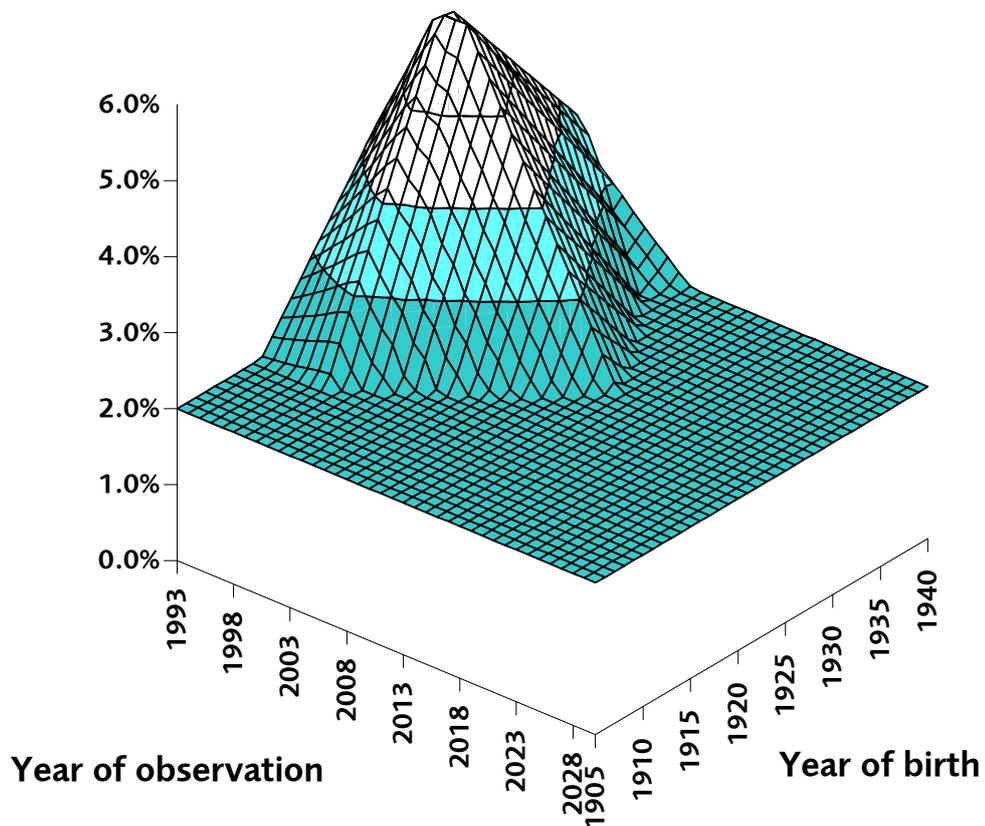


# Financial aspects of longevity risk

Stephen Richards  
Gavin Jones



Mortality improvements by year of birth under CMIB mid-intensity cohort projection, with 2% floor in any given year (Source: own calculations, CMIB data).

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# Prologue

In 1965, André-François Raffray, a lawyer in the southern French city of Arles, made a deal with a ninety-year-old local woman. In a contract relatively common in France, he agreed to pay her an income for the rest of her life in exchange for inheriting her house upon her death.

Unfortunately for M. Raffray, the woman was Mme. Jeanne Calment, who went on to be the longest-lived person in the world at 122 years. She outlived the luckless M. Raffray, who paid more than the value of the house before pre-deceasing her.

"In life, one sometimes makes bad deals", said Mme. Calment of M. Raffray.

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## **1 Executive Summary**

This paper examines longevity risk and its implications for actuaries working in the private sector. Longevity risk varies hugely according to the nature of the contract which contains it, sometimes in unexpected and surprising ways. Indeed, the greatest private-sector exposure to longevity risk is not to be found in the annuity portfolios of the quoted life assurance sector; rather it is shareholders of many industrial and service companies which have much greater exposure to longevity risk through their defined-benefit pension schemes.

For many products, it is important to know how long people will live. The most obvious examples in the private sector are pensions and annuities. Despite its crucial nature, longevity assumptions in some corners are very out-dated. This paper spells out some of the more important areas of concern, with potential implications for millions of people in the United Kingdom.

## **2 Macro-economics: interest rates and inflation**

Before turning to longevity risk, it is necessary to place it correctly within the current macro-economic environment. It appears unlikely any time soon that U.K. base rates will be quite as stable and low as they were during the twelve years between late 1939 and late 1951 – a period of no interest rate changes whatsoever and a constant interest rate of just 2%! (Source: Bank of England). It appears equally unlikely that the UK will return any time soon to the volatility and double-digit interest rates of much the last quarter of the 20<sup>th</sup> Century. In an environment of lower and more stable inflation, lower nominal investment returns and lower real and nominal interest rates, actuaries' attention is increasingly focused on mortality rates. This is not just because the relative importance of mortality assumptions increases against a backdrop of lower interest rates, but also because those mortality rates have changed very radically, too.

The business of UK life insurers is changing. Falls in sales of savings products have been caused by reduced nominal investment returns and reduced tax advantages. In place of products with a limited level of actual life assurance, the UK life industry has increasingly been writing risk business: sales of pure risk business, such as term assurance and critical illness, have blossomed in place of endowments, for example. The market for transferring longevity risk, the subject of this paper, also seems set for a long and sustained period of serious growth. This growth stems from the growing body of maturing personal pensions, and also the restructuring of company-sponsored defined-benefit schemes. Life and pension actuaries will both be very busy with longevity risk, albeit on opposite sides of the fence.

One could regard this sea change as actuaries and insurers returning to their proper historical and economic role - the transfer of risk, as opposed to the management of savings. If actuaries want to keep their position in this new era of financial services, they must re-learn some neglected skills for handling mortality rates and longevity risk.

## **3 Regulatory context**

Actuarial work in the U.K. is subject to an ever-changing regulatory framework, whether it is on the pension side (FRS 17, IAS 19) or the life side (IPSB, ICA). The figures calculated here are largely based on the FSA's outgoing reporting basis, but the central messages are largely independent of whether one is valuing using "gross yield less default allowance", or "gilt yield plus liquidity premium".

## 4 Immediate annuities

With the advent of stable low interest rates, longevity is now the dominant risk for immediate annuities. Default experience on backing assets can be a close-run second, however.

### 4.1 Definition

An immediate annuity is a regular income payable throughout life. Usually secured in exchange for a lump sum, an annuity can be thought of as insurance against living too long, or else as insurance against outliving one's savings.

Annuities play an important role in personal finance, as only the very richest can afford to take on the risk of their own longevity. The subject of alternative strategies, and why annuities are still essential in personal finance, is covered in great detail in Wadsworth, Findlater & Boardman (2001). Annuities can also be viewed as a pure investment decision, as discussed in section 5.4.

### 4.2 Past and present

At the time of writing in September 2004, the Bank of England base rate is 4.75%. Precisely twenty years earlier, the same base rate was 11.5%<sup>1</sup> (Source: Bank of England). This fall in interest rates would cause a difference of around 35.8% in a level pension<sup>2</sup>. By way of contrast, the difference between male and female annuity rates in the current market is only around 10%.

Changes in interest rates were clearly the most important driver for annuity rates over much of the previous two decades. Co-incidentally, the major U.K. insurers have also accumulated substantial annuity liabilities over this period, as Table 1 shows.

**Table 1. In-force annuity liabilities for selected major U.K. life assurers**

| Company name         | Annuity liabilities (£bn): |                 |           |
|----------------------|----------------------------|-----------------|-----------|
|                      | (a) policyholder           | (b) shareholder | (c) total |
| Prudential           | 13.5                       | 3.2             | 16.7      |
| L&G                  | 1.8                        | 11.0            | 12.8      |
| Norwich Union        | 2.0                        | 11.5            | 13.5      |
| Standard Life        | 10.8                       | -               | 10.8      |
| Royal & Sun Alliance | 4.2                        | -               | 4.2       |
| Scottish Widows      | 0.5                        | 3.3             | 3.8       |
| Friends Provident    | 2.2                        | 1.0             | 3.2       |
| Canada Life          | -                          | 2.6             | 2.6       |
| Total                | 35.0                       | 32.6            | 67.6      |

Source: Company returns at end-2003. Figures include deferred annuities, but exclude with-profit annuities and reserves for guaranteed annuity options (see section 8 on page 23). In cases where it is not clear, liabilities have been ascribed to shareholders: one company has 11 sets of statutory returns, for example.

<sup>1</sup> In fact the base interest rate in the U.K. was no less than 17% per annum just five years earlier, and they remained at that level for nearly eight months before "dropping" to 16%. Under such conditions, annuity payments would be around double what they are now for a given pension fund.

<sup>2</sup> Level annual annuity in advance to a single male aged 65. Mortality from Prudential generalised linear model.

Total industry liabilities for immediate annuities are thus likely to be in excess of £70bn, although companies vary hugely in the extent to which shareholders are directly exposed to this risk. In some instances, with-profit policyholders have substantial exposure to longevity risk.

The statutory reserving bases for these major insurers have also been the focus of much change over the past two years. These changes have largely resulted from revised projections of mortality improvements on a year-of-birth or "cohort" basis from the CMIB (2002). Willets (1999, 2004a) explores possible causes of this so-called "cohort effect" in some detail, and it is also covered in section 16.4.

**4.3 The future**

Despite the steep fall in nominal interest rates, the volume of annuity sales has grown significantly on the back of growth in money-purchase pension plans. The advent of portable personal pensions in 1988 is a major factor in this growth, as is the growing tendency for companies to close defined-benefit pension schemes in favour of money-purchase ones. As these plans mature, compulsory annuity purchase<sup>3</sup> drives growth in the individual annuity market. New annuity business amounted to £7.4bn in 2003 (Source: ABI), with commentators projecting medium-term growth of the order of 10% per annum. This figure excludes bulk annuities, which is another significant market for longevity risk transfer.

**4.4 Mortality v. interest rates: a comparison**

The Bank of England has changed the base rate thirty-nine times in the past decade, yet on only seven occasions was this change as high as 50bps (0.5%). Most of the other changes were 25bps (0.25%) or less. A well-matched annuity portfolio can take these sorts of changes in its stride. In contrast, several differentials in estimated mortality can exceed this level, as shown in Table 2, and such shifts in new business mix take place silently and unannounced compared to changes in interest rates.

**Table 2. Mortality differentials expressed as adjustment to interest rate**

| Differential                    | Equivalent change in interest rate |
|---------------------------------|------------------------------------|
| Pension/annuity size            | 36bps (0.36%)                      |
| Regional differentials          | 37bps (0.37%)                      |
| Lifestyle (top two groups)      | 40bps (0.40%)                      |
| Duration (time in retirement)   | 45bps (0.45%)                      |
| Lifestyle (top v. bottom group) | 175bps (1.75%)                     |

Source: Prudential generalised linear mortality model, level single-life annuity payable annually in advance to a male aged 65, valued at 5% interest. Figures above are the interest-rate adjustment required to equate annuity values between comparison cases, e.g. the difference between the top two lifestyle groups equates to 40bps. More details on this methodology can be found in Appendix I: Equivalent annuities.

Now, it is true that shifts in mortality differentials take place over a much longer time frame than interest-rate changes. However, where a life office writes annuity business through the competitive open market, it is perfectly possible to experience such shifts (and worse). If an

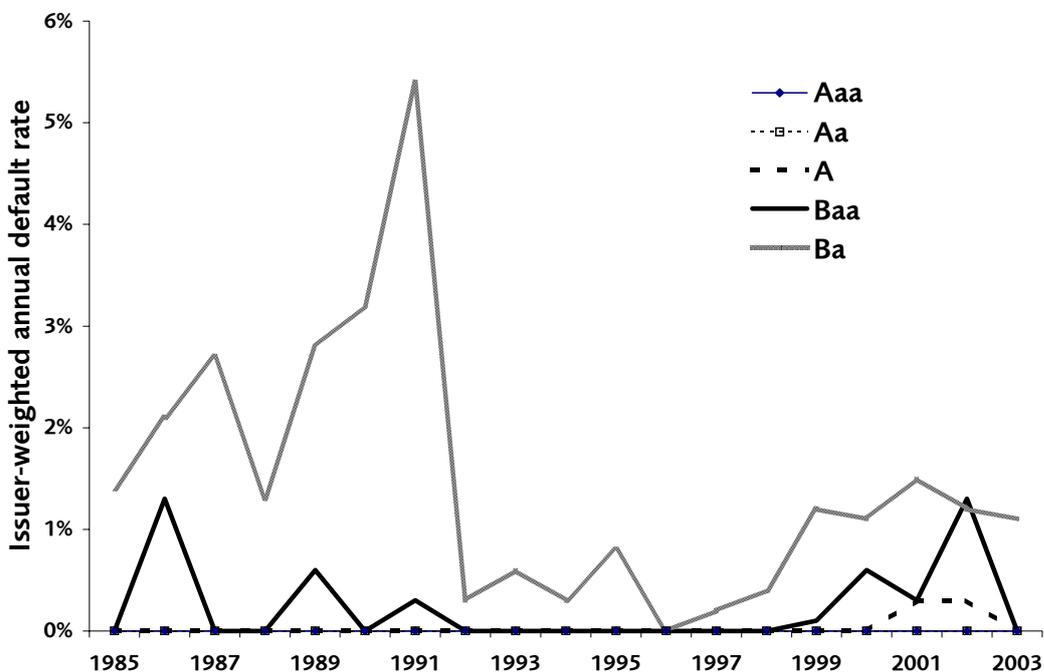
<sup>3</sup> Compulsory annuitisation is at age 75 for pension plans in the U.K., although the overwhelming majority of annuities are purchased well before this age.

office writes annuity business without regard to mortality differentials by region, duration or lifestyle, then that office can be selected against by those offices which do<sup>4</sup>.

#### 4.5 Defaults and credit spreads

Most insurers back their annuity liabilities with at least some corporate debt. There is default risk on such debt, and this risk is measured in the credit rating. Figure 1 shows the default rates on European issuers from 1985, which shows both the huge variability in default rate between the different credit ratings, and also the stark volatility over time within a given credit rating. Most U.K. insurers use the higher-rated debt, and very little of the Baa- and Ba-rated debt in Figure 1 would be found in an insurer's annuity portfolio. Indeed, such portfolios are largely dominated by the Aaa-, Aa- and A-rated debt, and it is notable that the default rate for the first two categories has been zero since 1985, which is why the rates are barely visible in Figure 1. Thus, as long as insurers stick to the higher-rated corporate debt, the default risk should remain secondary to longevity risk.

**Figure 1. Default rates by credit rating (European issuers)**

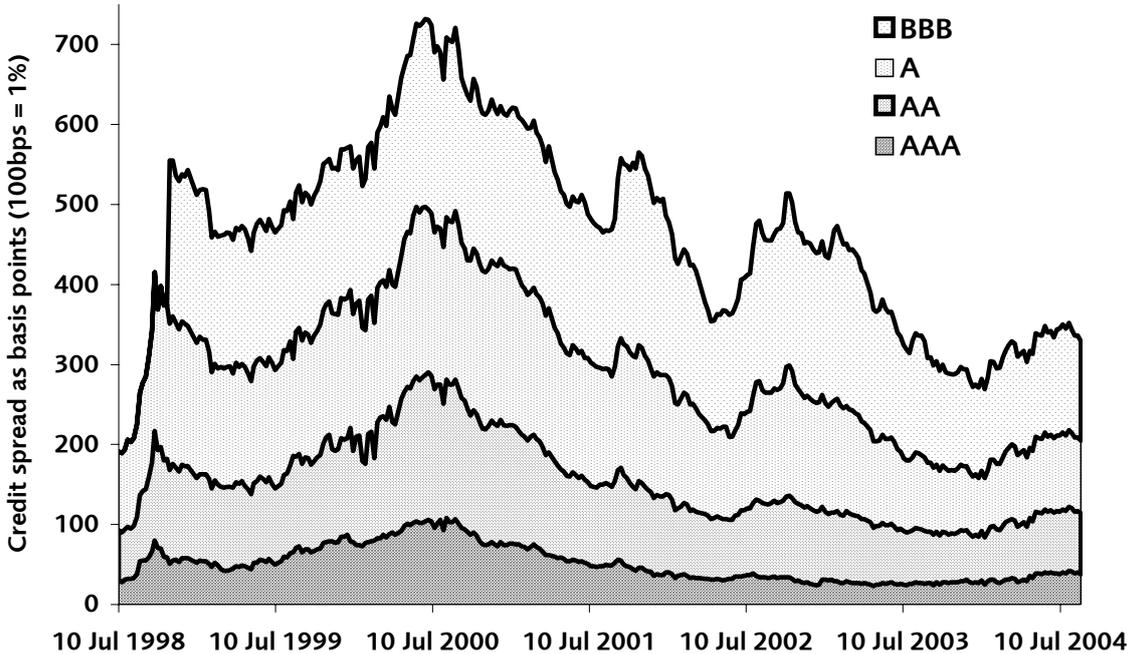


Source: Moody's.

There is another source of risk for insurers, but this is more of a regulatory risk. If the valuation regulations permit liabilities to be valued using gross portfolio yield less a default allowance, the value of assets and liabilities will move in concert if the office has a matched position. If, however, the valuation regulations specify that liabilities must be valued using gilt yields plus, say, a liquidity margin, a volatile valuation strain is introduced. Although this is not a risk in terms of losing money due to experience, it is a risk for the shareholders in the sense that widening credit spreads would create the need for extra capital under such a regulatory regime. For example, Figure 2 suggests that July 2000 would have been a particularly testing time for annuity portfolios under this kind of valuation regime, the more so if the portfolio was weighted towards the lower-rated investment-grade bonds.

<sup>4</sup> Current market practice is not (yet) to directly use these rating factors, but awareness and continual monitoring of them in the business mix is best practice.

**Figure 2. Credit spreads over gilts**



Source: Merrill Lynch indices of spread pricing for sterling non-gilt-edged stocks with maturity in 10-15 years.

**4.6 Conclusion**

Significant volatility in shareholder capital requirements would arise from valuation based on "gilt yields plus liquidity premium" instead of "gross portfolio yield less default allowance". Aside from this, with stable and low interest rates the greatest financial risk in immediate annuities lies in correctly pricing the longevity risk. Default experience on backing assets comes second, but this depends on the portfolio investment policy. The close study of longevity risk is therefore crucial for annuity writers<sup>5</sup>.

<sup>5</sup> Throughout this paper we will refer to "annuity writers" as including defined-benefit pension schemes with pensions in payment as well as life insurance companies writing annuity business.

## 5 Deferred annuities

The key risk for deferred annuities is long-term interest rates, with longevity risk strong but secondary. Deferred annuities from final-salary pension schemes harbour significant and unmatchable risk from both interest rates and inflation.

### 5.1 Definition

A deferred annuity is a regular income for life, commencing at some point in the future. The commonest form of deferred annuity stems from preserved pensions in defined-benefit pension schemes, i.e. the accrued pension rights of early leavers.

### 5.2 Interest-rate risk

Leaving aside the special case of so-called "undated" stocks, the longest U.K. gilt in issuance will be redeemed in 2036, an outstanding term of 32 years at the time of writing. Most U.K. gilts currently in issuance will be redeemed within twenty years. Corporate bonds are similar, if not shorter in term. Matching immediate annuities in payment is therefore relatively straightforward, since most annuities also have a discounted mean term under twenty years. An annuity writer can therefore theoretically manage its reinvestment risk on immediate annuities to zero. This crucially assumes that the annuity writer has got its mortality assumptions correct, however: if not, then reinvestment risk re-appears if mortality trends significantly deviate from expectations. In practice, it is impossible to exactly model future mortality, and hence projected liabilities, so an element of reinvestment risk will always remain.

However, a typical deferred annuity to a forty-five-year-old may still be in payment fifty years hence. A life office might calculate the likelihood of this as 39% for males and 52% for females, which would leave a significant proportion of such deferred-annuity liabilities in payment (Source: Own calculations using PMA92 and PFA92 with CMIB medium-cohort projections). Since there are no backing assets of this kind of term, either gilts or corporate bonds, a life office writing deferred annuities must contend with unmatchable reinvestment risk in the last twenty-odd years at least. If mortality trends go against the office – and there is more time for this to happen with deferred than immediate annuities – the reinvestment risk can grow further over time. The same applies to defined-benefit pension schemes, which is where most deferred annuities are to be found.

A closed portfolio of deferred annuities must start out with unmatched assets as above, but clearly the portfolio can ultimately be matched as time goes on. There will, however, be substantial interest-rate risk for a number of years until this can be achieved.

### 5.3 Inflation risk

Inflation is an additional risk for deferred annuities, particularly for so-called 'deep deferreds', i.e. those annuities with more than fifteen years to the actual start of pension payments.

An immediate annuity may be subject to LPI indexation<sup>6</sup>, i.e. increased in line with inflation, subject to an annual cap. Thus, the annuity writer is protected from an inflation shock by the year-on-year cap. Previous increases below the cap are not taken into consideration: the LPI process is "memoryless".

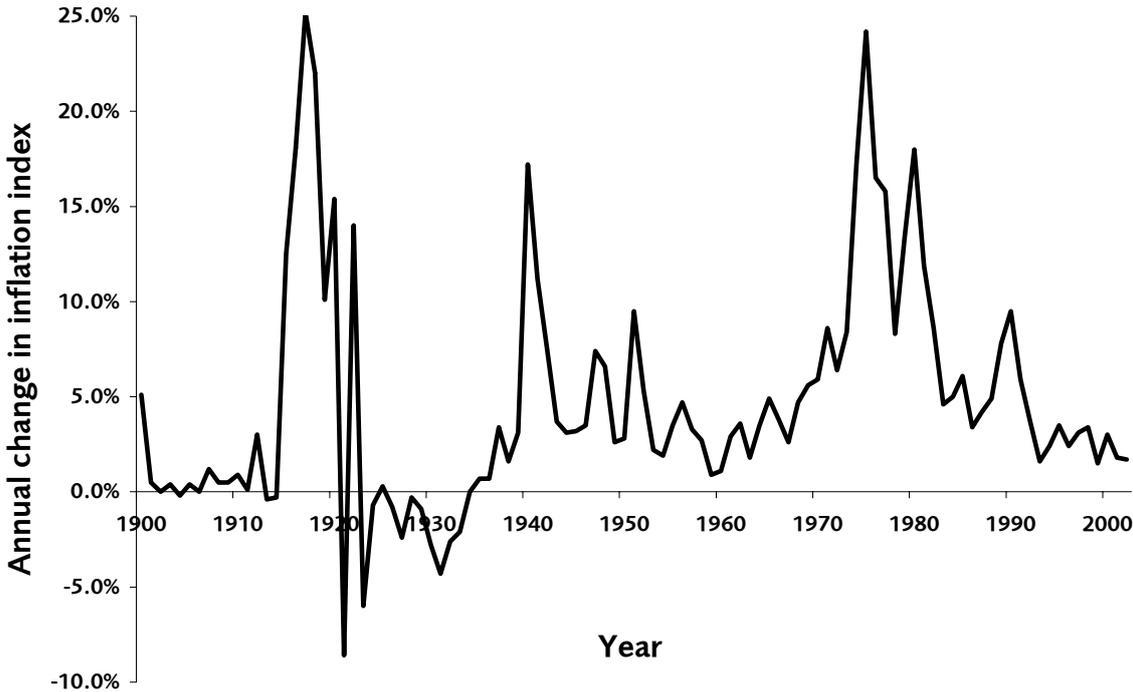
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<sup>6</sup> The historic LPI cap is 5% on the inflation rate in any single year. LPI applies to pension entitlements built up after 6 April 1997, and also applies to protected-rights benefits from contracted-out final salary pensions and personal pensions in respect of Department of Social Security (DSS, now DWP) rebates for the 1997/1998 tax year onwards. The Pensions Bill (2004) reduces the LPI cap from 5% to 2.5%.

A deferred annuity may also be subject to LPI indexation when in payment, but it is also subject to revaluation during the deferred period. Revaluation is also subject to a cap<sup>7</sup>, but, crucially, this cap *applies over the entire period of deferment*. Thus, "unused" inflation allowances can be carried forward. If inflation has generally been low and below the cap, such as over the past decade, the annuity writer is vulnerable to an inflation shock which suddenly raises the value of all deferred annuities. The greater the period of deferment, the greater the inflation risk.

Without wishing to contradict earlier comments about low and stable interest rates in section 2(!), inflation shocks are still a real risk, as Figure 3 demonstrates.

**Figure 3. Annual inflation rate in the United Kingdom since 1900**



Source: Research Paper 03/82, House of Commons Library.

In the past century there have been five major inflation shocks, defined as a peak inflation rate above 10% per annum (or three shocks with two following "aftershocks", to borrow earthquake terminology). Inflation rates over the past decade have been very low, and some argue that the high inflation rates of the past can never return. In answer to this, we would point out that inflation rates were also low in the decade between 1955 and 1965, but this did not stop inflation hitting 24.2% during 1975. Deferred annuities are a (very) long-term business, and it is longer-term inflation risk which counts.

A revaluation cap of 5% per annum implies that, after a decade, a deferred annuity written in 1992 would have a potential liability increase of up to 26% due to an inflation shock. Not only is this a risk, it is not one which can be matched: there are no assets which exactly behave like revaluation liabilities do under an inflation shock. To be safe, deferred annuities should be treated as "RPI uncapped", rather than as quasi-LPI liabilities. Of course, this would involve acknowledging an increased cost.

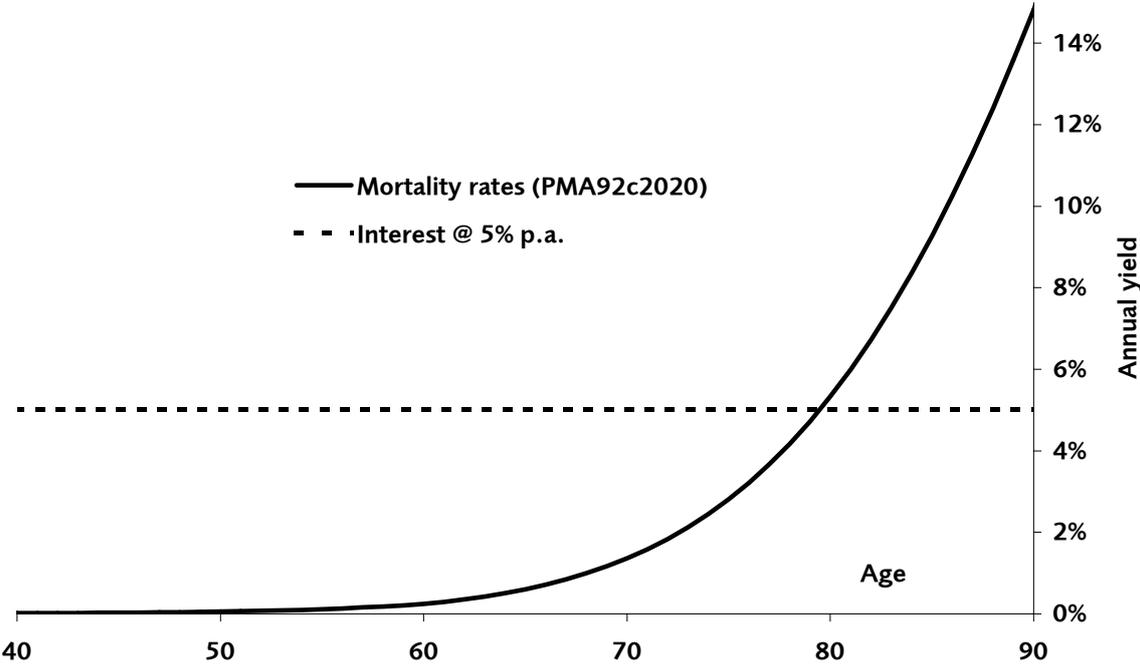
<sup>7</sup> The revaluation cap is 5% per annum over the entire period of deferment. This has not been changed in the Pensions Bill (2004).

Figure 3 also raises another very interesting question, namely the risk of deflation, which was a reality during much of the late 1920s and early 1930s. Technically speaking, LPI- and RPI-adjusted benefits would be reduced during a period of deflation following high inflation, i.e. exactly the situation which occurred from 1915 to 1935. In practice, a life office could only do this if the contract terms and conditions were carefully enough worded to permit this, otherwise actuaries would have to reserve for this situation. Deflation is usually accompanied by adverse investment conditions, so the deferred-annuity writer would need extra reserves at the very point when solvency was most likely to be already under pressure.

**5.4 Interest v. mortality**

There are several ways to measure the relative significance of interest-rate and longevity risk, none of which are perfect because it is difficult to disentangle their interaction. One approach is simply to graph the relative rates of interest and mortality by age, as in Figure 4. From the point of view of an annuity writer - either life office or pension scheme - we can see that the interest yield dominates at younger ages, particularly so for deferred annuities written at younger ages below 55. From the customer's point of view, the combined yield from interest and mortality becomes a compelling investment proposition above age 75: it is hard to see where else a customer can get a guaranteed lifetime gross running yield of over 7% per annum (5% interest plus 2% mortality). The mortality component of this combined annuity yield is known as "mortality drag" in the world of income drawdown products, and represents the extra investment return a customer has to achieve to justify *not* annuitising a pension fund.

**Figure 4. Comparison of interest and mortality rates as investment**



Source: CMIB data.

**5.5 Conclusion**

Deferred annuities have a very different risk profile compared to immediate annuities, and these differences are magnified by a longer deferred period. Long-term interest rate risk is more significant than longevity risk, and there is also significant inflation risk. These differences are magnified by a longer deferred period.

## 6 Defined-benefit pension schemes

Some of the greatest longevity risks borne by shareholders lie in defined-benefit pension schemes, not insurance companies. Some of the greatest future 'surprises' from longevity risk may come from companies with large defined-benefit pension schemes.

### 6.1 Definition

A defined-benefit pension scheme is the means whereby an employer promises a pension on retirement, based on the employee's final salary. The definition of "final salary" varies and may include bonuses or commission, but the promise is of a pension for life and is therefore a longevity risk for the employer.

### 6.2 Size of the risk

Shareholders in U.K.-listed insurers have direct longevity exposure of upwards of £30bn (Source: FSA Returns, see Table 1 on page 6). Shareholders have further indirect exposure through annuity liabilities held in 90:10 with-profits funds. These liabilities are tightly regulated, with some degree of public disclosure of the longevity assumptions underpinning reserving practice and margins to cover uncertainty. The FSA also exerts a still-greater degree of supervision through the undisclosed Financial Condition Reports (FCRs).

Shareholders in other U.K. companies have longevity exposure of a quite different order of magnitude: £762bn (Source: GAD, Eleventh Survey of Occupational Pension Schemes, 2000). Furthermore, the liability calculations are not as tightly regulated, and there is very limited disclosure of the longevity assumptions behind them. This is a concern, as several FTSE-100 companies have very large and mature pension schemes in relation to their market capitalisation, as Table 3 demonstrates.

**Table 3. Relative size of pension scheme for selected FTSE-100 companies**

| Company name                      | Size of scheme relative to market capitalisation |
|-----------------------------------|--|
| British Airways                   | 899%   |
| ICI                               | 352%   |
| BAE Systems                       | 242%   |
| BT                                | 224%   |
| Rolls Royce                       | 199%   |
| Royal & Sun Alliance <sup>8</sup> | 182%   |
| Land Securities                   | 3%   |
| The British Land Company          | 2%   |
| Liberty International             | 2%   |
| Vodafone Group                    | 1%   |

Source: Lane, Clark and Peacock Annual Survey, 2004. End-2003 figures. Size of scheme is the greater of assets and liabilities.

<sup>8</sup> Bearing in mind Table 1, one might wonder what total longevity exposure looks like for shareholders of U.K. insurers, if one considers their annuity liabilities *together with their defined-benefit pension schemes*. Unlike other shareholder-owned companies, however, a significant proportion of insurers' pension-scheme liabilities (and deficits) are attributable to policyholder operations, not shareholders. In any case, the R&SA figure here has been overtaken by a comprehensive restructuring.

The authors re-calculated these figures as at early September 2004 and found them broadly validated, albeit at slightly lower levels due to changed market capitalisations. The greatest change was for British Airways (BA), where the 899% figure fell to 450% as a result of swings in the share price. In its newsletter of March 2003, BA informed pension-scheme members of a £928m deficit. In December 2003, BA re-entered the FTSE- 100 index of Britain's largest listed companies with a market capitalisation of £2.4bn. With an unfunded longevity liability amounting to around one-third of the value of the company, it is little wonder that the chief executive described the pension scheme as being the "elephant in BA's rowing boat". Looking at Table 3 one understands what the Financial Times meant when it recently described BA as "a leveraged investment trust with a troublesome sideline in air travel".

Table 3 does raise one further subtle question regarding pension-scheme deficits: to what extent is their existence and behaviour already factored into a company's share price?

**6.3 Nature of the risk**

Most of the recent focus on pension schemes has been on investment risk, as exemplified by the widespread scheme deficits caused by the poor equity returns over the past few years. Arguably, these deficits were not caused by investment risk per se, but are a consequence of a severe mismatch between assets and liabilities. These widely differing attitudes to equity investment and liabilities are illustrated in Table 4.

**Table 4. Risks in defined-benefit pension schemes for selected FTSE-100 companies**

| <b>Company name</b> | <b>Size of scheme relative to market capitalisation</b> | <b>Equity investment level</b> |
|---------------------|---|--------------------------------|
| HBOS                | 19%   | 77%                            |
| ICI                 | 352%  | 24%                            |
| Boots               | 62%   | 0%                             |
| BAE Systems         | 242%  | 71%                            |

Source: Lane, Clark and Peacock Annual Survey, 2004. Size of scheme is taken as the greater of assets and liabilities. The equity investment level is across each company's schemes world-wide.

HBOS has a relatively small scheme in relation to market capitalisation, so it can afford to take the risk of a higher equity level in scheme assets. In contrast, ICI has a relatively large scheme, so it has adopted a much lower level of equity investment.

The Boots Group, however, is one of only four FTSE-100 companies which has an FRS 17 funding level greater than 100% (Source: Lane, Clark and Peacock Annual Survey, 2004). Arguably, Boots could afford a higher equity level amongst scheme assets. Despite this, Boots has chosen a conservative, bond-only investment strategy. In contrast, a more aggressive investment policy has been chosen by BAE Systems, which has both a relatively large scheme and an FRS 17 funding level of just 75%, yet also has a high equity investment level of 71%. There is vigorous debate on the appropriateness of such strategies, with pension-scheme funding the subject of three other SIAS papers this year already: Wise et al (2004), Carne (2004) and Cardinale (2004).

Investment risk is about funding the pension promise, yet at its core this promise is a longevity liability: a pension for life. There is, however, one other large source of risk: Government action. The past two decades have seen a slew of legislation which increased the cost of defined-benefit pension schemes under both Conservative and Labour governments. Some of the more notable changes include:

- Preserved pensions and revaluation of benefits in deferment.
- LPI indexation of pensions in payment.
- Withdrawal of tax relief on dividends.
- Past encouragement to enhance benefits during times of investment surplus.

To pick just one example, no-one would argue against the fairness of the regulations which protected early-leaver benefits. Equally, however, this measure has increased the cost compared to the employer's original expectation when the scheme was set up. An employer can be forgiven for feeling that defined-benefit pension schemes have been a bit of a one-way street in recent years.

## **6.4 Managing the risks**

Awareness of the risks in defined-benefit pension schemes has shot up in the past decade. Most of this awareness has been driven by the deficits which opened up due to pension schemes' heavy equity exposure during a prolonged fall in stockmarket valuations, combined with new disclosure standards like FRS 17 and IAS 19. While most of the focus has recently been on lower nominal anticipated investment returns, longevity assumptions are now starting to take on increased significance.

It is hard to assess the extent of the longevity risk in defined-benefit pension schemes, not least because there is very little by way of disclosure of mortality assumptions. Nevertheless, it is likely that some schemes are using more optimistic mortality assumptions than others. A white-collar scheme valued for convenience on the old MFR mortality basis of PA(90) less two years to age, for example, would be grossly underfunded: using PA(90) -2 years yields liability values 22% below those suggested by PMA92 with the mid-intensity cohort projection for improvements (see Table 17). The former is the Minimum funding Requirement (MFR), but the latter is much closer to what a life office would actually charge.

As awareness of the risks posed by a defined-benefit pension scheme has grown, the past five years have seen a wide variety of approaches to managing these risks. Some of these approaches are discussed below.

### **6.4.1 Closing the scheme to new entrants**

This involves limiting membership of the defined-benefit pension scheme to existing employees. New employees join a different pension scheme, usually on a money-purchase basis. This option is common, not least because it is sometimes the one easiest to sell to the existing workforce: their pensions are unaltered and it is only the voiceless and unknown future members who are being excluded. This option is also sometimes just the first in a number of changes to a pension scheme.

Closing the scheme to new entrants does not stop the longevity risk from growing, of course, but at least it slows down the rate of growth. Around half of the U.K.'s defined-benefit pension schemes are now closed to new entrants, according to the Association of Consulting Actuaries.

Closing the scheme to new entrants is not a risk-free option in terms of employee relations, however. Unionised workforces at Caparo (steel) and Rhodia (chemicals) went on strike in 2003 over pension-scheme changes, including closure to new members. After strike threats, Network Rail agreed a compromise deal on the closure of its defined-benefit scheme: new entrants join a money-purchase scheme, but may join the defined-benefit scheme after five years' service (Source: Network Rail press release, June 2004).

#### **6.4.2 Changing the definition of 'final salary'**

A relatively uncommon option is to change the definition of salary away from the actual salary earned in the final year of employment. A variety of new definitions is possible, including "career revaluation", where the revaluation might be in terms of an inflation index, as opposed to a (higher) earnings index. Career revaluation was the option chosen by Sainsburys earlier this year for its scheme.

#### **6.4.3 Modifying pay rises**

Pensions have been referred to as "deferred pay" since the landmark legal judgement "Barber v. GRE" in 1990. Differentiating current pay rises on the basis of future pensions is perhaps the most explicit recognition of this. In April 2003 the Financial Services Authority (FSA) adopted an uncommon - yet wholly logical - approach: members of the closed final-salary scheme received an explicitly lower pay rise (4.2%) compared to staff who were not members (6.7%).

#### **6.4.4 Increase employee contributions**

Although it does not change the total longevity risk, this option does at least redistribute the cost of funding it. This 're-balancing' of the risk was suggested by the Office of the Deputy Prime Minister in a consultation paper in 2003. Many schemes have seen the re-introduction of employee contributions, which were zero during such prolonged "contribution holidays" that many members erroneously thought their scheme was non-contributory.

#### **6.4.5 Reducing the rate of future accrual**

A scheme offering  $1/60^{\text{th}}$  of final salary per year of service might declare that future accrual will take place at a lower rate, e.g.  $1/80^{\text{ths}}$  or even  $1/100^{\text{ths}}$ . Reducing the rate of future accrual does not get rid of the longevity risk, but it does reduce the rate at which the problem grows. This was the avenue taken by Rolls Royce in settling a pension dispute with the Amicus trade union in November 2003. According to a survey of smaller firms, around 1 in 10 schemes have changed their accrual rate, with a move from  $1/60^{\text{ths}}$  to  $1/80^{\text{ths}}$  being the most common (Source: Association of Consulting Actuaries).

#### **6.4.6 Increasing the retirement age**

This option not only increases the period of accrual, but also reduces the period of pension payment. Both the Teachers Pension Scheme and the National Health Service Superannuation Scheme face proposals to raise the retirement age from 60 to 65, and also to increase the earliest age at which non-ill-health pension benefits can be drawn<sup>9</sup>.

#### **6.4.7 Closing the scheme to future accrual**

This involves not only closing the scheme to new entrants, but also stopping future benefit accrual for existing members. This drastic option stops the longevity risk from growing, but it is understandably met with much more resistance from existing staff and their unions or representatives.

However, one major obstacle to closing the scheme to future accrual is that the Trust Deeds of some schemes specify that this automatically triggers wind-up and buy-out. Since many schemes are not funded to a discontinuance level, this would crystallise the need for a cash injection into the scheme. For these reasons, closure to future accrual is likely to be a last resort for an employer.

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<sup>9</sup> This was also the option chosen in the United States when President Reagan (then aged 72) signed a law in 1983 raising the state retirement age from 65 to 67.

#### 6.4.8 Combination approaches

There is a seemingly limitless number of combinations possible. For example, in early 2004 Standard Life announced the closure of its scheme to new entrants (6.4.1). This was followed more recently with an announcement of further changes to scheme membership: existing members can either start contributing to continue accrual at the rate of 1/60<sup>th</sup> of final salary per year of service (6.4.4), or, if they will not contribute, then future accrual will be at a rate of 1/80<sup>th</sup> (6.4.5).

#### 6.4.9 Winding up and buying out

There is an ever-lengthening list of reasons why sponsoring employers might seek to rid themselves of the risks in a defined-benefit pension scheme:

- Changes to legislation, in particular the "debt on employer" rules on scheme wind-up.
- FRS 17 and IAS 19 have made the risks more apparent to investors in financial statements.
- An increasing focus of attention from analysts, rating agencies and providers of corporate finance.
- Employer exposure to the costs of funding deficits, but often without the ability to benefit from any emerging surplus.
- Uncertainty about future trends in longevity and other demographic factors.
- Uncertainties in the development of pensions legislation, such as risk-related levies under the Pensions Protection Fund and requirements under scheme-specific funding standards.

The only way for employers to completely rid themselves of longevity and other risks is to wind up the scheme and secure benefits with an insurance company. This is known as a buy-out: the purchase of annuities *en masse* in lieu of the scheme's benefits. Buy-outs can be on a group basis (where the insurance policy is an asset of a continuing scheme), or on an individual basis (where the insurance policies are in members' names).

Buy-outs can appear expensive to pension scheme trustees, but this "expense" is more apparent than real. Much of the difference lies in the fact that insurance companies are subject to far more stringent regulations:

1. Insurers are forbidden from ever having reserves less than the actuarial value of benefits. Insurers must also hold so-called "resilience test reserves" to ensure solvency under some extreme investment scenarios. Pension schemes, by contrast, have no such obligations and are allowed to run (temporary) deficits.
2. Insurance companies are forced to hold mismatching reserves if their backing assets do not behave similarly to the value of the liabilities. In contrast, pension schemes have great freedom to choose assets which do not behave like the liabilities, as exemplified by the very high proportion of schemes' assets which are invested in equities.
3. Insurance companies are forced to reserve prudently, and also to hold solvency-margin capital. Neither of these apply to pension schemes.

These more demanding regulations and capital requirements cause insurers to rate liabilities higher than pension schemes, and this is a major source of the apparent "expense" of buying out. However, it is often far from clear how adequate pension schemes' funding is in the first place, especially with regards to mortality and longevity assumptions. Insurance companies have been in the vanguard of the development and use of improvement bases, for example, and these bases are disclosed in publicly available returns to the FSA. There is no such transparency and disclosure for the valuation of defined-benefit pension schemes.

Thus, a given block of benefits will usually have a higher liability on the insurer's balance sheet than on that of the pension scheme. Part of this is due to regulatory constraints, but part may simply be due to insurance companies using more up-to-date longevity assumptions.

## **6.5 Options for buying out**

Understandably, an increasing number of companies want to rid themselves completely of the longevity (and other) risks in their defined-benefit pension schemes. One way to do this is to pass these risks to an insurance company by means of a so-called bulk annuity or bulk buy-out. There are now three options for Trustees looking to control their risk in this way:

### **6.5.1 Traditional buy-out**

The traditional bulk annuity or bulk buy-out is structured as a single premium paid to the insurer in exchange for taking over the liabilities, including all longevity and investment risk. The difference in assessment of cost can often be a major barrier to this kind of transaction: a scheme usually needs to be more than fully-funded on its own valuation basis to be able to afford a buy-out<sup>10</sup>. The single-premium nature of the traditional buy-out crystallises the problem for the sponsoring employer at a single point in time and sometimes necessitates an injection of funds even for apparently solvent schemes.

### **6.5.2 Structured buy-out**

A relatively new approach to buy-outs involves staging the buy-out as a regular-premium contract instead of a single-premium one. This has the advantage of allowing the Trustees of the scheme to lock in to a particular buy-out basis, while giving the sponsoring employer more time to find the additional funds necessary. As with the traditional single-premium buy-out, longevity risk is fully removed on day one.

### **6.5.3 Refundable buy-out**

The traditional buy-out transfers all risks from scheme to insurer. A refundable buy-out holds the possibility of a return of some assets, dependent on scheme experience. This allows Trustees to specify a level of retained risk between the extremes of zero risk (full buy-out) and full risk (no buy-out). A particular appeal of this option is that the scheme will never be asked to contribute more than the initial premium, yet may still participate in positive experience variance.

## **6.6 FRS 17 – not the last word**

Part of the controversy surrounding FRS17 statements is the fact that they often disclose deficits even when the scheme valuation claims otherwise. Given that schemes promise a pension for life, however, it is truly remarkable that the FRS17 specification makes no mention whatsoever of the assumptions to use in estimating the length of that life! As this omission in the FRS17 specification suggests, there remains the suspicion that parts of the pension world have yet to fully catch up with the reality of increasing life expectancy. There is thus reason to believe that some of the current FRS17 deficits are under-estimates compared to what the figures would show with more realistic longevity projections.

FRS 17 is not the end of increased pension-scheme disclosure, however. From end-2004 International Accounting Standard 19 will apply. IAS 19 is similar in many ways to FRS 17, most notably in being a bond-based approach to calculating liabilities. Unlike FRS 17, which

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<sup>10</sup> Interestingly, buy-out costs are also typically greater than the value of benefits calculated according to FRS 17, which is supposed to be a realistic assessment of the liabilities. Since FRS 17 includes no mention of mortality assumptions whatsoever, part of the gap between buy-out costs and FRS 17 liabilities may be due to differences in longevity assumptions.

discloses a capitalised deficit or surplus figure, under IAS 19 actuarial gains and losses<sup>11</sup> are recognised as income or expense only to the extent that they exceed 10% of the defined-benefit obligation or 10% of the fair value of scheme assets. The critical aspect of IAS 19 for the purposes of this paper is that the actuarial gains and losses are recognised over the average remaining working lives of employees participating in the scheme. For companies looking to amortise such experience variance, some disclosure of the longevity assumptions behind this calculation is essential.

## **6.7 Conclusion**

Defined-benefit pension schemes harbour plenty of risks, of which longevity risk is only one. However, since this sector has appeared to focus so exclusively on investment risk, there remains the possibility of significant surprises on the longevity front. Without greater transparency and disclosure of mortality bases by schemes it is impossible to be sure, but these "surprises" seem unlikely to be of the pleasant kind. We would agree with O'Brien (2003) and Willets et al (2004b) in calling for the disclosure of life expectancy assumptions in scheme reports.

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<sup>11</sup> "Actuarial gains and losses" comprises both experience variation and changes to actuarial bases and assumptions.

## 7 Enhanced and impaired-life annuities

The greatest risk for enhanced annuities lies in underwriting, i.e. correctly estimating the extra payment afforded by a particular medical condition. A second risk is of substantial increases in life expectancy brought about by improvements in treatments for key conditions underwritten in the enhanced market.

### 7.1 Definition

Enhanced annuities for impaired lives offer an increased annuity or pension on the basis of a condition which reduces life expectancy. These products range from non-underwritten "smokers' annuities" with limited uplift, to annuities that require evidence of a serious medical condition but offer substantially increased benefits.

### 7.2 Growth and size of the enhanced market

At the time that Ainslie (2000) reviewed the impaired-life annuity market, sales were around £200m pa. By the end of 2002 this market had more than tripled to £651m pa (Source: Watson Wyatt Impaired Annuity Survey). Enhanced annuities represent close to 10% of all individual annuity premiums and 21% of open-market annuities.

Until recently the market was split between true *impaired-life annuities*, which offered significant uplifts in annuity rates with full individual underwriting, and *enhanced annuities*, which offered more modest uplifts but without full underwriting. The leading writer of enhanced annuities, Britannic Retirement Solutions (BRS), closed to new business in 2003, shrinking the overall market as the remaining players were primarily focused on impaired-life annuities. At the time of writing, the team behind BRS is poised to re-enter the market in late 2004 as a company called Just Retirement.

### 7.3 Mortality dynamics

The mortality dynamics of an enhanced annuity portfolio are different from a standard portfolio for obvious reasons. Initial elevated mortality will ultimately reduce, with survivors' mortality converging towards conventional rates.

A portfolio of enhanced annuities is likely to be weighted towards exposure to a handful of impairments, particularly cardio-vascular disease and conditions related to smoking. Pricing bases need to be reviewed regularly to keep up-to-date with developments in survivability of these key conditions. A good example is cardio-vascular mortality: the past few years have seen rapid growth in the prescription of statins<sup>12</sup> and ACE<sup>13</sup> inhibitors, both of which separately make for dramatic reductions in mortality rates due to heart disease. It is this exposure to a breakthrough in a single condition which demands that enhanced products are priced on a higher margin (or higher return on capital) than standard annuities.

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<sup>12</sup> There are at least six commonly prescribed statins (in the U.S.A.) and they all act to reduce the level of Low-Density Lipoprotein (LDL) cholesterol in the blood. High blood levels of LDL cholesterol lead to arterial deposition, and thus narrowed arteries and increased risk of heart attack.

<sup>13</sup> ACE = Angiotensin-Converting Enzyme. Angiotensin II is a chemical which causes contraction of the muscles surrounding blood vessels, thus narrowing them and raising blood pressure (hypertension). Angiotensin II is created by the action of ACE (Angiotensin-Converting Enzyme), and ACE inhibitors do exactly this – inhibit the action of ACE, thus slowing the creation of Angiotensin II and lowering blood pressure.

## 7.4 Impact on standard annuities

Using a simple model, Ainslie (2000) identified a threshold level of 7.5% uptake of enhanced annuities to cause material anti-selection in the standard annuity market. Although this threshold has only just been reached in the market overall (around 10% of premiums), it has been firmly breached in open-market annuities, of which around 21% are now enhanced. Thus, anti-selection is likely to be focused strongly on open-market annuities, rather than the internal vesting books of U.K. insurers.

## 7.5 Modelling anti-selection

Since the enhanced-annuity market has been in operation for a comparatively short time, there is little experience to go on (either of the enhanced annuities themselves, or of their effect on standard annuities). To explore anti-selection, it is necessary to follow the lead of Ainslie (2000) by creating a simple model.

For example, suppose the population splits 20:80 into two mortality groups, the first with an elevated mortality of 200% of PMA92 and the second with reduced of 80% of PMA92. From the steady state where the cost of an annuity is close to that of the underlying PMA92 mortality, suppose the higher-mortality population selects into an enhanced annuity product. The remaining population experiences 80% mortality, which implies an increase in standard annuity cost of in excess of 4%<sup>14</sup>. The high-mortality group has a potential reduction in annuity cost of upwards of 15%, although the extent of the mortality saving passed on will depend on a number of other factors.

The actual impact of the impaired annuity market is very difficult to assess due to the range of potential enhancements, the brief period of operation and the extremely rapid growth of the market. This all makes a steady-state position difficult to assess with any confidence, and the full effect on the standard market will not be known with any certainty for some years. Experience monitoring is therefore key, not just for the impaired-life annuity product itself, but also to understand the impact of anti-selection for the standard annuity market.

## 7.6 Trends and mortality improvements

It is difficult to assess the appropriate allowance for future mortality improvements for enhanced annuities. For example, one of the key drivers of recent overall improvements has been reducing mortality from cardiovascular disease. If those diagnosed with cardio-vascular disease preferentially select into the enhanced annuity market, they may be expected to have markedly different improvement rates compared to those suffering from cancer, where survival rates have been more resistant to change.

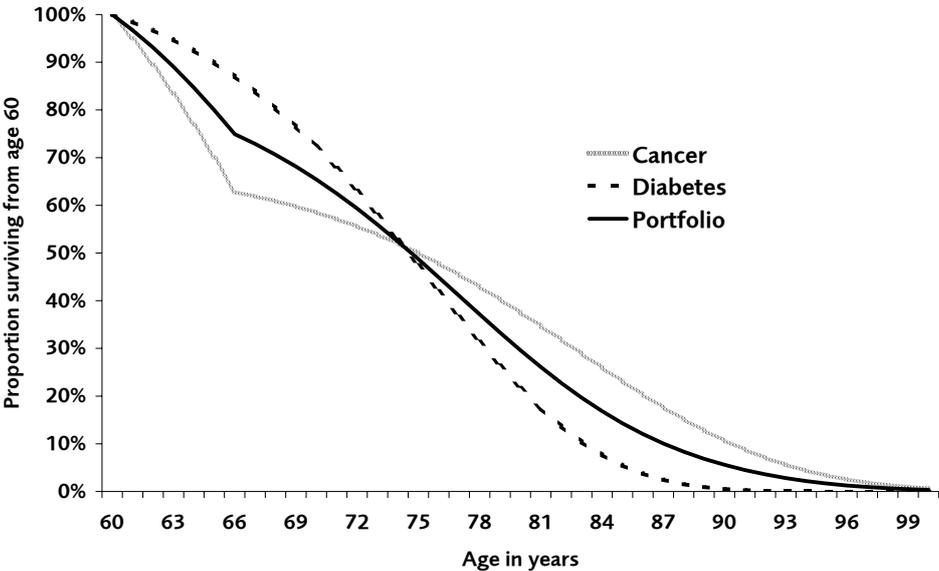
The existence of the enhanced market is also a severe complication in the setting of future improvement assumptions for the standard annuity market: how much improvement should be ascribed to general trends, and how much to the operation of the impaired-life market? The increasing selection of smokers (who are more likely to be able to access such products) into the enhanced market may lead to initial increased improvements for the conventional annuity product, as the population of smokers within this market decreases. This could plausibly lead to a situation where, even if the smoking population were static, the effects of selection lead to the almost total absence of smokers within the conventional standard-annuity market. At this point historical tables may offer poor guidance to the underlying mortality of a non-smoker population.

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<sup>14</sup> Reference annuity is a level annual pension in advance, payable throughout life to a single male aged 60, and is valued at an interest rate of 5% per annum using PMA92 without future mortality improvements.

The combination of conditions and the impact on life expectancy is particularly liable to change over time. For example, consider a portfolio of impaired annuitants split 50:50 between cancer and a degenerative disease such as diabetes. Cancer mortality may be modelled by assuming that the annuitant suffers increased mortality over the five years from entry, after which point the mortality reverts to the general population<sup>15</sup>. In contrast, a degenerative disease will exhibit elevated mortality over the entire future age range. Figure 5 shows the survival curves for the two conditions, and the portfolio as a whole. It illustrates survivorship of a 50:50 mix of annuitants, where the two conditions are a cancer-type condition with 70% survival after 5 years, and a degenerative condition, whereby mortality is at a fixed multiple of standard mortality. For demonstration purposes, mortality has been calibrated so that the annuity cost at age 60 is equal in both cases.

**Figure 5. Illustrative survival curves in an enhanced-annuity portfolio**



Source: Own calculations.

One way of costing these would be to compute the equivalent multiple of the base mortality (the appropriate measure for the degenerative condition is approximately 260%). However, as the graph shows, the early high cancer mortality wears off leaving a residual group of "healthy" lives. Figure 5 shows why an aggregate mortality basis is inappropriate for valuation purposes: the financial impact could become increasingly severe depending on the future mortality improvements of the two populations. The exposure of the cancer population is relatively brief, under the assumption that the extra mortality runs off after five years. The exposure to medical breakthroughs is therefore small, especially for a condition (like cancer) where survivability has changed little over time. In contrast, the extra mortality of the degenerative condition is particularly susceptible to medical developments. Ongoing monitoring of enhanced portfolios is necessary to validate valuation assumptions, particularly during run-off.

**7.7 Conclusion**

The major risks in enhanced annuities are underwriting, i.e. correctly assessing the level of impairment, and medical breakthroughs in the short-term survivability of the conditions underwritten.

<sup>15</sup> Cancer survival rates in the medical literature are typically given as five-year survival probabilities. We have simplified the cancer model by assuming that the annuitant is effectively cured of the original cancer if (s)he survives five years from outset.

## 8 Guaranteed Annuity Options

Increasing expectations of longevity have a highly leveraged effect on reserves for guaranteed annuity options (GAOs). The fall in interest rates has laid bare the problem, but it is increasing longevity expectations which are driving up costs now.

### 8.1 Definition

Under a guaranteed annuity option, an insurer guarantees to convert a policyholder's accumulated pension funds to a life annuity at a fixed rate at maturity. If the guaranteed annuity rates are more beneficial to the policyholder than the prevailing market rates, the insurer has to make up the difference. The risk to the insurer lies in granting such options based on over-generous assumptions for interest rates and longevity.

GAOs are also sometime known as GARs - guaranteed annuity rates. A similar idea sometimes exists within defined-benefit pension schemes for precisely the reverse, namely a guaranteed basis for commuting pension into a lump sum. Unlike for insurance companies, the schemes run relatively little risk from having outdated commutation bases, however. Indeed, commutation on the basis of outdated mortality assumptions is a boost for the scheme, if not the individual members concerned<sup>16</sup>.

### 8.2 History

Guaranteed annuity options were common amongst unit-linked life offices (and others) selling pension plans during the 1980s and 1990s. They were the source of much controversy then (as now) with the actuarial profession setting up the Maturity Guarantees Working Party to assess the correct approach to reserving for them. GAOs were often under-priced, with the guarantees sometimes being granted without an appropriate charge.

### 8.3 Implied cost of GAOs

One approach to examining GAOs is to consider a typical guaranteed annuity option, say £111 per £1,000 of pension fund. Applying a base table of PMA92 in 1992 (no improvements) suggests the guarantee would bite with an interest rate of 7.3% per annum. Including CMIR17 mortality improvements increases the implied interest rate to 7.75%, while using the medium cohort improvements implies 8.2%. These figures are not inconsistent with the yields applying from 1970 to the early 1990s. However, they are very generous indeed compared with current rates, as Figure 6 makes clear.

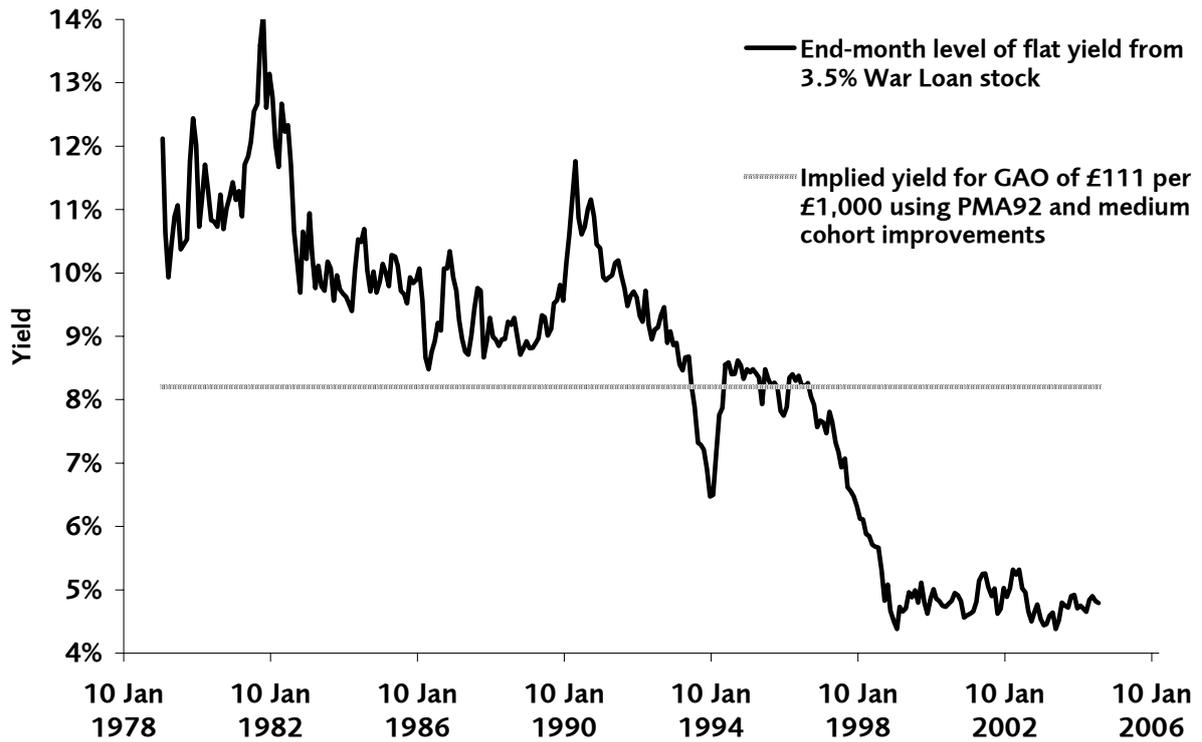
### 8.4 Mortality expectations

As Figure 6 shows, the issue of GAOs was caused by the steep fall in interest rates over the past two decades. Against a backdrop of low and stable expectations for interest rates, the primary force now driving the cost of guaranteed annuity options is the expectation of longevity. Figure 7 demonstrates the large rises in costs of GAOs caused by expectations of increasing longevity, as represented by successive actuarial mortality tables.

Looked at another way, the typical pricing basis at the point of sale of many GAOs was a(55). Using this table, the life expectancy of male age 65 is 14.3 years. A life office today using PMA92c2020 would estimate a life expectancy of 19.8 years (Boyle and Hardy, 2003), an increase of nearly 40%.

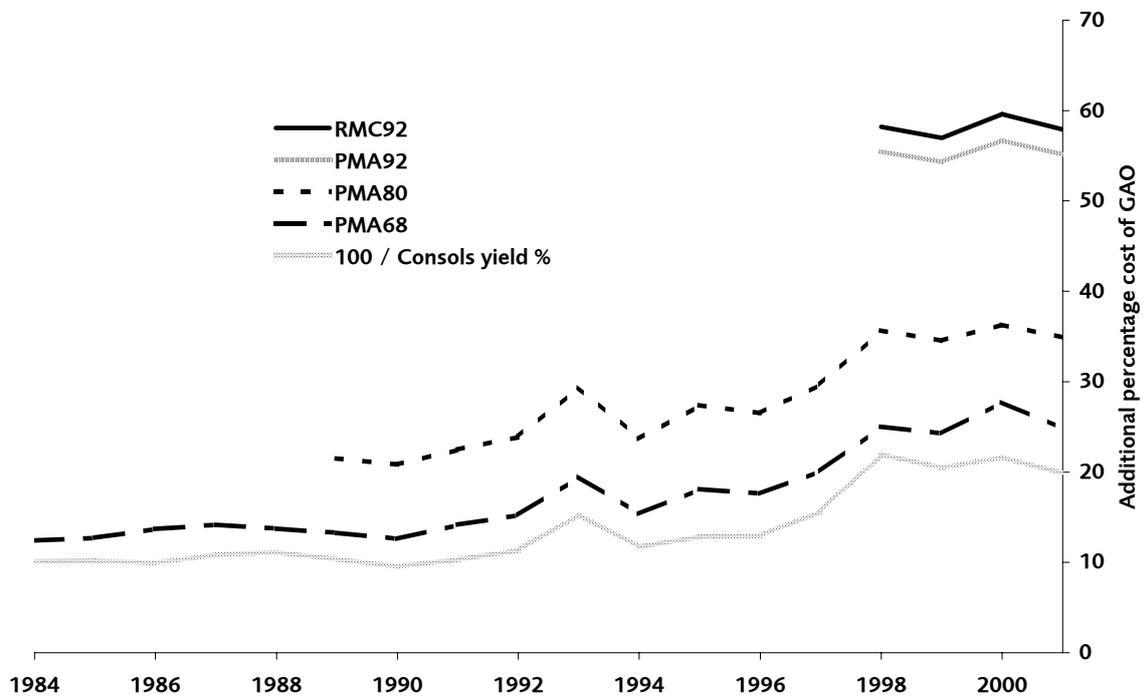
<sup>16</sup> A similar comment applies to transfer values out of schemes made using outdated longevity assumptions: good for the scheme, but bad for the individual transferring (ex-)members. A scheme is, however, at risk of loss if transfers in are granted on an out-of-date mortality basis.

**Figure 6. Gilt yields and interest rate implied by a sample GAO annuity rate**



Source: Own calculations and Bank of England data, following format suggested by Boyle and Hardy (2003).

**Figure 7. Additional cost of GAO under different mortality bases**



Source: Wilkie, Waters and Yang (2003)

## **8.5 Hedging GAO risks**

Hedging GAO risks is not straightforward, but some insights and strategies can be found in O'Brien (2002) or Wilkie, Waters and Yang (2003). O'Brien (2002) describes two bonds bought at £0.53bn each by Scottish Widows in 1999 from two European banks, and which were carefully structured to hedge a portfolio of guaranteed cash flows. The impact of mortality on the transaction will depend on the precise structure of the contract, i.e. whether only interest rate risk is transferred - as is likely - or whether longevity risk is also covered. The timing of this and similar transactions may be important, since they pre-date much of the recent important mortality work done within the profession, including Willets (1999), CMIB (2002) and Willets et al (2004b).

## **8.6 Conclusion**

Guaranteed annuity options are a highly leveraged bet against long-term interest rates and longevity expectations, since their cost is the difference between two annuity rates. The sustained fall in interest rates has put GAOs "in the money", but it is increasing longevity expectations which are driving their costs higher still.

## 9 Lifetime Mortgages

Lifetime mortgages contain longevity risk tied to property-price risk. Unlike the longevity risk associated with annuities, equity-release mortgages have no practical limit on the liability.

### 9.1 Definition

A lifetime mortgage is designed to release a capital sum to the owner of a domestic property. The mortgage is typically non-interest-bearing, i.e. the interest on the mortgage is not paid by the borrower, but is added to the outstanding loan. The borrower continues to live in the property until death or entry into long-term care, with most mortgage lenders permitting surviving spouses to continue living in the property until same. Many modern products contain a no-negative-equity guarantee, whereby any shortfall in property value on redeeming the mortgage will not become a charge on the deceased's estate.

### 9.2 Past and present

Lifetime mortgages were until recently known as equity-release mortgages (ERMs). Neither is to be confused with the "reversion-type" schemes sold in the 1980s, which are now discredited. Sales of lifetime mortgages are now regulated, and a voluntary code of conduct exists under the Safe Home Income Plan (SHIP) scheme. Lifetime mortgages adhering to this code carry the SHIP accreditation.

### 9.3 Development of the market

The market for lifetime mortgages continues to grow, most obviously in terms of the outstanding mortgages (net of redemptions) and the average advance (see Table 5).

**Table 5. New and in-force lifetime mortgages**

| Year |    | New advances: |            |             | Mortgages outstanding: |            |             |
|------|----|---------------|------------|-------------|------------------------|------------|-------------|
|      |    | Number        | Value (£m) | Average (£) | Number                 | Value (£m) | Average (£) |
| 2002 | H1 | 5,973         | 225        | 37,729      | 30,292                 | 1,157      | 38,185      |
|      | H2 | 10,329        | 429        | 41,558      | 37,935                 | 1,548      | 40,806      |
| 2003 | H1 | 11,870        | 504        | 42,493      | 52,658                 | 2,258      | 42,887      |
|      | H2 | 13,244        | 597        | 45,066      | 64,127                 | 2,836      | 44,230      |
| 2004 | H1 | 11,204        | 517        | 46,145      | 71,426                 | 3,298      | 46,168      |

Source: Council of Mortgage Lenders. Figures exclude home-reversion schemes. Mortgage balances reflect impact of redemptions and step changes may be a result of additional lenders contributing to survey data.

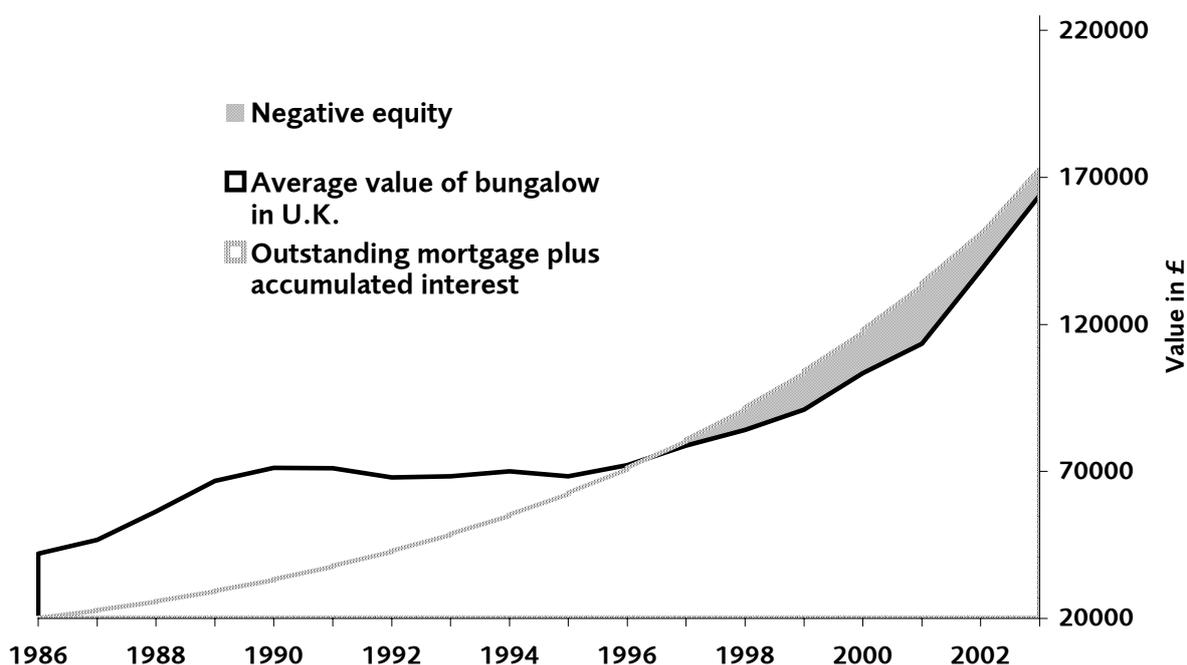
### 9.4 Longevity risk

One way of looking at the longevity risk in a lifetime mortgage is to focus on the common guarantee of "no negative equity" when the insured lives die (or enter long-term care) and the mortgage is repaid. This guarantee is a condition of receiving SHIP accreditation, and stops any negative equity becoming a claim on the deceased's estate.

Figure 8 shows the average price of a bungalow in the United Kingdom from 1986 onwards. It also shows the development of a hypothetical lifetime mortgage written on such a house in 1985. This figure is not designed to be an accurate reflection of lifetime mortgages then or now, but to demonstrate two oddities of longevity risk for equity-release mortgages:

- (i) Longevity risk (measured by the negative-equity) expands rapidly when house-price inflation is less than the interest rate accumulating on the mortgage balance. The period 1997-2001 with our hypothetical mortgage shows negative equity as the outstanding mortgage plus interest (grey line) exceeds the value of the house (solid line). If long-term property-price inflation is less than the interest rate charged on the mortgage, there is longevity risk if the insured lives live a lot longer than anticipated .
- (ii) In stark contrast to annuities, longevity risk on lifetime mortgages can also shrink as the "life assured" gets older. The lender's exposure to negative equity in our hypothetical example is shrinking between 2001 to 2003, as the gap between the property price and the accumulated mortgage shrinks almost to zero.

**Figure 8. Hypothetical equity-release mortgage written in 1986**



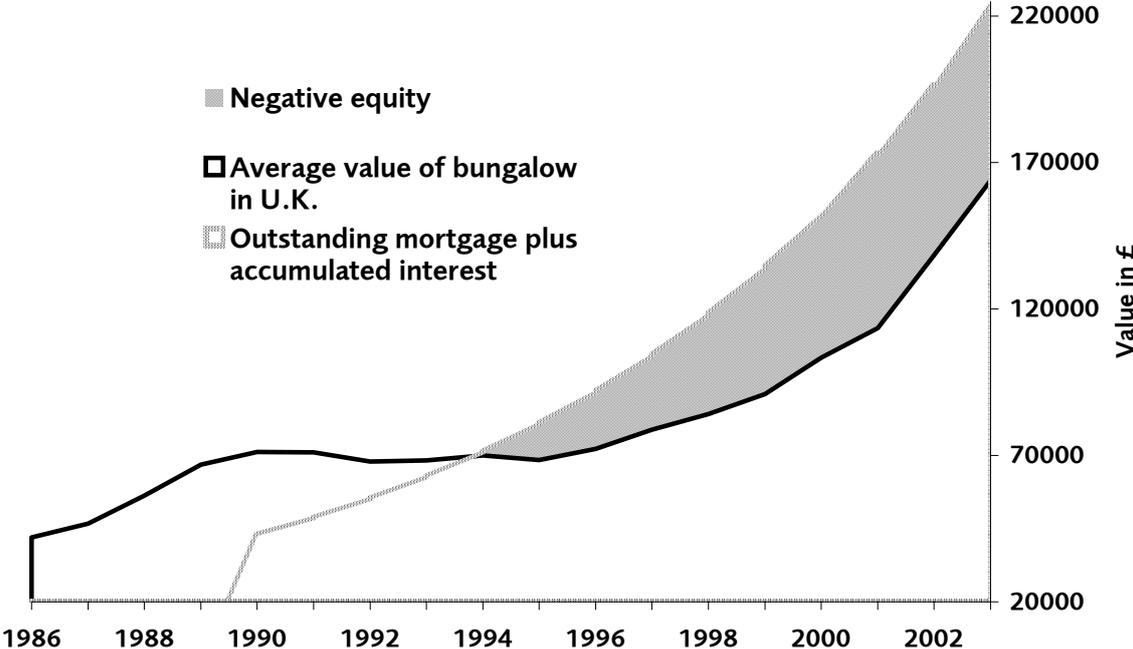
Source: Own calculations<sup>17</sup>, Data from Office of the Deputy Prime Minister, 2004

Figure 9 shows the same bungalow, but from 1990 onwards with an equity-release mortgage written with a similar loan-to-value ratio at outset as in Figure 8. Here the longevity risk is very much more substantial, simply due to timing: the negative-equity gap that has opened up is very large after a mere ten years, and may well get worse the longer the "insured lives" live.

Of course, it is moot whether this is truly longevity risk, or whether it is first and foremost property-price risk. Either way, it is a risk which broadly tends to increase with increasing longevity. This is mollified somewhat by the reality of the pricing basis, which includes a margin between the cost of funding and the interest rate charged on the mortgage. The increased costs due to longevity would be partially offset by the extra margin earned on this difference.

<sup>17</sup> The choice of 13.5% interest is hypothetical, since non-interest-paying lifetime mortgages did not exist in 1986. The Bank of England base rate varied between 11.375% and 13.875% during that year, although the then-applying long-term interest-rate expectations were below 13.5%. However, lifetime mortgages are currently written at an interest rate around 3% higher than the base rate, so the 13.5% figure is not unreasonable for this demonstration.

Figure 9. Hypothetical equity-release mortgage written in 1990



Source: Own calculations<sup>18</sup>, Data from Office of Deputy Prime Minister, 2004

**9.5 Conclusion**

Even if you regard no-negative-equity guarantees as being primarily a property-price risk, the financial liabilities tend to rise with increasing longevity.

<sup>18</sup> The interest rate has been kept at 13.5% for comparability (the Bank of England base rate never fell below 13.875% in 1990). The initial advance has been updated to keep the loan-to-value (LTV) ratio comparable, i.e. between 45% and 50% of the house value. The LTV is strongly dependent on the age of the borrower, and the specimen figure here would only apply to a fairly elderly couple.

## 10 Other contracts with longevity risk

There is a wide variety of other types of contract with longevity risk, albeit not always the main risk. Some examples of such contracts are discussed below.

### 10.1 Structured settlements

One example of a newly emerging contract with longevity risk is the market for structured settlements. A structured settlement is a payment in respect of a general insurance liability related to human life. Most commonly, structured settlements arise due to serious injury, medical negligence or occupational injury. Until this year, a structured settlement usually took the form of a lump sum payable in respect of the injured party's lost earnings and/or the cost of care if seriously injured.

Commencing in 2005, judges are now encouraged to consider using an annuity for life as a form of structured settlement. The U.K. may thus develop along the lines of the United States, where there is a large and competitive market for structured settlements. While the overall size of the new market is appealing to life insurers (potentially hundreds of million of pounds of new business premiums), it is also a market requiring specialist underwriting skills. One oft-unappreciated problem with the large premium volumes is that this stems from low numbers of cases with a very much larger-than-average case size. Seven-figure settlements are relatively common, and portfolio experience will be far more volatile as a result (see comments on amounts-driven volatility in section 11.5).

Structured settlements are particularly prone to the "loser takes all" risk identified by Ainslie (2000), where offices only win business in competitive bidding when they get their underwriting wrong.

### 10.2 Long-Term Care

The phrase "long-term care" refers to the care and shelter given to the very elderly who are no longer capable of looking after themselves. Historically, the bulk of long-term care in the United Kingdom has been provided as a tax-funded public service. The first private insurance policies for long-term care costs were introduced in 1991, although the market has always remained small.

There are two kinds of LTC insurance policy, neither of which has substantial longevity risk. The first kind is a pre-funded plan, where the primary risk is inflation in care-home costs, not longevity. The second is an "immediate needs" annuity, where the main risk lies in estimating the remaining life expectancy. With a typical life expectancy of around twelve months after entry into long-term care<sup>19</sup>, longevity improvements are clearly not a meaningful risk for this product.

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<sup>19</sup> With a life expectancy this short, one wonders why it is called "long-term" care...

## 11 Uncertainty

Actuarial business practices sometimes neglect basic uncertainty. Simple statistical uncertainty is enough to wipe out (or double) profit margins on annuities, for example. Uncertainty must be an explicit part of the management process for longevity risk. This includes pricing, profits-reporting and statutory valuation. Companies with small portfolios suffer much more from uncertainty than larger ones, although even the largest is never immune.

### 11.1 Uncertainty over projections of future mortality

In 2002 the CMIB made the first step in bringing the actuarial profession towards everyday recognition of uncertainty. For the first time, the CMIB did not publish a single projection of future mortality rates, but a selection of three: the so-called short-, medium- and long-cohort projections. This is part of a deliberate move away from the false certainty of a single projection, and a step towards explicit recognition of the uncertainty surrounding the path of future improvements. Table 6 shows the impact of this particular range of uncertainty on annuity costs.

**Table 6. Increase in annuity costs over CMIR 17 improvement projection**

| Interest rate | CMIB cohort projection basis: |                    |                      |
|---------------|-------------------------------|--------------------|----------------------|
|               | (i) low-intensity             | (ii) mid-intensity | (iii) high-intensity |
| 0.0%          | 6.5%                          | 8.6%               | 12.1%                |
| 2.5%          | 5.1%                          | 6.5%               | 8.8%                 |
| 5.0%          | 4.0%                          | 5.0%               | 6.3%                 |

Source: Own calculations using PMA92 and CMIB cohort projection bases, starting from 1992. Figures are based on immediate level annuities payable to a single-life male aged 65.

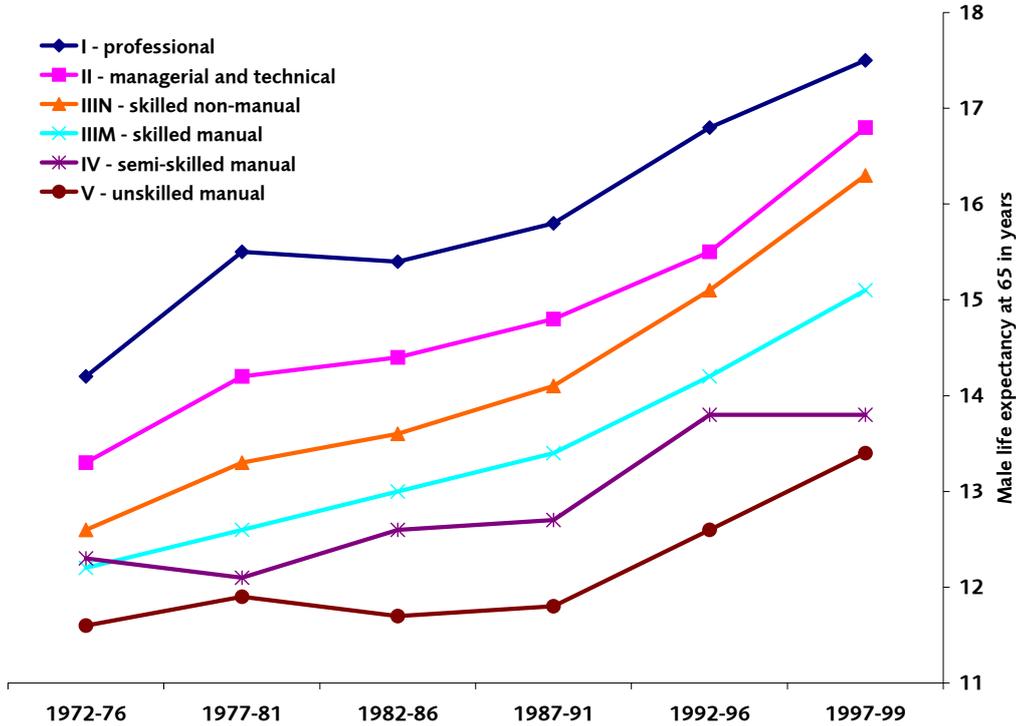
Most of the larger U.K. insurers currently reserve on an improvements basis somewhere between the mid- and high-intensity cohort projections. Two variants are in current use: the first is to take a blend of the mid- and high-intensity projection, and the second is to apply a "floor value" to the mid-intensity projection, which would otherwise tail off to a long-term improvement rate of zero.

Projecting future mortality trends is full of pitfalls for the unwary: CMIB (2004) contains a very thorough and technical consideration of the issues surrounding such projections.

### 11.2 Uncertainty over future projections by sub-group

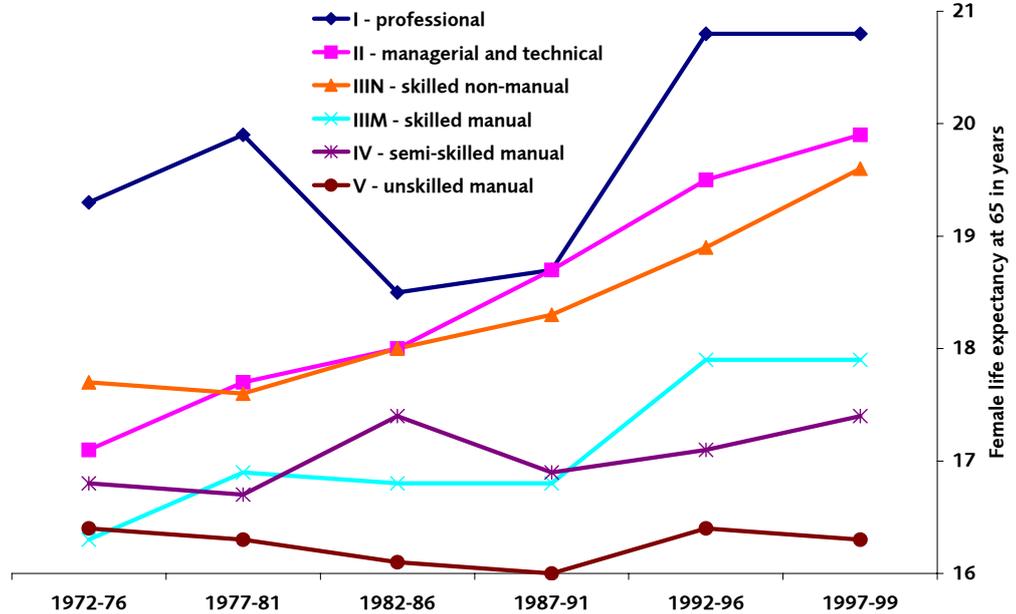
Differentials in life expectancy by socio-economic group are long established in the United Kingdom, as illustrated in Figure 10 and Figure 11. Patterns for males are particularly well-defined: although the differentials appear to have widened at the extremes (from 2½ years in the early seventies to 4½ years in the late nineties), the life expectancy for all socio-economic groups has improved substantially over the thirty-year period. Differentials in life expectancy appear to have been both pronounced and consistent throughout time. Great care is required in using these ONS figures, however, as they are known to be subject to a number of very important caveats in drawing more specific conclusions.

Figure 10. Male life expectancy from age 65 by socio-economic group



Source: ONS Longitudinal Survey.

Figure 11. Female life expectancy from age 65 by socio-economic group

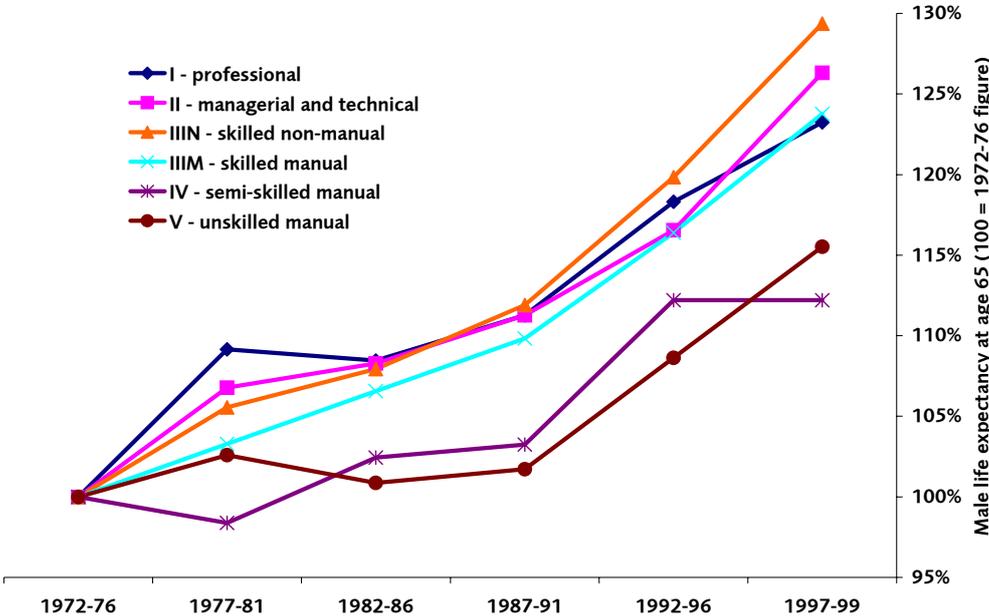


Source: ONS Longitudinal Survey.

Figure 12 and Figure 13 show the same data, but re-based to show the relative improvement. In the case of males in Figure 12, there would appear to be two groups when it comes to longevity improvements, with socio-economic groups IV and V experiencing lower improvements than the rest. Interestingly, III N (skilled, non-manual workers) has experienced

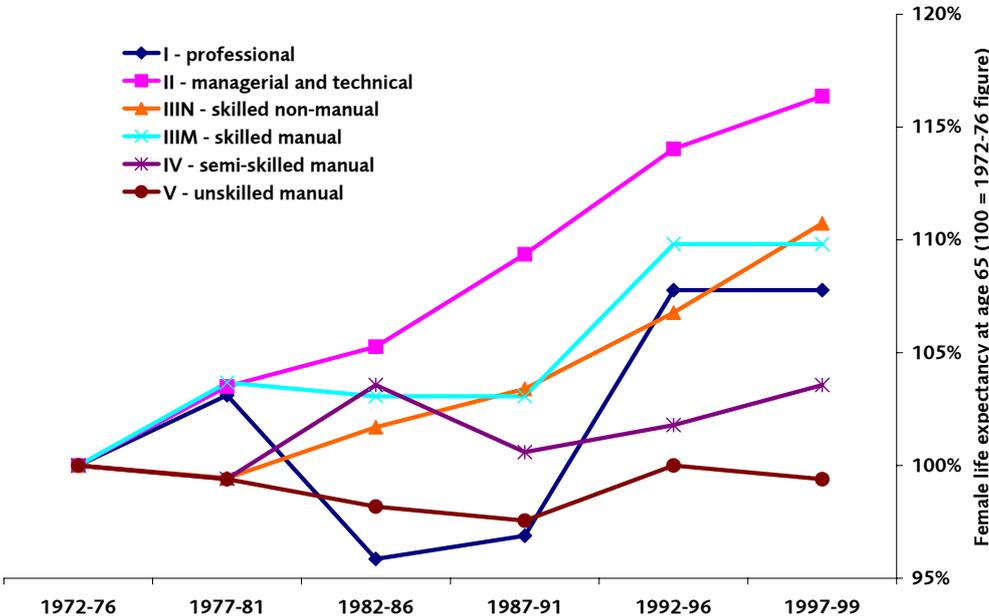
the fastest relative improvement since 1986-91, while for females the fastest rate of change has been for class II.

**Figure 12. Relative improvement in male life expectancy by socio-economic group**



Source: Own calculations using data from ONS Longitudinal Survey.

**Figure 13. Relative improvement in female life expectancy by socio-economic group**



Source: Own calculations using data from ONS Longitudinal Survey.

Such socio-economic mortality differentials are perhaps most important for defined-benefit pension schemes. Since such schemes often group people in the same industry and occupation, they can have a more concentrated socio-economic profile. The schemes undergoing the fastest mortality transition might be those with a large proportion of males in

IIIN: not only has this group experienced the fastest relative longevity improvement since 1987-91, but it has narrowed the gap with groups I and II.

**11.3 Uncertainty over recent mortality rates**

Each actuary must carry out regular experience investigations, including mortality. While the actual mortality experience might be known for the portfolio in question, the underlying mortality rates are not. In simple statistical terms, the mortality experience of a given portfolio can only ever be used to provide an *estimate* of the underlying mortality. Every mortality investigation therefore provides an estimate, with confidence intervals showing where the underlying mortality rates are likely to actually lie, as in Table 7.

**Table 7. Width of 95% confidence intervals for mortality of annuities business**

| Mortality measure | Interval width for: |             |
|-------------------|---------------------|-------------|
|                   | (a) males           | (b) females |
| Annuities         | ±2.1%               | ±3.5%       |
| Lives             | ±2.6%               | ±4.5%       |
| Amounts           | ±7.0%               | ±11.3%      |
| Liabilities       | ±8.3%               | ±11.1%      |

Source: Prudential plc. 95% confidence intervals are for a subset of the overall in-force, with experience expressed relative to PMA92c2003 and PFA92c2003 (all ages - central experience estimates not shown). Confidence intervals are parametric and approximate, but have been verified using non-parametric methods.

There are four points worth noting about Table 7:

- (i) Confidence intervals are narrower for males largely because they account for four-fifths of the overall experience. Confidence intervals shrink with larger counts.
- (ii) Confidence intervals for lives are wider because many people have multiple annuities. As an example, one annuitant in the above in-force had no fewer than fourteen separate annuities.
- (iii) Confidence intervals are much wider for amounts due to variability in pension size. The wide range of amounts introduces a very large additional degree of uncertainty over the experience as a whole.
- (iv) Confidence intervals are wider still for liabilities. Not only do pension sizes vary, but there is also extra variability arising from the options for escalation rates and spouse's pensions.

The above points have three critical consequences:

- (a) Even the largest in-force cannot eliminate the most basic statistical uncertainty: the above figures cover over 300,000 individual annuitants, yet substantial uncertainty remains. The data in Table 7 are for a subset of a larger overall experience, but even this subset easily exceeds the in-force of smaller companies. Smaller portfolios suffer much wider confidence intervals, possibly so wide as to render the mortality investigation useless.
- (b) Pricing and reserving cannot be done purely with central estimates of recent experience data: measures of uncertainty must also be included in setting bases, or else included in pricing margins.
- (c) Variability in annuity or pension size causes a very large step increase in the overall uncertainty. While all pensions must be priced according to their expected risk, larger pensions must also be priced in relation to the additional uncertainty they cause in the portfolio overall.

## 11.4 Financial impact of uncertainty - large portfolios

Table 7 shows the uncertainty surrounding the underlying mortality of a large portfolio of annuities. Mortality measured by amounts shows significant extra variability compared to mortality by lives, and it might be felt that this was purely an effect of heterogeneity due to socio-economic mortality differentials. If this heterogeneity were allowed for, say by identifying homogeneous sub-groups with respect to rating factors like lifestyle, region and duration, would this variability be reduced or even eliminated?

If we take a male in the top lifestyle group (lowest mortality), living in the lower-mortality southern part of the UK and receiving a relatively large pension, the uncertainty over even this narrowly defined sub-group still results in a difference in annuity factor of 2.7%<sup>20</sup>. This is a material source of risk when set aside a typical annuity profit margin of perhaps 4%. Thus, even the application of a highly developed model cannot fully eliminate the uncertainty over current mortality rates.

## 11.5 Financial impact of uncertainty - small portfolios

The 2004 Finance Act contained a surprise addition, namely that pension schemes with fewer than fifty members cannot self-insure pensions in payment and must secure them as annuities with an insurance company. This appears controversial to some, but in reality this is a thoroughly reasonable regulation when one considers the large variations involved with small numbers. Table 8 shows the extra funding required to be 99% confident<sup>21</sup> of meeting all benefits for a variety of scheme sizes.

**Table 8. Extra funding required for 99% confidence of meeting identical benefits**

| Number of lives<br>in pension scheme | Interest rate: |           |
|--------------------------------------|----------------|-----------|
|                                      | (i) 2.5%       | (ii) 5.0% |
| 5                                    | 30.4%          | 23.1%     |
| 50                                   | 10.3%          | 8.4%      |
| 500                                  | 3.4%           | 2.8%      |

Source: Own calculations using 10,000 simulations of stochastic mortality process according to PMA92. Groups of identical male lives aged 60 with identical pensions payable yearly in advance.

Table 8 makes a number of important assumptions, not least of which is that all pensions are of equal size. In practice, this is most emphatically not the case: pension schemes have widely differing pension sizes, not least because different salaries lead to different final-salary pensions. Table 9 shows the extra funding required for three different schemes, each with fifty lives and a total annual benefit of 50 p.a., but where there are widely differing pension sizes.

In each case, the scheme has both the same number of lives and the same expected value. The differences in the required extra funding are therefore purely driven by the variation in pension size within the scheme. The greater the variety in pension size, the greater the funding level required to be reasonably sure of paying all the benefits<sup>22</sup>.

<sup>20</sup> Difference between annuity factor calculated using upper and lower 95% confidence intervals for mortality rates from age 65 onwards. Source: Prudential generalised linear model, outlined in more detail in section 12.

<sup>21</sup> If you think that 99% certainty is too strong, think how you would feel if there were a 1% chance that your salary would suddenly stop without warning at some point in the future.

<sup>22</sup> An alternative approach would be to calculate the risk of being unable to pay all benefits from a given funding level. In this case, the conclusion would be the same: the smaller the scheme, the greater the risk of not being able to pay all benefits; also, the greater the variability in pension size, the greater the risk of not being able to pay all benefits.

**Table 9. Extra funding required for 99% confidence of meeting varied benefits**

| Scheme benefit<br>structure                   | Totals:   |              | Interest rate: |           |
|---|-----------|--------------|----------------|-----------|
|   | (a) lives | (b) benefits | (i) 2.5%       | (ii) 5.0% |
| 50 lives receiving 1 p.a.                     | 50        | 50 p.a.      | 10.3%          | 8.4%      |
| 41 x 1 p.a., with 1 x 5 p.a. and 8 x ½ p.a.   | 50        | 50 p.a.      | 11.9%          | 9.5%      |
| 31 x 1 p.a., with 1 x 10 p.a. and 18 x ½ p.a. | 50        | 50 p.a.      | 15.2%          | 11.6%     |

Source: Own calculations using 10,000 simulations of stochastic mortality process according to PMA92. Groups of identical male lives aged 60 with non-identical pensions payable yearly in advance.

Even based on just this simple stochastic model of mortality, the regulatory requirement based on fifty lives is anything but contentious. Certainly, when one considers the further additional variation caused by uncertain mortality trends, volatility in investment experience and employer solvency risk, one can hardly argue against reducing the level below fifty lives. In fact, depending on scheme circumstances, one could easily argue in favour of increasing this level.

### 11.6 Conclusion

Pricing for longevity risk is competitive – annuity rates are simple to understand and easy to compare. This keeps insurers from over-charging. However, it is an open question as to whether every insurer fully appreciates the uncertainty surrounding the longevity risk being taken on. The uncertainty over long-term future projections is relatively well understood, yet few people appreciate the uncertainty stemming from simple everyday variation. Some of the worst-affected portfolios are small pension schemes.

## 12 Mortality differentials

The debate about which mortality improvement projection to use has obscured a more important basis element: initial mortality rates and initial differentials.

### 12.1 Mortality in the general population

Ever since actuarial work first began, it was known that there were strong mortality differentials by age and gender. Actuaries have also long been familiar with the differences between the insured and general population. The previous section introduced the idea of life expectancy varying by socio-economic group (see Figure 10 and Figure 11), but there are also regional mortality differentials (see Table 10 and Table 11). But are these differentials in the general population also reflected in the insured population? And how can one disentangle regional mortality patterns from regional differentials in wealth and socio-economic group?

**Table 10. Mortality differentials by U.K. country**

| <b>U.K. country</b> | <b>Standardised Mortality Ratio</b> |
|---------------------|-------------------------------------|
| Scotland            | 114                                 |
| Northern Ireland    | 104                                 |
| Wales               | 102                                 |
| England             | 98                                  |
| United Kingdom      | 100                                 |

Source: Own calculations for ages 60-95 using GAD interim life tables 2000-02.

**Table 11. Mortality differentials by English region<sup>23</sup>**

| <b>English region</b> | <b>Standardised Mortality Ratio</b> |
|-----------------------|-------------------------------------|
| North-East            | 112                                 |
| North-West            | 109                                 |
| Wales                 | 104                                 |
| West Midlands         | 103                                 |
| East Midlands         | 102                                 |
| Yorkshire & Humber    | 102                                 |
| London                | 97                                  |
| East                  | 95                                  |
| South-West            | 93                                  |
| South-East            | 93                                  |
| England & Wales       | 100                                 |

Source: ONS death registrations for 2003.

<sup>23</sup> The two tables of figures, regional and sub-regional, are not directly comparable as they use different base populations, apply to different time periods and use different methodologies (as exemplified by the anomalous 102 and 104 figures given for Wales). The core point remains: there are substantial regional and sub-regional mortality differentials in the United Kingdom.

## 12.2 Mortality differentials in the insured population

The first step in measuring and understanding mortality differentials in the insured population is to fit a model to some experience data. For the purposes of this section, we fitted a generalised linear model<sup>24</sup> to the mortality experience in the calendar year 2002 of the portfolio of annuitants alive as at 31/12/2001. There were nearly 11,000 deaths out of 375,000 annuitants<sup>25</sup>. Table 12 shows the relative significance of six major rating factors for annuitant mortality.

**Table 12. Relative strength of mortality rating factors using gender as baseline**

| Factor    | Relative strength |
|-----------|-------------------|
| Age       | 2095              |
| Gender    | 100               |
| Lifestyle | 51                |
| Duration  | 25                |
| Amount    | 8                 |
| Region    | 8                 |

Source: Own calculations using generalised linear model, calibrated using mortality experience of 2002. Figure shown is drop in scaled deviance for each factor (including one half of the associated two-way interactions), expressed relative to the figure for gender.

Age and gender are long-established (and self-explanatory!) rating factors. "Lifestyle" is similar to socio-economic group<sup>26</sup>. "Duration" refers to the time since retirement: a sixty-five-year-old retiring today has lighter mortality than someone who retired five years ago (all other things being equal). "Amount" refers to the observation that people with larger pensions tend to have lighter mortality, even after allowing for the obvious link with socio-economic group. Finally, "Region" refers to geographical differences throughout the U.K., with a North-South divide remaining even after allowing for all the other factors.

The model shows the overwhelming dominance of age in determining mortality patterns. It also shows gender as being more important than the four other rating factors put together. This is particularly interesting when set against the poorly substantiated claim made in the recent draft directive from the European Commission (2003), namely that gender is a less significant rating factor than lifestyle.

While Table 12 is instructive, it is incomplete in two crucial ways:

- (i) The table measures variation in the overall portfolio experience, not the strength of the individual rating factors in absolute. For example, the impact of gender differentials is understated due to the fact that only around 20% of the annuitants in this particular portfolio are female<sup>27</sup>. If the split were 50:50, the importance of gender as a rating factor would rise still more, although such a split might be unlikely to happen in practice.

<sup>24</sup> The model fitted is logistic binomial regression on  $q_x$ , i.e. a simplified version of the Perks Law of mortality.

<sup>25</sup> This is a subset of the entire portfolio. In fact, there are three-quarters of a million annuities in payment overall.

<sup>26</sup> Socio-economic group is determined by occupation in population statistics - see page 31. "Lifestyle", in contrast, is determined indirectly by observing mortality differentials related to a wide variety of other indicators.

<sup>27</sup> This insurer portfolio is by no means atypical in having a rough 80:20 of male:female annuitants and pensioners. An occupational pension scheme might have a very different split, depending on the industry.

- (ii) The model measures variation in mortality patterns without regard to the time value of money. For example, in a pure mortality model, differentials at age 90 are given the same weight as differentials at age 65. When used in a financial calculation, however, the time value of money ascribes more weight to differentials at younger ages.

In order to address these two issues, we need to take a closer look at the financial impact implied by these mortality differentials.

### **12.3 Financial differentials – level pensions**

Table 13 on page 39 shows the large changes in price which occur when switching levels for each particular factor. The base case is a female in the top lifestyle group, duration zero (i.e. immediately retired), with a high income and living in the "Southern" region. The annuity factor in question is for an immediate level single-life annuity from age 65, valued at an interest rate of 5% per annum compound. Each step change in rating factor, say from female to male, increases the expected mortality and thus the annuity rate.

When you contrast the figures with the profit margin on an annuity (perhaps 4-5%), the importance of correctly rating the initial mortality differentials becomes starkly clear.

### **12.4 Financial differentials - comparison with gender**

The analysis in Table 13 appears to put gender, lifestyle and duration on a broadly equal footing. In fact, the significance of lifestyle and duration are exaggerated somewhat in this simplified presentation, since they are both multi-level factors, while gender is a simple binary factor. A fairer comparison would be to step-change each level within a factor, as in Table 14 on page 39. Here we can see the true situation, namely that gender is the most powerful factor for explaining longevity differences after age.

In practical annuity pricing, gender remains the dominant rating factor after age, with no other rating factor coming close in significance.

### **12.5 Financial differentials – escalating pensions**

It is often said that escalating pensions contain greater longevity risk. It is instructive to repeat the exercise in Table 13, but using an interest rate of 2.5% as a rough proxy for an escalating annuity. This is done in Table 15 on page 39, which neatly demonstrates two closely related points:

- (i) mortality differentials are of even greater importance for escalating annuities, and
- (ii) the lower the interest rate, the greater the importance of mortality assumptions.

### **12.6 Conclusion**

Correct estimation of initial mortality differentials is critical in pricing and reserving for annuities and pensions. This is particularly true of escalating pensions, such as to be found in defined-benefit pension schemes, where exposure to longevity risk is larger than with fixed or level pensions.

**Table 13. Financial impact of mortality rating factors - level pensions**

| Factor                | Step change | Annuity factor | Change |
|-----------------------|-------------|----------------|--------|
| Base case             |             | 13.39          |        |
| Gender                | Female→male | 12.14          | -9.3%  |
| Lifestyle             | Top→bottom  | 10.94          | -9.9%  |
| Duration              | Short→long  | 9.88           | -9.7%  |
| Income (pension size) | High→low    | 9.36           | -5.2%  |
| Region                | South→North | 8.90           | -4.9%  |
| Overall               |             |                | -33.6% |

Source: Own calculations using generalised linear model, parameterised using 2002's mortality experience. Annuities payable annually in advance, valued using 5% interest.

**Table 14. Financial impact of mortality rating factors (intra-factor steps)**

| Factor                | Step change  | Annuity Factor | Change:      |            |
|-----------------------|--------------|----------------|--------------|------------|
|                       |              |                | Single level | All levels |
| Base case             |              | 13.39          |              |            |
| Gender                | Female→male  | 12.14          | -9.3%        | -9.3%      |
| Lifestyle             | Top→second   | 11.77          | -3.1%        |            |
|                       | Second→third | 11.36          | -3.4%        |            |
|                       | Third→bottom | 10.94          | -3.6%        | -9.9%      |
| Duration              | Short→second | 10.50          | -3.9%        |            |
|                       | Second→third | 10.27          | -2.1%        |            |
|                       | Third→fourth | 10.05          | -2.1%        |            |
|                       | Fourth→long  | 9.88           | -1.5%        | -9.7%      |
| Income (pension size) | High→low     | 9.36           | -5.2%        | -5.2%      |
| Region                | South→North  | 8.90           | -4.9%        | -4.9%      |
| Overall               |              |                | -33.6%       | -33.6%     |

Source: Own calculations using generalised linear model, parameterised using 2002's mortality experience. Annuities payable annually in advance, valued using 5% interest.

**Table 15. Financial impact of mortality rating factors - escalating pensions**

| Factor                | Step change | Annuity factor | Change |
|-----------------------|-------------|----------------|--------|
| Base case             |             | 16.97          |        |
| Gender                | Female→male | 15.02          | -11.5% |
| Lifestyle             | Top→bottom  | 13.31          | 11.4%  |
| Duration              | Short→long  | 11.88          | -10.8% |
| Income (pension size) | High→low    | 11.18          | -5.9%  |
| Region                | South→North | 10.52          | -5.9%  |
| Overall               |             |                | -38.0% |

Source: Own calculations using generalised linear model, parameterised using 2002's mortality experience. Annuities payable annually in advance, valued using 2.5% interest.

## 13 Asset backing

Actuaries are charged with recommending suitable assets to back liabilities. This is particularly important for longevity-related liabilities, where the current yield curve has an extra sting in the tail for the incautious.

### 13.1 Introduction

It may seem odd to include discussion of assets in a paper devoted to the financial impact of longevity. However, the financial management of annuity reserves and defined-benefit pension schemes is founded on key actuarial assumptions linking assets and longevity, whether these assumptions are explicitly recognised or not.

### 13.2 (Non-)Correlation is critical

Whether explicit or not, most actuarial models for the management of longevity risk assume that longevity and asset returns are uncorrelated (zero correlation). A welcome correlation would be if investment returns increased when longevity increased: the extra returns on the assets would ease the losses suffered by increased longevity. A most unwelcome correlation would be if investment returns decreased when longevity increased: the longevity losses on the liabilities side would be made still more painful by accompanying losses on the asset side.

### 13.3 Expectations are enough

In fact, market expectations and perceptions are enough to create a correlation, particularly for the shares and bonds of listed companies with very large defined-benefit schemes (see section 6). Consider the following hypothetical scenario:

- (a) A rating-agency analyst feels that longevity is improving faster than allowed for by certain pension schemes.
- (b) Some schemes are so large relative to the sponsoring employer that a credit downgrade is felt necessary.
- (c) The prices of both those companies' shares and their debts fall in response.

If the rating-agency analyst is reacting to similar information as the actuaries, then there is a non-zero correlation between investment returns and increasing longevity. If the actuary is managing an annuity portfolio which includes such corporate debt, (s)he experiences a "double whammy" of increased reserves and reduced asset values. If the actuary is advising a defined-benefit pension scheme which includes such an equity, (s)he also experiences a "double whammy" of increased scheme liabilities and reduced scheme assets.

The above scenario is not imaginary: in May 2003 Standard and Poors downgraded the credit rating of Rolls Royce from A- to BBB, citing concerns over the company's then-£1.4bn pension scheme deficit. In this particular instance, Rolls Royce's shares only fell around 1% as a result, partly because this act was in line with market expectations, but the risk to certain companies remains. Rolls Royce was one of twelve companies placed on credit watch by Standard and Poors in February 2003, citing concerns about pension-scheme deficits.

### 13.4 Obvious and non-obvious linkages

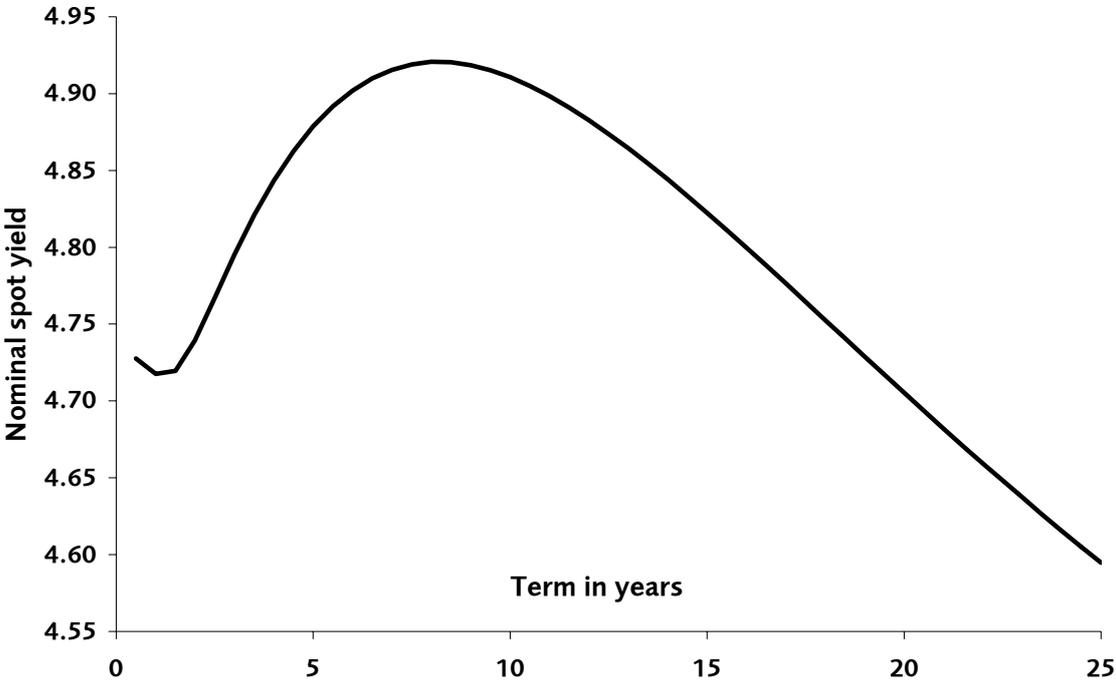
Perhaps the most public and direct linkage between corporate finances and pension schemes in 2004 was from Marks and Spencer, a company in the FTSE index of the 100 largest U.K.-listed stocks. M&S announced in March 2004 that it was injecting £400m into the pension scheme to narrow the funding deficit from 18% to 6%. This £400m was raised as an explicit public bond issue (Source: Marks & Spencer press release, 1<sup>st</sup> March 2004).

There are, however, more complicated and subtle linkages between asset values and longevity. For example, at the time of writing Norwich Union has recently completed the fourth highly successful securitisation of equity-release mortgages. While these are no doubt suitable for numerous investment purposes, they might be felt to be unsuitable for, say, backing annuity liabilities, as this would be a doubling up of longevity risk on both the asset and liability sides.

**13.5 Reinvestment risk**

If an actuary has under-estimated future longevity, current investment conditions have a "double whammy" in store: not only are more funds required than expected, but the current yield curve means that the newly lengthened duration forces calculation of the liabilities at a lower interest rate (see Figure 14).

**Figure 14. Nominal spot gilt yield curve for 2<sup>nd</sup> September 2004**



Source: Bank of England.

An illustration of the effect is given by calculating the implied constant valuation rate of interest, as derived from the equivalent annuity calculation described in Appendix I: Equivalent annuities. Using PA(90), the constant valuation rate of interest is 4.82%, whereas using PMA92c2020 is drops 2 bps to 4.80%. Thus, if a portfolio were hedged using out-of-date mortality rates, the current yield curve delivers a second blow to the valuation of liabilities.

As if this weren't enough, there is a further sting in the tail: the longer the term, the less scope there is to use the extra yield available on corporate bonds, thus reducing the yield still further.

**13.6 Conclusion**

Actuaries need to examine their portfolio exposure to longevity risk, not just in the liabilities but also in the assets. Investment policies may well need updating to minimise unwanted correlation. Great care is required in treating investment and mortality assumptions holistically.

## 14 Hedging of longevity risk

Hedging of longevity risk is desirable, but there has historically been limited appetite from reinsurers and no credible capital-market solution. If the restructuring of defined-benefit schemes steps up, some kind of Government-sponsored benchmark may be needed, around which capital-market solutions could develop.

### 14.1 Introduction

Insurers hold capital in respect of uncertainty and the guarantees that they provide. In the case of longevity, uncertain cashflows arise due to statistical variation in experienced mortality and also trend variations. Additional uncertainty arises from the difficulty of finding appropriately matching assets for long-duration longevity risks, in particular for the deferred annuities which come from defined-benefit pension schemes. By reducing the level of uncertainty within the cashflows, the insurer should be able to reduce the capital requirements underpinning the guarantees in an annuity contract.

Current EU solvency regulations oblige insurers to hold a minimum solvency margin of 4% of the mathematical reserves for an annuity portfolio. In some cases the FSA specifies a higher solvency margin of 5% or 6%, and individual offices may hold additional explicit reserves in respect of uncertainty over future mortality improvements. Reduced capital requirements may follow either by reducing the explicit uncertainty within the portfolio, such as through reinsurance, or else by hedging. The hedging may come from some kind of longevity bond, or else writing insurance products with opposing mortality dynamics. A seemingly perfect hedge for annuitant longevity would be a pure whole-of-life contract written to the same lives: the extra profits on one would cancel the extra losses on the other.

### 14.2 Reinsurance

Reinsurers have historically not been keen on longevity risk, but a few treaty deals have been done in recent years. As a rule, reinsurers wouldn't take longevity risk unless it was:

1. For an existing client,
2. Was capped at a relatively small level, and
3. Was part of an overall package of risks besides longevity.

However, reinsurers' appetite for longevity risk transactions may be increasing, partly as a result of improved knowledge of the risk, and partly because there is a growing demand from insurers for some kind of transfer of this risk.

### 14.3 Hedging through balancing products

As an example of the possibility of hedging the longevity risks consider two products, one a conventional level annuity and one a whole-life assurance to the value of the cost of the conventional annuity. The variation in cost of the two products by rate of future improvement is shown in Table 16.

What is clear is that though the annuity cost increases with increasing longevity improvements the cost of the life assurance reduces, despite the increasing sum assured. This implies that, by carrying a suitable combination of longevity and mortality risk, the insurer's exposure to future mortality improvements may be limited and thus capital held in respect of this risk may be reduced. One way of achieving this might be for a holder of longevity risk to enter into a contract with a term assurance portfolio in order to mitigate each other's exposure to these

opposing risks. The exact structure of the contract would determine whether the risk being hedged was the statistical variation, the implicit risk in a one-year contract, or the longevity improvement risk, which would dominate in a long-term contract. In practice, however, the market for protection business for the over-65s is strictly limited and is likely to remain so.

**Table 16. Change in reserve upon inclusion of mortality improvement rate**

| <b>Mortality improvement rate</b> | <b>Conventional annuity</b> | <b>Whole-of-life assurance</b> |
|-----------------------------------|-----------------------------|--------------------------------|
| 1%                                | +3.2%                       | -1.0%                          |
| 2%                                | +6.6%                       | -2.6%                          |

Source: Own calculations using PMA92, payments in arrears, 5% interest per annum. Males aged 65.

**14.4 Hedging through capital-market solutions (longevity bonds)**

An alternative approach to mitigating longevity risk would be through longevity-indexed instruments. This may enable access to capital markets for longevity risk, where, at the moment, appetite for this risk is concentrated solely in a small number of insurers.

In principle such instruments are relatively easy to construct - for example, Swiss Re issued a five-year mortality bond in 2003. With this instrument, the principal was at risk if mortality levels as measured by WHO mortality statistics in any single calendar year exceeded 130% of the base mortality. Given a suitable index it would be possible to construct longevity-related bonds with either the coupon or principal (or both) at risk of default if longevity improvements in excess of expectations occurred. In practice, longevity improvements are difficult to measure due to the volatile mortality rate at older ages. There would also remain significant basis risk, i.e. a portfolio of annuitants may exhibit a very different pattern of longevity improvements compared to the underlying index, and so the bond would be a partial hedge at best.

Blake and Burrows (2001) suggested that an asset class of survivor bonds (or longevity-indexed bonds) should be created, possibly by governments, in order to enable exposure to mortality improvements to be effectively managed. The authors note that such an instrument would be essentially identical in structure to the 1759 Geneva Tontine. With the existence of an appropriate reference asset class, the construction of standard financial instruments such as options and futures contracts should enable a more active secondary market in longevity risk than currently exists. This absence of an active market almost certainly reflects the long-term nature of the risk, as well as the historical underestimation of mortality improvements. As longevity becomes a more significant part of overall demographic risk, the demand for products to manage this risk will increase. Whether there will be a concomitant increase in supply of such products remains to be seen, however.

**14.5 Conclusion**

With reinsurers historically less than keen to take longevity risk, and in the absence of a viable capital-market solution, longevity risk will remain concentrated in defined-benefit pension schemes and life assurance companies for the foreseeable future.

## 15 Mortality tables

There is a wide variety of mortality tables in common use, some of which are alarmingly old and outdated for modern actuarial purposes.

### 15.1 Introduction

The Continuous Mortality Investigation Bureau (CMIB) is the primary source of mortality tables used in U.K. actuarial work. Statutory reserving requirements for life insurers in the U.K. specify that reserves must be calculated with reference to a standard, published table. In theory, anyone could publish a mortality table, and an office could use any table the actuary deemed fit. In practice, both life and pensions actuaries largely restrict themselves to using CMIB tables, and sometimes some quite old ones at that.

It is standard practice for an insurer to disclose at the very least the base table and mortality projection used in statutory reserves. In common with the tendency for pension schemes to spend more time on investment matters than mortality, there is no such equivalent requirement for pensions actuaries. In this the pensions actuaries are not acting alone: the standard for deficit calculation, FRS 17, goes into great detail for most assumptions with the conspicuous exception of longevity.

### 15.2 Financial impact of table choice

The regulations surrounding the operation of defined-benefit pension schemes are full of prescriptive mortality bases, often archaic ones. The most prevalent mortality table in the regulations was PA(90) rated down two years, and many regulations are still framed around this, including the Minimum Funding Requirement (MFR).

In fact, a pension scheme currently finds itself having to providing funding statements on at least four bases, listed as follows in typical order of ascending cost:

1. The Minimum Funding Requirement (MFR).
2. The scheme-specific funding basis.
3. FRS 17 and IAS 19.
4. The discontinuance basis (buy-out cost).

The gap between the scheme-specific funding basis and buy-out cost is covered in 6.4.9 (Winding up and buying out), and Table 17 overleaf provides an approximate illustration of the gap between the MFR and the discontinuance basis. Note the interpretation of these figures; if a scheme full of males is 100% fully funded according to PA(90 -2 years (the Minimum Funding Requirement), a further 29% of funds is required if actual mortality experience is in accordance with PMA92. Under such a scenario, the MFR-funded scheme would in reality be under-funded by around 22%<sup>28</sup> ( $=1 - 1/1.29$ ).

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<sup>28</sup> The MFR mortality basis above only applies to small schemes, i.e. those with liabilities under £100m on the gilt-yield-based valuation. For larger schemes, professional guidance requires the scheme actuary to use a mortality basis in line with actual scheme experience. This is itself an issue, bearing in mind the comments about uncertainty in section 11.5.

**Table 17. Excess cost of pension annuities relative to PA(90) -2 years**

| <b>Mortality basis</b>     | <b>Males</b> | <b>Females</b> |
|----------------------------|--------------|----------------|
| PA(90)M/F -2 years         | 0%           | 0%             |
| PM/FA80c2010               | 6%           | 3%             |
| PA(90)M/F -4 years         | 7%           | 6%             |
| PA(90)M/F -6 years         | 14%          | 13%            |
| PM/FA92                    | 18%          | 9%             |
| PM/FA92 with medium cohort | 29%          | 17%            |

Source: Willets et al (2004b), Tables 6.11a and 6.11b. Figures are for level annuities payable monthly in arrears from age 65, calculated at an interest rate of 2.5% per annum to approximate the net effect of interest at 5% per annum and 2.5% per annum pension escalation.

### **15.3 The '00 Series**

At the time of writing a new series of mortality tables is planned towards the end of 2004. The tables will be created from the graduation of the all-office experience in the 1999-2002 quadrennium.

### **15.4 The '92 Series**

This series of mortality tables is the most up-to-date one available, and the one in common use by life offices in the United Kingdom. The '92 series of tables was created from the graduation of the all-office experience in the 1991-94 quadrennium, and there are three potential tables for use with valuing longevity liabilities:

1. The  $l_{xx}92$  tables for immediate life annuitants, e.g. purchased-life annuities. These tables are appropriate where there is a clear element of choice on behalf of the policyholder to buy an annuity.
2. The  $R_{xx}92$  tables for pension annuities purchased by holders of retirement-annuity contracts and personal pensions. These tables are appropriate for pensions business only, i.e. where there is little element of choice on behalf of the policyholder to buy an annuity due to compulsion in the tax regime.
3. The  $P_{xx}92$  tables for life-office pensioners. Again, these tables are appropriate only for pensions business where there is little element of choice.

Table specifications take a shorthand form, e.g. PMA92 reads as "male pensioner mortality by amounts from the 92 series" and IFL92 reads as "female immediate annuitant mortality by lives from the 92 series". Table specifications are often given in conjunction with mortality improvement factors from CMIR17, e.g. PMA92c2004 reads as "male pensioner experience from 1992 by amounts, with mortality rates reduced according to the CMIR17 projection to 2004".

There are two noteworthy aspects to these tables, especially the pensioner tables (i.e.  $P_{xx}92$ ):

1. The mortality rates are mainly of generations before the so-called "cohort effect" took hold (or was deemed to have taken hold). As such, these rates were felt to have become rapidly out-of-date, and this led to the release of the interim cohort projection bases for use alongside the '92 Series (CMIB, 2002).
2. In contrast to this, the experienced mortality rates for ages 50-60 are several times heavier than implied by the pensioner tables. Only the rates above age 60 appear to be reliable for practical use with non-impaired lives.

The 92 series may be getting on a bit, and it does pre-date the recent work on the cohort effect. Nevertheless, these tables are still appropriate for life-office use if used in conjunction with CMIB updates (2002) and life offices' annual experience investigation.

### **15.5 The '80 Series**

The '80 series was created from the graduation of the all-office experience of the 1979-82 quadrennium. The data underlying this table is now over two decades old. However, Figure 15 shows that the common practice of using PMA80c2010 is perhaps still justified for industrial-type schemes with heavier-than-average mortality.

### **15.6 PA(90)**

PA(90) sounds like a relatively modern table, but the number in the name is quite misleading. In fact, this table was already thirty years old when its use for modern actuarial work was questioned by Willets (1999). The following quotation from the CMIB in 1995 demonstrates just how old this table is:

*"The PA(90) was a projected table [...] (and) is virtually parallel to the Peg 1967-70 table upon which it is based. By (1979-82) the basic mortality curve of the PA(90) table was the wrong shape."*

Source: CMIR 14 (1995), section 8.

If PA(90) was the wrong shape in 1979-82, then it is even more so two decades later. Despite this, regulations are still framed in terms of PA(90) and other such antiquated mortality tables. As recently as April 2003, for example, the FSA specified the use of PA(90) minus 4 years for the purposes of pension redress calculations (Source: FSA press release, April 2003). Prior to this, the specified table was PA(90) minus 1 year. On either basis, Table 17 shows the gap between calculations made on PA(90) and more modern mortality tables.

The Inland Revenue also specifies PA(90) -2 years for numerous purposes. For example, this table is used in regulations specifying the maximum funding level of Small Self-Administered Schemes (SSAS). This seems harsh if the actual mortality experience is more in line with PMA92 (see Table 17 and Figure 15).

### **15.7 a(55)**

This table was created from the mortality experience of annuitants over the three-year period 1946 to 1948. It was designed to be applicable for annuities being taken out in 1955. It is based on data now over half a century old and is unlikely to find common application in modern business use. Despite this, the Inland Revenue still makes reference to this antiquated table in its most recent rules:

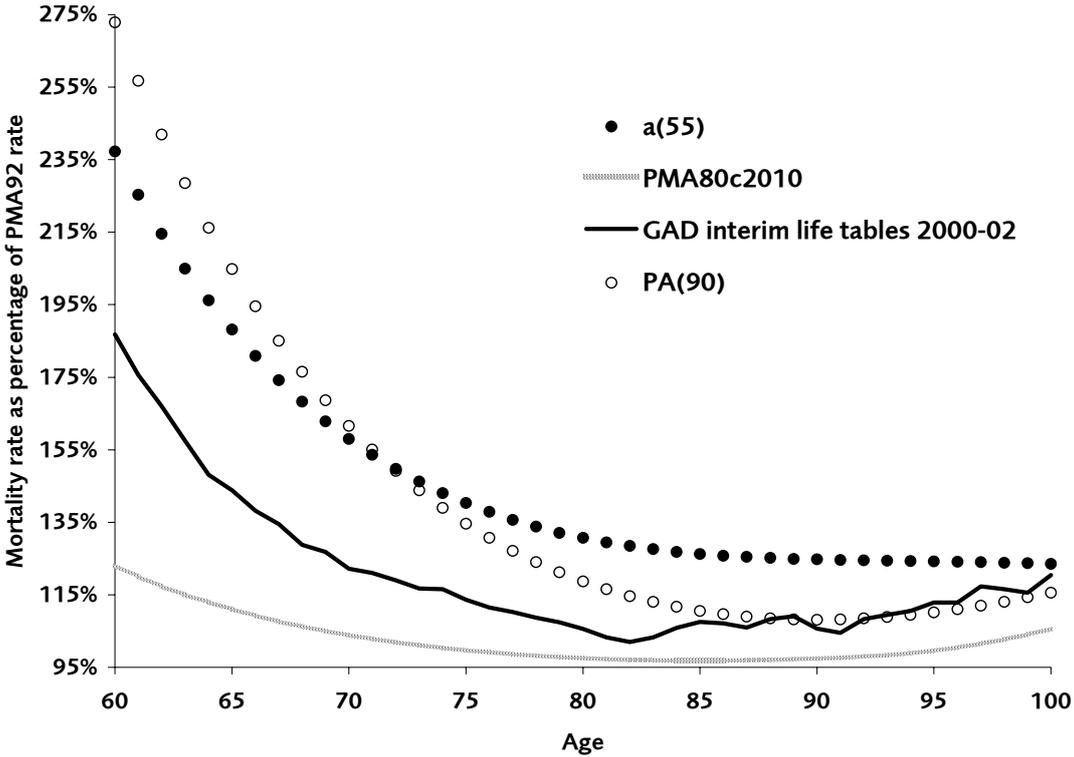
*"For commutation purposes the following tables are acceptable for both sexes:- PA90, PA90-1, a(55) and a(55)-1 "*

Source: Inland Revenue, Pension Schemes Manual, PSI8.2.5

This is quite harsh, even for the Inland Revenue: using such an out-of-date mortality tables such as a(55) and PA(90) forces many retirees to sacrifice more of their pension to obtain a given lump sum from pension commutation than would be the case with a more modern table.

The extent of the heavy mortality implied by a(55) and PA(90) is shown in Figure 15, which shows various mortality tables relative to PMA92.

Figure 15. Some standard mortality tables as percentage of PMA92



Source: Own calculations, CMIB and GAD data, male rates only.

It is a long-standing actuarial observation that the mortality of the insured population is lighter than the general population. What the above shows is that a(55) has heavier mortality at all ages between 60 and 100 than even recent population mortality<sup>29</sup>. Similar comments apply to PA(90): up to age 72 it is even heavier still than a(55), falling eventually to a level similar to population mortality from age 88 onwards.

**15.8 Conclusion**

There is a very wide variety of mortality tables in current use, although some are clearly too archaic for everyday modern actuarial purposes.

<sup>29</sup> Mortality of male population of United Kingdom (England, Wales, Scotland and Northern Ireland) during the triennium 2000 to 2002.

## 16 Mortality projections

Mortality projections must take into account the inherent uncertainty of projecting into the future. In the U.K. they must also take into account cohort effects, i.e. mortality patterns by year of birth.

### 16.1 Introduction

A large part of longevity risk is the simple uncertainty about future mortality rates - the longer one looks into the future, the less certain one can be. All forms of projection are fraught with difficulties, and CMIB (2004) is an excellent - if highly technical - discussion of the issues.

### 16.2 Regulations and professional guidance

Future mortality improvements have been the subject of much debate within the U.K. actuarial profession of late, and both regulations and professional guidance now make explicit mention of them:

*"The rates of mortality or morbidity should contain prudent margins for adverse deviation [...]. In setting those rates, a firm should take account of anticipated or possible future trends in mortality."*

Source: FSA, Integrated Prudential Sourcebook for Insurers, PS04/16, paragraph 7.3.61

*"Assumptions about future mortality and morbidity must take into account recent relevant experience and trends of the industry and, if credible, of the insurer."*

Source: GN1: The Prudential Supervision in the UK of Long-Term Insurance Business, Version 3.0, paragraph 5.4

*"Benefit payments must be projected using a prudent allowance for mortality improvement."*

Source: GN9 : Funding Defined Benefits - Actuarial Reports, Version 7.0, paragraph 2.6.4.1

### 16.3 The '00 projection basis

At the time of writing, this new basis is not expected to appear at the same time as the '00 Series of mortality tables. The CMIB recommends continuing to use the existing cohort projection bases in conjunction with the '00 Series of tables until such time as the new projections are made available. An interim working paper on the projection methodology was published earlier this year (CMIB, 2004).

### 16.4 Cohort projection bases

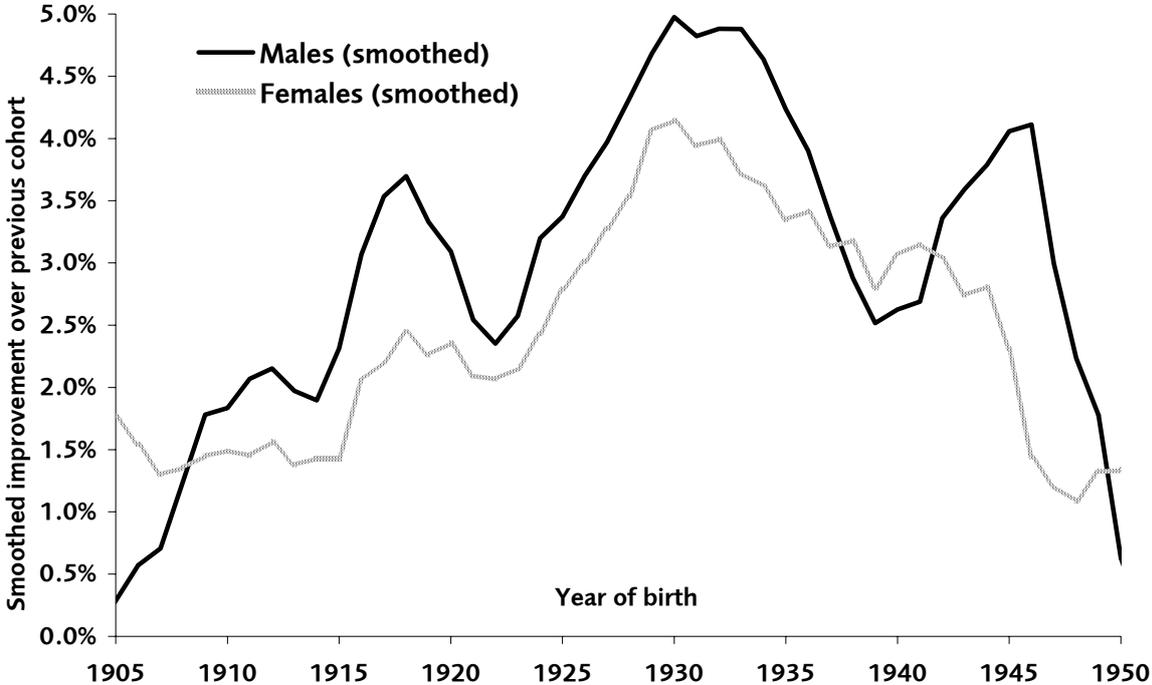
In common with a number of other developed countries, mortality improvements in the United Kingdom exhibit strong patterns by year of birth or "cohort" (Willets, 1999 and Willets et al, 2004b). The causes of this are open to interpretation, but an important part of this is down to changes in smoking behaviours (Willets, 2004a).

In recognition of the cohort effect, the CMIB issued an interim update to the mortality improvement projections in CMIR 17 (CMIB, 2002). In this update, improvement patterns are now based on year of birth. These mortality projections were derived from extrapolation of patterns in the assured lives data, not the annuitant or pensioner experience as the data was too scanty to permit analysis. The projections were to be applied to male lives only, again for reasons of data sparseness amongst females. These bases are shown graphically in Appendix II: CMIB cohort projections.

It is current practice amongst many life offices to use the CMIB mid-intensity cohort projection for reserving for males, but some still use the older CMIR 17 projection for females. The reason for this is unclear, but it has been claimed (albeit without backing evidence) that the cohort effect is solely due to smoking. Since the "smoking epidemic" was much greater for males, it is perhaps thought that cohort effects apply only to them and not females. This reasoning is flawed on two counts:

1. Willets (2004a) showed separate cohort effects by cause of death. Some of these cohort effects were undoubtedly due to smoking: the patterns for lung cancer are unmistakable. However, Willets also found cohort effects in other cause-specific mortality improvements which could not be obviously linked to smoking.
2. Population mortality improvements show very strong similarities in all-cause mortality improvements for both genders, as shown in Figure 16. This is despite very different patterns in lifetime smoking patterns.

**Figure 16. Mortality improvements in U.K. population by year of birth**



Source: Own calculations using GAD data for 2000-02 triennium compared to 1999-2001 triennium. Ten-year average annual mortality improvements are calculated, smoothed using a simple five-year moving average, then plotted against the central year of birth for the 2000-02 triennium.

Clearly, there are strong cohort mortality improvement patterns for both males and females in the United Kingdom. An actuary has to recognise the importance of these in pricing and reserving. If the actuary accepts cohort improvements are necessary for males, it is hard to argue against also applying them to females, albeit at a slightly reduced level of intensity. End-2003 FSA Returns suggest that, while most offices apply cohort projections to males, few apply them yet to females.

## 16.5 CMIR 17

Until CMIB (2002), CMIR 17 (1999) was the U.K. actuarial standard projection of future mortality improvements for annuitants and pensioners. It is still in widespread use, not least because the cohort projection bases are simply CMIR 17 with a localised adjustment by year of birth.

## 16.6 Regulations "behind the curve"

Surprisingly, even some of the most current regulations do not recognise well-established developments in knowledge. For example, the following is an excerpt from the new regulations covering illustrations for lifetime mortgages, part of the new mortgage code which comes into force on 31<sup>st</sup> October 2004 (i.e. five days after the presentation of this paper!):

*"PMA92(C=2010) and PFA92(C=2010) for males and females respectively, derivable from the Continuous Mortality Investigation Report 17, published by the Institute of Actuaries and the Faculty of Actuaries in 1999"*

Source: "Mortgages: Conduct of Business", Financial Services Authority

The CMIB has updated the material in Report 17 on several occasions to take account of the so-called "cohort effect", and the actuarial profession has heard much about this phenomenon over the past five years: Willets (1999), CMIB (2002), Willets (2004a) and Willets et al (2004b). Despite this, these brand-new regulations enforce illustrations on a mortality projection basis which has long been overtaken by new knowledge.

## 16.7 Conclusion

Mortality improvements have been a hot topic of late in the actuarial profession. Projection bases are developing rapidly and the profession has a public duty to remind legislators and regulators of the suitability (or otherwise!) of enshrining particular tables or projections in the rules.

## 17 Public policy

The focus of this paper has very much been on the private sector. However, some comment is necessary on the financial aspects of longevity risk in the public sector.

Many people work within the public sector, which typically offers generous final-salary benefits, albeit largely unfunded. Many other people receive state pension benefits. In both cases, the ultimate underwriter of these colossal longevity liabilities is the U.K. Government.

Unfunded public-sector pension liabilities are claimed to be £580bn, an increase of £200bn on government figures of £380bn dating from 31st March 2002 (Source: Watson-Wyatt press release, August 10<sup>th</sup> 2004). Most of this increase is said to be due to a reduction in the assumed discount rate, but 5% of the uplift is claimed to be due to increasing longevity. These sums have to be funded out of taxation receipts, and the upward pressure of increasing longevity has led to proposed changes to public-sector scheme retirement ages, including:

- an increase to the minimum age at which early pension benefits are payable - from 50 to 55 - but with the exception of ill-health retirement, and
- an increase in the retirement age from 60 to 65.

This would match the increase in age for eligibility for state retirement benefits, which will equalise at age 65 for men and women from 2020 onward. The U.S. government is one step ahead of the U.K., however, having already implemented in 1983 a stepped increase in normal retirement age by year of birth. For those born after 1959, the normal retirement age in the U.S. is 67, rather than 65 for those born before 1938.

By contrast, when the means-tested pension was first introduced in the U.K. in 1909, the qualification age was set at 70 for males. This was reduced to 65 years in 1928, but was also conditional on an adequate contribution record. This was not a major financial issue, not least because mortality rates did not change much during the first half of the Twentieth Century. Mortality rates have declined dramatically in the latter half, so perhaps we can expect the restoration of state retirement at age 70?

Public policy towards early retirement in private pensions is also hardening, for example with the proposal by the Department of Work and Pensions (2002) that "that the earliest age at which a pension may be taken should increase from age 50 to 55 by 2010".

The U.K. government's exposure to longevity is not, of course, simply limited to unfunded public-sector defined-benefit liabilities. The wider fiscal issues of increasing longevity are explored, for example, in the HM Treasury publication "Fiscal sustainability with an ageing population". But that is a SIAS paper for someone else!

## **18 Summary of paper and conclusion**

The greatest private-sector exposure to longevity risk is not to be found in the annuity portfolios of the quoted life assurance sector. It is the shareholders of many industrial and service companies which have the greatest exposure to longevity risk through their defined-benefit pension schemes. These risks are not only often larger in absolute terms, but also in relative terms, i.e. in relation to the market capitalisation or balance sheet.

The subject of uncertainty is particularly important, yet is often overlooked in some fields of actuarial work. Here, at least, the regulations are leading the actuarial profession down the correct route: the stochastic modelling of liabilities required by the FSA's Integrated Prudential Sourcebook and the 2004 Finance Act's obligation to buy-out pensions for small pension schemes to name but two.

Regulations are, however, substantially behind the curve in other areas. To pick an example of great importance to many thousands of pensioners, the Minimum Funding Requirement for pension schemes is set with reference to a completely archaic mortality table. The actuarial profession has a duty not just to follow the rules and regulations, but also to make sure that those rules and regulations are fit for purpose.

## Appendix I: Equivalent annuities

A technique used frequently throughout this paper and in actuarial work in general is the *equivalent-annuity calculation*. This is defined as:

$$a_x^1 = a_x^2$$

where (1) and (2) denote the two bases being equated. The annuities may be payable yearly, monthly or continuously, and may be single- or joint-life. The annuities may also be level or escalating - the choice depends on the nature of the portfolio. A particularly important choice is the average age to use: perhaps somewhere around 65 for working with new business pricing, 70 for in-force annuity portfolios, or even higher for a mature pension scheme. The average age should be amounts- or liabilities-weighted, rather than the simple average age of the lives in the portfolio.

Typically, the equivalent-annuity calculation solves for a single basis element which will equate the two annuity values. This basis element could be:

- an interest rate, as in section 13.5 where we seek the equivalent constant rate of interest for the given yield curve,
- an interest-rate margin, as in Table 2 where we seek the equivalent margin in respect of mortality differentials,
- an age adjustment, as in section 7.10 in Willets (1999), where an age adjustment of -11 years was required to make a basis using PA(90) yield the same answers as the more up-to-date '92 series tables with cohort mortality projections,
- a percentage of the base table, as is often used in equating an office's own mortality experience to that of a standard table.

Perhaps surprisingly, equivalent-annuity calculations prove to be quite robust. Some examples of equivalent-annuity calculations are tabulated overleaf (Table 18, Table 19 and Table 20). These figures are interesting in that they can be used to put uncertainty in an easy-to-understand context. For example, the 95% confidence intervals for female experience by amounts in Table 12 are of similar order to mis-stating the age by one year according to Table 18. However, this has a far less stable expression in terms of basis points: anything from -86bps to +92bps, depending on age. This is significant, since most life offices use a margin measured in basis points for pricing, usually of the order of these latter two figures. This means that simple uncertainty over current mortality rates can either wipe out (or double) a life office's profit margin if writing business at older ages, as is often the case in bulk buy-outs or portfolio transfers between offices.

An alternative to the equivalent annuity is to adjust either the base-table percentage or the age adjustment so that the ratio of actual and expected deaths is 100%. Although very commonly used, this approach is subject to some terrible distortions and the equivalent-annuity method is preferable in almost all cases.

**Table 18. Age ratings equated to table percentages and basis points**

|                | Age rating and start age |     |      |      |            |     |     |     |            |     |     |     |            |     |     |     | years   |
|----------------|--------------------------|-----|------|------|------------|-----|-----|-----|------------|-----|-----|-----|------------|-----|-----|-----|---------|
|                | -24 months               |     |      |      | -12 months |     |     |     | +12 months |     |     |     | +24 months |     |     |     |         |
|                | 60                       | 65  | 70   | 75   | 60         | 65  | 70  | 75  | 60         | 65  | 70  | 75  | 60         | 65  | 70  | 75  |         |
| <b>Males</b>   | 78                       | 77  | 78   | 80   | 88         | 88  | 88  | 89  | 114        | 114 | 113 | 112 | 130        | 131 | 128 | 124 | % PMA92 |
| <b>Females</b> | 79                       | 78  | 79   | 81   | 89         | 88  | 89  | 90  | 113        | 114 | 113 | 111 | 127        | 129 | 126 | 123 | % PFA92 |
| <b>Males</b>   | -44                      | -72 | -115 | -166 | -23        | -38 | -60 | -86 | 25         | 42  | 65  | 92  | 52         | 90  | 135 | 188 | bps     |
| <b>Females</b> | -34                      | -53 | -84  | -117 | -18        | -28 | -41 | -61 | 19         | 31  | 46  | 64  | 40         | 65  | 95  | 132 | bps     |

Source: Own calculations, CMIB data for base tables and mid-intensity cohort projection. Base case 100% of standard table (PMA92 or PFA92) and projection for an immediate level annual annuity to a single life, valued at 5% interest per annum.

**Table 19. Table percentages equated to age ratings and basis points**

|                | Table percentage (of PMA92 or PFA92) and start age |     |      |      |     |     |     |     |      |    |    |    |      |    |    |     | years         |
|----------------|--|-----|------|------|-----|-----|-----|-----|------|----|----|----|------|----|----|-----|---------------|
|                | 80%  |     |      |      | 90% |     |     |     | 110% |    |    |    | 120% |    |    |     |               |
|                | 60   | 65  | 70   | 75   | 60  | 65  | 70  | 75  | 60   | 65 | 70 | 75 | 60   | 65 | 70 | 75  |               |
| <b>Males</b>   | -22  | -21 | -22  | -24  | -10 | -10 | -10 | -10 | 9    | 9  | 9  | 10 | 16   | 16 | 17 | 20  | months-to-age |
| <b>Females</b> | -23  | -22 | -23  | -25  | -11 | -10 | -11 | -12 | 9    | 9  | 9  | 11 | 18   | 17 | 19 | 21  | months-to-age |
| <b>Males</b>   | -39  | -63 | -103 | -167 | -19 | -31 | -50 | -82 | 18   | 29 | 50 | 80 | 36   | 57 | 98 | 160 | bps           |
| <b>Females</b> | -32  | -48 | -79  | -121 | -16 | -24 | -38 | -59 | 15   | 23 | 37 | 58 | 30   | 45 | 73 | 115 | bps           |

Source: Own calculations, CMIB data for base tables and mid-intensity cohort projection. Base case 100% of standard table (PMA92 or PFA92) and projection for an immediate level annual annuity to a single life, valued at 5% interest per annum.

**Table 20. Basis-point offsets equated to age ratings and table percentages**

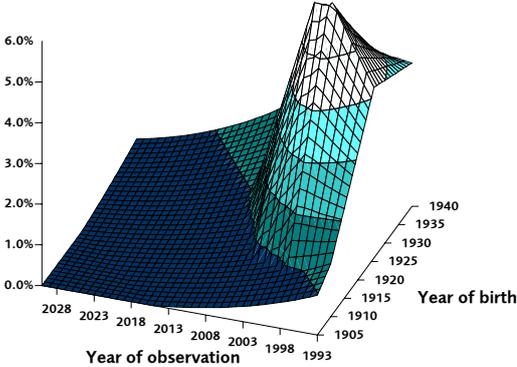
|                | Basis-point offset and start age |     |    |    |        |    |    |    |        |     |     |     |        |     |     |     | Years         |
|----------------|----------------------------------|-----|----|----|--------|----|----|----|--------|-----|-----|-----|--------|-----|-----|-----|---------------|
|                | -20bps                           |     |    |    | -10bps |    |    |    | +10bps |     |     |     | +20bps |     |     |     |               |
|                | 60                               | 65  | 70 | 75 | 60     | 65 | 70 | 75 | 60     | 65  | 70  | 75  | 60     | 65  | 70  | 75  |               |
| <b>Males</b>   | -10                              | -7  | -4 | -2 | -5     | -4 | -2 | -1 | 6      | 3   | 2   | 1   | 9      | 6   | 4   | 2   | months-to-age |
| <b>Females</b> | -14                              | -10 | -6 | -4 | -7     | -5 | -3 | -2 | 7      | 3   | 3   | 2   | 12     | 8   | 5   | 3   | months-to-age |
| <b>Males</b>   | 90                               | 93  | 96 | 98 | 95     | 96 | 98 | 99 | 105    | 103 | 102 | 101 | 111    | 107 | 104 | 102 | % PMA92       |
| <b>Females</b> | 87                               | 90  | 95 | 97 | 94     | 95 | 97 | 98 | 107    | 104 | 103 | 102 | 113    | 109 | 105 | 103 | % PFA92       |

Source: Own calculations, CMIB data for base tables and mid-intensity cohort projection. Base case 100% of standard table (PMA92 or PFA92) and projection for an immediate level annual annuity to a single life, valued at 5% interest per annum.

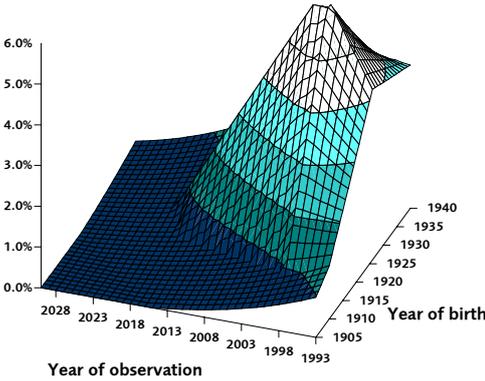
# Appendix II: CMIB cohort projections

Figure 17. Perspective views of CMIB cohort mortality improvements

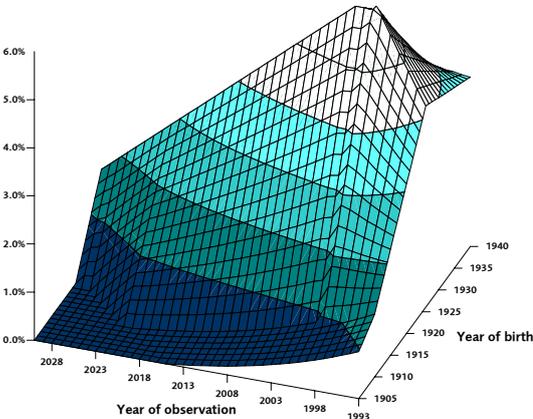
Low-intensity cohort projection (short cohort):



Mid-intensity cohort projection (medium cohort):



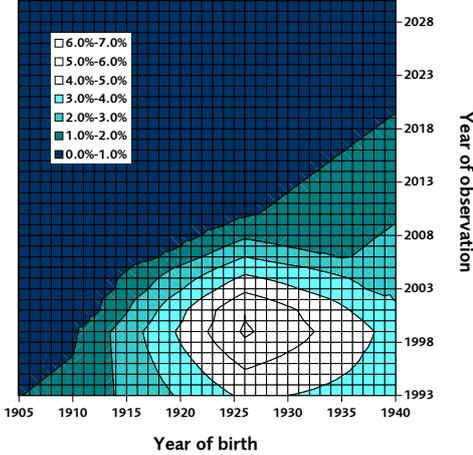
High-intensity cohort projection (long cohort):



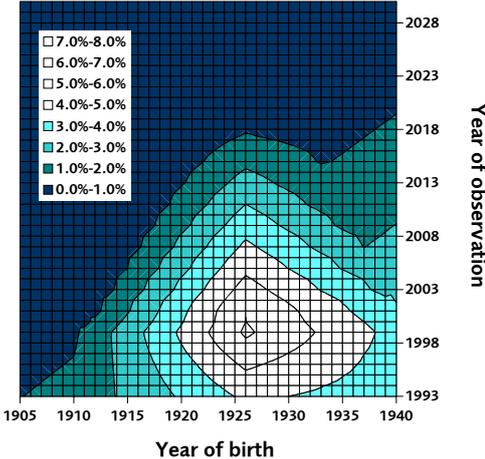
Source: Own calculations, data from CMIB (2002).

**Figure 18 Contour views of the CMIB cohort mortality improvements**

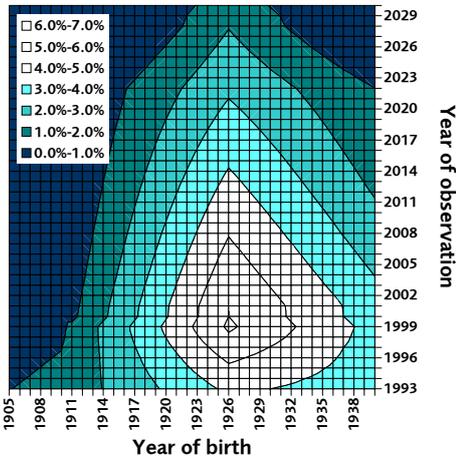
Low-intensity cohort projection (short cohort):



Mid-intensity cohort projection (medium cohort):



High-intensity cohort projection (long cohort):



Source: Own calculations, data from CMIB (2002).

## Appendix III: References

- AINSLIE, R. R. (2000) *Annuity and Insurance products for Impaired Lives*, SIAS.
- BENJAMIN, B AND POLLARD, J.H. (1980) *The Analysis of Mortality and Other Actuarial Statistics*, Heinemann, London.
- BLAKE, D. AND BURROWS, W. (2001) *Survivor Bonds: Helping to Hedge Mortality Risk*, Journal of Risk and Insurance.
- BOYLE, P. AND HARDY, M (2003) *Guaranteed Annuity Options*, ASTIN Bulletin. 33.2 125-152.
- CARDINALE, M. (2004) *The Long-Run Relationship between Pension Liabilities and Asset Prices: a Co-Integration Approach*, SIAS.
- CARNE, S. (2004) *Being Actuarial with the Truth*, SIAS.
- CMIB (1995) Report No. 14, Continuous Mortality Investigation Bureau.
- CMIB (1998) Report No. 16, Continuous Mortality Investigation Bureau.
- CMIB (1999) Report No. 17, Continuous Mortality Investigation Bureau.
- CMIB (2002) Working Paper No. 1, Continuous Mortality Investigation Bureau.
- CMIB (2004) Working Paper No. 3, Continuous Mortality Investigation Bureau.
- DEPARTMENT OF WORK AND PENSIONS (2002) *Simplicity, Security and Choice - Working and Saving for Retirement*, Green paper.
- EUROPEAN COMMISSION (2003) *Proposal for a Council Directive Implementing the Principle of Equal Treatment between Women and Men in the Access to and Supply of Goods and Services*.
- O'BRIEN, C. D. (2002) *Guaranteed Annuity Options: Five Issues for Resolution*, British Actuarial Journal 8, Vol III, 593-629.
- O'BRIEN, C. (2003) *The challenge of increased longevity for pension providers*, Nottingham University Business School. Paper presented to the 25<sup>th</sup> U.K. Insurance Economists' Conference.
- WADSWORTH, M., FINDLATER, A. AND BOARDMAN, T (2001) *Reinventing Annuities*, SIAS.
- WILKIE, A. D., WATERS, H. R. AND YANG, S. Y. (2003) *Reserving, Pricing and Hedging for Policies with Guaranteed Annuity Options*, British Actuarial Journal, Vol. 9, Part II, No. 41.
- WILLETS, R (1999) *Mortality in the next Millennium*, SIAS.
- WILLETS, R (2004a) *The Cohort Effect: Insights and Explanations*, British Actuarial Journal (to appear).
- WILLETS, R., GALLOP, A. P., LEANDRO, P. A., LU, J. L. C., MACDONALD, A. S., MILLER, K. A., RICHARDS, S. J., ROBJOHNS, N., RYAN, J. P. AND WATERS, H. R. (2004b) *Longevity in the 21<sup>st</sup> Century*, British Actuarial Journal (to appear).
- WISE, A., MCCARTHY, D., NEATE, J., PARDOE, M. AND HORWITZ, B. (2004) *Pensions and Economics: The Way Ahead*, SIAS.

## Appendix IV: Internet resources

[www.aca.org.uk](http://www.aca.org.uk)

Website of Association of Consulting Actuaries. Holds survey information on defined-benefit pension schemes.

[www.actuaries.org.uk](http://www.actuaries.org.uk)

Website of U.K. actuarial profession. Holds sessional papers on mortality topics and CMIB working papers.

[www.bankofengland.co.uk](http://www.bankofengland.co.uk)

Website of Bank of England. Holds extensive online databases of interest rates, including historical figures for both sterling and other major currencies.

[www.demogr.mpg.de](http://www.demogr.mpg.de)

Website of Max Planck Institute for Demographic Research. Holds online mortality databases, including the Kannisto-Thatcher database on the 'oldest old'.

[www.fsa.gov.uk](http://www.fsa.gov.uk)

Website of Financial Services Authority, the body charged with regulating the financial services industry in the United Kingdom.

[www.gad.gov.uk](http://www.gad.gov.uk)

Website of Government Actuary's Department. Holds interim life tables for U.K. population and constituent countries (England, Wales, Scotland and Northern Ireland), as well as data on occupational pension schemes.

[www.iasb.org](http://www.iasb.org)

Website of the International Accounting Standard Board, which holds information on the IAS 19 disclosure standard for pension scheme liabilities.

[www.inlandrevenue.gov.uk](http://www.inlandrevenue.gov.uk)

Website of Inland Revenue, the tax authority in the U.K. and source of regulations pertaining to pension schemes.

[www.longevity-science.org](http://www.longevity-science.org)

Website of Professors Leonid and Natalia Gavrilov, holding extensive material on longevity studies, mortality and ageing.

[www.mortality.org](http://www.mortality.org)

Website of the Human Mortality Database. Holds mortality rates and life tables for twenty international populations.

[www.ons.gov.uk](http://www.ons.gov.uk)

Website of Office of National Statistics. Holds extensive data on mortality rates and life expectancy, including socio-economic and regional differentials.

[www.sias.org.uk](http://www.sias.org.uk)

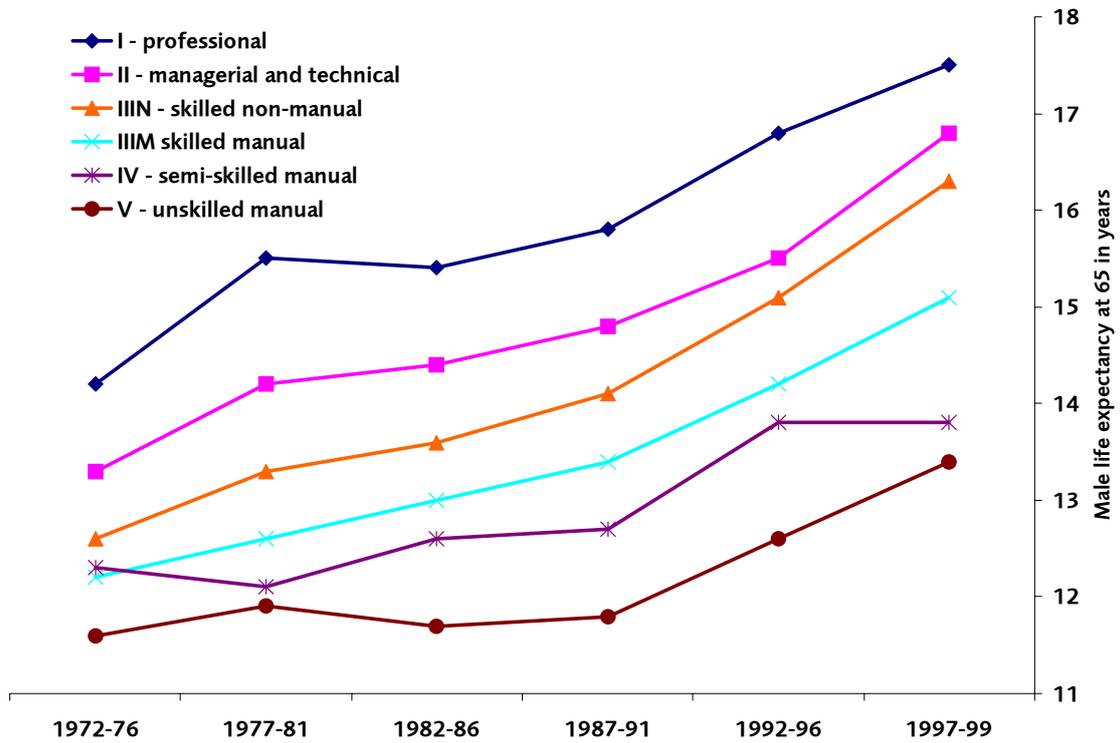
Website of Staple Inn Actuarial Society. Holds several papers on mortality studies, and also actuarial discussion of management of defined-benefit pension schemes.





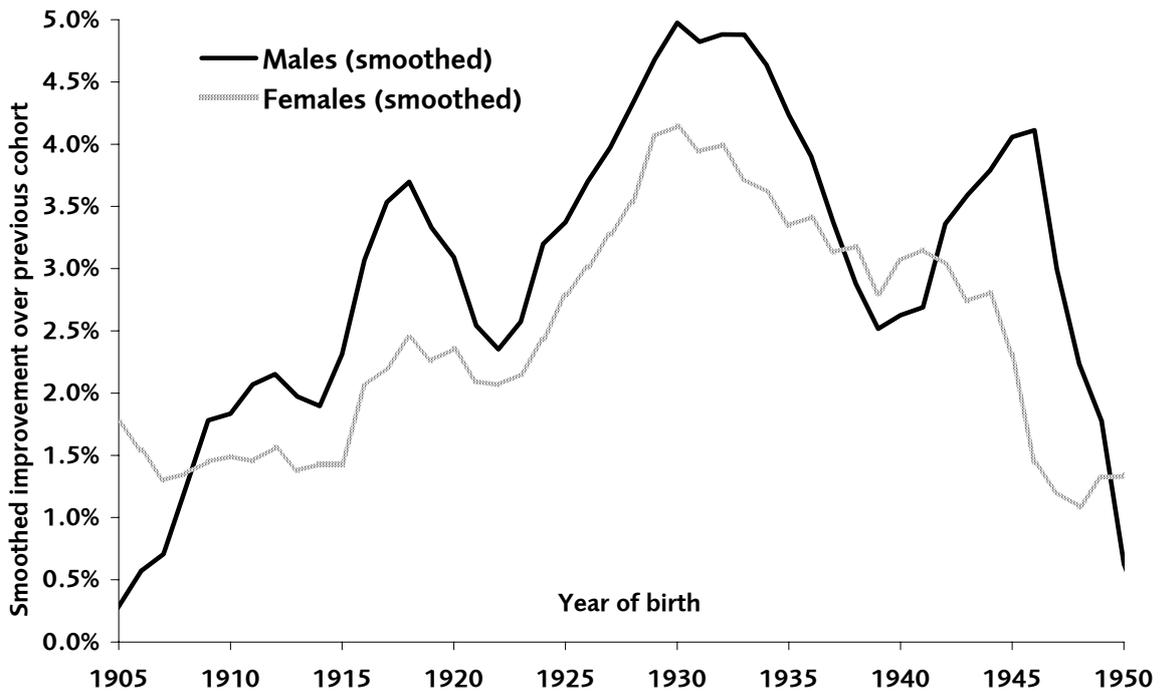


## Male life expectancy at age 65 by socio-economic group



Source: ONS Longitudinal Survey

## Mortality improvements by year of birth



Source: Own calculations, GAD data from 2000-02 interim life table.