0.8 = Percentage of levy which is risk based.
- c = Risk-based levy scaling factor, which is estimated on yearly basis to ensure that the total levy collected matches the total estimated levy.

The underfunding risk is calculated as a percentage of the difference between a scheme's asset and liability. If a scheme's projected liability is denoted by PL, scheme's asset by A and the underfunding risk by U. In year 2011/2012, the underfunding risk is calculated as follows:

- If A $<$ 135% of PL: U=PL*1.36-A;

- If (135% of PL) $\leq$ A $<$ (140% of PL): U=1%*PL;
- If (140% of PL) $\leq$ A $<$ (145% of PL): U=0.75%*PL;
- If (145% of PL) $\leq$ A $<$ (150% of PL): U=0.5%*PL;
- If (150% of PL) $\leq$ A $<$ (155% of PL): U=0.25%*PL;
- If A $\geq$ (155% of PL): U=0.

PPF assumed probability of insolvency (P) is provided by Dun & Bradstreet (D&B) 12-month ahead insolvency probabilities for the scheme sponsor. The insolvency probabilities are measured by 1-100 D&B failure score and subject to an upper cap.

The insolvency probabilities calculation is also related to the number of sponsors of an eligible scheme. Schemes are classified into single-employer schemes and multi-employer schemes. For single-employer schemes, the formula above applies for the RBL.

Multi-employer schemes are further divided into two main categories: segregated pension schemes and non-segregated pension schemes. If multi-employer schemes have the option to segregate on partial wind-up, the RBL is called a "segmented levy". The insolvency risk used to calculate the segmented levy is estimated from the weighted average insolvency probabilities for all sponsors in the scheme according to the number of employees under each employer. Non-segmented pension schemes that have no option to segregate on cessation of participants (which means that the scheme's liabilities can only be taken over by the PPF only after the last sponsor in the scheme becomes insolvent), are charged a lower rate of RBL. This RBl is called "last-man-standing (LMS) levy". The insolvency risk used to determine the LMS levy is calculated in the same way as a "segmented levy" but scaled down by 10% to ensure that the correct hierarchy of risk is maintained between the various types of multi-employer schemes.

The RBL is capped at 1% of the scheme's liability to protect those schemes which are underfunded or in high risk. This cap prevents the levy burden to damage the financial strength of the scheme any further. Around 5% of schemes benefited from this levy cap in year 2009/10. However, the liabilities of those schemes only contributed to around 1% of the total liability of the PPF.

In October 2010, the PPF proposed a new approach in its policy statement 2011 (The Pension Protection Fund and The Pensions Regulator (2010b)) to the pension protection levy from 2012/13 onwards to replace the levy system which has been running since 2006. The proposal is aimed at finding a formula that can last for a period of three years, improve predictability and stability in individual scheme levies and allowing for investment risks.

A bottom-up approach where individual scheme's levy is linked directly to its risks is included in this proposal. This is in contrast to the current approach where the total levy is calculated first and individual scheme's levy is adjusted accordingly. The drawback of this approach is that the PPF is exposed to the uncertainty of the amount of total levy. In order to reduce the degree of uncertainty, the PPF has proposed to review levy every three years and revise levy parameters only when the levy exceeds a ceiling set by legislation, differ from the previous year's levy estimate by more than 25% or estimated SBL exceeds 20% of the total expected levy.

The proposed formula for the total levy remains the same as a mixture of RBL and SBL. The formula for RBL remains the same as a product of underfunding risk, insolvency risk and a fixed scaling factor. The formula for SBL would ordinarily be set so that it is enough to meet the cost of capping (the additional cost to meet the risks from those schemes which are paying a capped levy) during the fixed period.

Although the formula for RBL is the same as the current one, the calculation of underfunding risk is subject to a significant change. The underfunding risk will be estimated by a "smoothed" funding position averaged over a period of time instead of the funding position at a specific time point. A roll-forward value of assets by reference to a 5 year moving average return is used to find the smoothed value of the scheme's funding position. The funding level is also subject to a proposed stress testing of the sensitivities to the market movement. As a result, the individual scheme's investment risk is also allowed in the RBL. The proposed rates for assets stresses are shown in Table D.1.

Table D.1: Asset Value Stress Rates.

Corporate Bonds	-4.6%
Nominal Gilts	+9.8%
Index-linked Gilts	+19.1
UK Equity	-21.7%
Overseas Equity	-18.5%
Property	-7.1%
Cash	0%
Other	-21.7%

The PPF has also proposed a new approach to insolvency probability. They have proposed 6 bands to replace the D&B 1-100 score system. The new system is given in Table D.2.

Table D.2: PPF proposed levy rates (2010).

PPF Band	1	2	3	4	5	6
D&B Failure Score	100-97	96-90	89-69	68-42	41-6	5-1
Levy Rate	0.2%	0.5%	1.1%	1.6%	4.0%	4.0%

Using this new proposal along with a smoothed insolvency probability over 12 months, the volatility in levy payments will be reduced compared to the current approach.

The new proposal also discusses whether the contributions committed through recovery plans should be taken into account in the PPF levy. However, this new proposal is still in the consultation process.

Appendix E

Bond Total Return Index from Porteous and Tapadar (2005)

The following assumptions were used when converting bond yield to a total return index in Porteous and Tapadar (2005).

- Coupons are paid annually in arrears.
- Bonds are redeemed at par at maturity.
- Bonds with the fixed n year term is always available in the market.
- Sell the bond holding at every year end and buy back a bond with the same term at that time.
- Bond yield C_t is known at the start of every year.

The following notations were used:

- D: Annual coupon payment.
- n: Term of the bond in years.

- C_t: Bond yield applicable at time t.
- P_t: Price of the bond at time t.
- CR_t: Bond total return index at time t.

Based on these assumptions, the price of a n-year bond at time $(t-1)$, can be calculated as:

$$P_{t-1} = \frac{D}{1+C_{t-1}} + \frac{D}{(1+C_{t-1})^2} + \frac{D}{(1+C_{t-1})^3} + \cdots + \frac{D}{(1+C_{t-1})^n} + \frac{1}{(1+C_{t-1})^n}$$

We assume the coupon payment $D = C_{t-1}$, then $P_{t-1} = 1$. After 1 year, the price of this bond at the end of the year will become:

$$P_t = \frac{D}{1+C_t} + \frac{D}{(1+C_t)^2} + \frac{D}{(1+C_t)^3} + \cdots + \frac{D}{(1+C_t)^{n-1}} + \frac{1}{(1+C_t)^{n-1}}$$

The capital return for this bond is $(P_t - P_{t-1})$, the total return for this bond is:

$$\frac{D}{P_{t-1}} + \frac{P_t}{P_{t-1}} - 1$$

After this, the total return index of the bond can be produced as:

$$CR_t = CR_{t-1} \times \left(\frac{D}{P_{t-1}} + \frac{P_t}{P_{t-1}} \right)$$

At the beginning of year t. We will sell the existing bond holding for CR_t, and buy this amount of new bond with term n at the price of:

$$P_t = \frac{D}{1+C_t} + \frac{D}{(1+C_t)^2} + \frac{D}{(1+C_t)^3} + \cdots + \frac{D}{(1+C_t)^n} + \frac{1}{(1+C_t)^n}$$

This process is repeated to produce a total bond index by having $CR_0 = 1$.

Appendix F

USS Valuation Assumptions

The USS model discussed in this thesis is based on the data and assumptions provided in the USS triennial actuarial valuation carried out as at 31 March 2008.

The valuation has been carried out under different basis: the scheme funding regulations, the trustee company's historic funding basis, the Pension Protection Fund regulations and the FRS17 basis. The funding levels calculated were 103%, 71%, 107% and 104% respectively. The variation between these assumptions are mainly caused by the discount rate used in value liabilities. Our assumptions used in this thesis is based on the scheme funding regulations which is introduced by the Pensions Act 2004 aiming to have sufficient and appropriate assets to cover technical provisions.

Referring to the Projected Unit method formula:

$$AL = \frac{P \cdot S}{A} \cdot (\frac{1+e}{1+i})^{R-x} \cdot a_R^{'}$$

The USS have assumed P which is a member's past service to be the length in years a member contributing into the USS. The USS have assumed the year in service to be the number of years between the year of joining the USS and the year of the member's retirement.

The USS have assumed the member's salary S will follow the salary scale for University teachers at different ages. A which is the rate of pension accrual is assumed to be 80.

The annual earnings growth e is assumed to be at the rate of 6.4% for both pre-retirement and post-retirement investment returns. The retirement age R is assumed to be 62. The $a_R^{'}$ which is the value of an annuity from retirement age is assumed to be the present value of an annuity from age 62. The discount rate i is assumed to be at 6.4% per year.

The key points of USS's scheme funding regulations valuation assumptions from USS valuation report 2008 are summarised below.

- The method used in value liabilities is the Projected Unit method under which the member's salary increases are projected until that member is assumed to leave the scheme by death, retirement or withdrawal from service.

- A yield based on market returns on UK Government gilts stocks and other instruments which reflects a market consistent discount rate for the profile and duration of the scheme's accrued liabilities, plus an Asset Out-performance Assumption of 2% p.a. to reflect the prudent allowance the Trustee has agreed for additional investment returns is used as the deterministic discount rate. Investment returns are discounted at a rate of 6.4% p.a.

- RPI price inflation rate 3.3% p.a. A deduction of 0.3% has also been included. This is to allow for the current high inflation implied by government bonds, compared to the Bank of England's target of 2.75% per annum.

- Increases in pensions are assumed to be in line with the RPI index.
- The mortality table used was PA92 medium cohort mortality table for males and females. Allowance for future improvements in longevity and the experience of the scheme is also allowed in mortality rates. The PA92 Year of Birth tables with medium cohort improvements are used for both retired and non-retired members.
- The USS have assumed that no members commute their pension for additional lump sum.
- The expenses are allowed by adding 0.3% of pensionable pay to the employer contribution rate.
- Contributions: Employer contributes 14% and member contributes 6.35% of the member's yearly salary every year.
- The normal retirement age is assumed to be 62 for both males and females.

The USS have used a salary inflation rate of 4.3% per annum which is 1.0% above the assumed inflation assumption of 3.3% per annum. In addition, the following assumptions for promotional salary increase, withdrawal rates and proportion of member married are used in the valuation.

Table F.1: Key USS 2008 valuation assumptions.

	Salary scale		Withdrawal rates		Proportion married	
Age	Male	Female	Male	Female	Male	Female
25	–	–	14.42%	19.28%	34%	56%
35	3.8%	3.1%	9.19%	11.40%	81%	84%
45	2.0%	1.8%	3.79%	3.83%	92%	93%
55	1.1%	1.4%	–	–	–	–

List of Symbols and Abbreviations

Abbreviation	Description	Definition
DB	Defined Bnenfit	page 20
DC	Defined Contribution	page 20
PPF	Pension Protection Fund	page 11
USS	University Superannuation Scheme	page 10
MFR	Minimum Funding Requirement	page 19
VaR	Value at Risk	page 32
FRS	Financial Reporting Standard	page 19
OECD	Organization for Economic Co-operation and Development	page 24
EIOPA	European Insurance and Occupational Pension Authority	page 10
OPRA	Occupational Pensions Regulatory Authority	page 128
IORP	Institutions for Occupational Retirement Provision	page 10
CMI	Continuous Mortality Improvement	page 57
RPI	Retail Price Inflation	page 51
PUM	Projected Unit Method	page 40

Abbreviation	Description	Definition
ALM	Asset and Liability Management	page 9
SCR	Solvency Capital Requirement	page 62

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