The Impact of Occupation and Gender on Pensions from Defined Contribution Plans

By

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Abstract: We present simulation results for the likely pension outcomes (measured in terms of the distribution of the pension ratio of actual pension to some fraction of final salary) for different defined contribution pension plan members distinguished by occupation and gender. Whilst our results suggest that key differences between outcomes depend on the strategic asset allocation strategy chosen (and hence on the rate of return on assets in relation to the growth rate in earnings), we also find that DC plans benefit most those workers who have the highest career average salary relative to final salary or whose salary peaks earliest in their careers. Thus low-skilled workers and women do relatively well from DC plans: the largest pension difference between occupations is 34% (for men) and 38% (for women), while the largest pension difference between women and men in the same occupation is 45%. We conclude that key aspects of plan design (in particular contribution rates) should be occupation- and gender-specific.

Key words: pension plans, defined contribution, defined benefit, gender, occupation, career salary profile, peak salary age, strategic asset allocation, pension ratio

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1. INTRODUCTION

Increasing numbers of people are joining defined-contribution (DC) pension plans, either because these are the only pension arrangements offered by their company or because their company has closed down its defined-benefit pension plan and transferred employees to a new DC plan.[1] The plan members are typically offered a range of investment funds for their contributions. These vary from low risk to high risk and plan members are usually advised that high risk funds will generate distributions of future pension values that have higher means and variances than those generated by low risk funds. Plan members will then select an investment fund that reflects their attitude to risk.

However, little is known about the way in which occupation and gender influence the size of the pension. This is a significant shortcoming because different occupations have very different career salary profiles (CSPs).[2] For example, professional sportsmen have steeply rising CSPs that peak at a very early age, while managers have less steeply rising CSPs that peak much later in their careers. There are also major differences between men and women in terms of their CSP, even within similar occupational groups: women tend to have flatter CSPs that peak earlier than those of men. These considerations suggest that a 'one size fits all' approach to pension plan design is inappropriate, and that the 'best advice' to any given DC plan member will be both occupation- and gender-specific.

This paper examines the impact of occupation and gender on the likely retirement income available from DC pension plans. It builds on our earlier simulation studies of the accumulation and distribution phases of such plans using the PensionMetrics model (Blake, Cairns and Dowd, 2001, 2003). These studies investigated pension-fund outcomes using a variety of alternative assumptions for the distribution of investment returns, but only for the CSP of a 'typical' male worker.

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[1] By June 2003, 70% of company defined benefit pension schemes in the UK had closed to new members and 10% had closed to additional contributions from existing members (FT.com, 12 June, 2003).

[2] Also known as a lifetime earnings profiles or age-earnings profiles.

They therefore ignored possible heterogeneities across occupation and gender: this paper seeks to fill this gap by systematically exploring the impact of such differences on prospective pension outcomes.

The layout of this paper is as follows. Section 2 sets out the model used in the study. Section 3 examines the CSP, and shows how it can be modelled by an occupation-specific quadratic function in age. Sections 4 and 5 present results for male and female workers respectively, taking account of occupational differences. Section 6 concludes.

2. THE PENSIONMETRICS MODEL

We employ a modified version of the PensionMetrics model calibrated to UK data (Blake, Cairns and Dowd, 2001). This model uses stochastic simulation to determine the likely distribution of pension outcomes (measured in terms of the distribution of the pension ratio of actual pension to some proportion of final salary) for the plan member on his or her retirement date and then uses value-at-risk techniques to assess the desirability of these outcomes.

In order to identify the pure effect of the CSP on pension outcomes, we make the following assumptions. Both male and female workers join the pension plan at the age of 20 and retire at 60[3]. The pension at retirement is based on unisex annuity rates.[4]

[3] A retirement age of 60 matches the normal retirement age for women in the UK. We could, as an alternative, have chosen a retirement age of 65 for both men and women, which would correspond to the normal retirement age for men in the UK. Although some women do work between the ages of 60 and 65, earnings after normal retirement age can be very different from pre-retirement earnings in most occupations. We wished to avoid any distortion to the female outcomes that might be induced by including this age range in our analysis. We also wanted to compare men and women on as level a playing field as possible, hence we selected a common retirement age of 60.

[4] The unisex annuity rates are based on a discount rate of 5% and survival probabilities which are calculated as the arithmetic average of PMA92 and PFA92 survival probabilities from age 60; these are taken from mortality tables produced by the Faculty and Institute of Actuaries for males and females respectively and are based on the mortality experience of pension annuitants in the UK in the early 1990s. In practice, quoted male and female annuity rates for the same age differ, but the assumption was

To begin with, we also assume that each year the worker contributes 14% of his or her earned income[5] to a DC pension fund, and the contributions are invested according to one of four alternative strategic asset allocation (SAA) strategies discussed below. The annual returns on the assets in the pension fund are assumed to follow a multivariate normal stochastic process[6] that is parameterised according to the realised real returns and volatilities on key UK and international securities over the post-war period.[7] When the worker reaches the retirement age of 60, the accumulated fund is converted into a single life annuity at the going market rate, which provides a level retirement income until death.

To facilitate comparison with final-salary defined benefit (DB) pension plans, a DB pension of 2/3rds of final salary[8] is taken as the benchmark against which we measure the prospective outcomes delivered by the DC pension plan. To reflect this benchmark, our simulation results are expressed in terms of the pension ratio – the ratio of the DC pension to the pension that would be achieved in a conventional DB pension scheme with the same salary experience and duration of membership. A pension ratio equal to unity therefore implies that the DC pension plan has replicated exactly the same pension as the DB plan.

We model the accumulation phase of the pension fund under each of four alternative strategic asset allocation (SAA) strategies:[9]

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again chosen to preserve a level playing field. Over time, as male and female mortality rates move closer together and anti-discrimination legislation is introduced, the assumption becomes increasingly realistic.

[5] The reason for this particular fixed rate is explained below.

[6] This was the simplest of the seven asset-return models considered by Blake, Cairns and Dowd (2001). This study showed that the model for asset returns had considerably less impact on pension outcomes than the strategic asset allocation strategy selected.

[7] The same data period is used as in Blake, Cairns and Dowd (2001), namely 1947-1998. See Appendix A for details of the properties of this data set.

[8] This is the maximum available pension in the UK from a DB plan with 40 years' continuous service on the basis of an annual accrual rate of 1/60th of final salary for each year of service. In order to finance such a pension, annual contributions equal to 14% of salary would need to be invested in a pension fund. This explains why we have selected a 14% contribution rate for the DC plan. We assume for ease of comparability that all workers, both men and women, work continuously for 40 years.

[9] The first two can be classed as high risk, while the last two can be classed as low risk. Further details

- An ‘equities only’ strategy – all contributions into the plan are invested in 100% UK equities for the entire investment period.
- A ‘pension fund average’ (PFA) strategy – a static strategy with the same portfolio weights over the entire investment period as the average UK defined-benefit occupational pension plan in 1998: 51% UK equities, 5% UK T-bills, 15% UK bonds, 5% UK property, 20% international equities, and 4% international bonds, with the latter two proxied by US equities and bonds.
- A ‘T-bills only’ strategy – 100% of the fund in UK T-bills for the entire investment period.
- A ‘bills-bonds’ strategy – 50% in UK T-bills and 50% in UK bonds for the entire investment period. Blake, Cairns and Dowd (2001) found that this strategy had the lowest risk of all those considered. With the exception of 100% T-bills, the other strategies delivered higher average pension ratios but also wider spreads.

With this brief explanation of the PensionMetrics model, we can now move on to discuss the structure of career salary profiles.

3. CAREER SALARY PROFILES (CSPs) AND THEIR IMPACT ON PENSION OUTCOMES

The focus of this study is on the impact of gender and occupational differences on pension outcomes. We consider male and female workers classified both in very broad ways (i.e., ‘all occupations’, ‘manual’ and ‘non-manual’) and in terms of the major occupational groups reported in the *New Earnings Survey*, namely, managers and administrators (‘managerial’), professional occupations (‘professional’), clerical and secretarial occupations (‘clerical’), technical and associate professional occupations (‘technical’), craft and related occupations (‘craft’), personal and protective service occupations (‘personal’), sales occupations (‘sales’), plant and machine operatives (‘plant operatives’), and other occupations (‘other’). The CSP data are prepared by the Office of National Statistics (1998, Part F). The data measure average gross weekly

are provided in Blake, Cairns and Dowd (2001).

earnings in pounds sterling and are reported for the following age ranges (with the central age for each age range reported in parentheses): below 18 (17), 18-20 (19), 21-24 (23), 25-29 (27), 30-39 (35), 40-49 (45), 50-59 (55), and 60-65 (63). Each CSP is therefore estimated using 8 observations.

As Figures 1 and 2 show for men and women respectively, the CSPs typically have a hump-shaped pattern for all occupations, reflecting the fact that earnings (expressed in constant earnings terms) generally rise initially with age and then subsequently fall[10]. We highlight two features of the CSP which we later show to be important determinants of the pension outcome: the relative career average salary (RCAS) which is defined as the arithmetic average of the CSP over all ages relative to its final value of unity[11] and the peak salary age (PSA)[12].

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[10] We need to be cautious when interpreting CSP data. These data show the average weekly earnings for members of a particular occupation in different age ranges at a given point in time, relative to the final salary (Samwick and Skinner (2004) use a similar approach for an analysis of 401(k) pensions plans in the US). They do not show the CSP of a particular individual throughout his/her working life. While the latter data are what we ideally need, they are not available from official sources for a complete career (the New Earnings Survey Panel Dataset started in 1975 (Dickens (2000)). What the available data do show, for all occupations and both genders, is a hump-shaped pattern to real earnings over the working life with both the starting and final salary being lower than the salary in middle age (in constant earnings terms). The rise in real salary to middle age is explained by the impact of merit increases and promotions early in the career. There are three key explanations as to why final real salaries are generally lower than real salaries in middle age. The first two are associated with selection effects. We might expect a proportion of individuals working in physically demanding or stressful jobs to switch into less demanding and less well-paid jobs within the same or possibly a different occupation later in life. We might also expect some retirement between ages 50 and 60 and it is likely that early retirees are typically the better-paid members of a particular occupation group at that age, leaving less well-paid members in work until the official retirement age. Finally, there is a cohort effect arising from the fact that the profiles are constructed from the salary data of different groups of workers at different ages, and the younger workers might be better educated than the older workers and hence have higher salaries.

[11] RCAS is defined as follows:

Although individuals can start work at 16, we assume that they do not join a pension scheme until 20 and work until 60, so are members of the pension scheme for 40 years. Given a raw age *x*, we define a rescaled age, *y*, as:

(1) $$y = (x - 20)/(60 - 20) \qquad x = 20, 21, ..., 60$$

Thus, $y = 0$ for a 20-year old starting work and $y = 1$ for someone who is retiring.

Each CSP in Figure 1 and 2 is modelled as a quadratic function of y[13]:

(2) $$w(y) = 1 + k_1 w_1(y) + k_2 w_2(y)$$

where:

$$\begin{aligned} \mathrm{RCAS} &= \frac{1}{40} \sum_{x=20}^{59} \frac{w\left(\frac{x-20}{40}\right)}{w\left(\frac{60-20}{40}\right)} \\ &= \sum_{x=20}^{59} w\left(\frac{x-20}{40}\right) \\ &\doteq \int_0^1 w(y)\, dy / w(1) \end{aligned}$$

where $w(y)$ is the wage at rescaled age $y = (x - 20)/40$, normalised to ensure that $w((60-20)/40) = w(1) = 1$.

[12] This statement is qualified later.

[13] The quadratic formulation is common in the labour economics literature and two principal explanations have been put forward to justify the shape. The first is derived from Becker's (1964, 1967) and Mincer's (1974) human-capital–earnings function. The second is derived from Lazear's (1981) seniority model of earnings. An example of the second approach is Card who uses a quadratic equation, but with experience replacing age and with an additional years of education variable (Card (1999, equation (1)). Other studies use higher-order polynomials: e.g., Murphy and Welch (1990), Robinson (2000) and Samwick and Skinner (2004) use fourth-order polynomials, while Cocco et al (1999) use third-order but also report fifth-order polynomials. We experimented with polynomials up to fifth order, and although they (marginally) fitted the CSP better, the addition of cubic, quartic and quintic terms made negligible differences to the distribution of the pension ratio.

(3) $$\begin{cases} w_1(y) = -1 + y \\ w_2(y) = -1 + 4y - 3y^2 \end{cases}$$

The CSP in (2) shows the individual's earnings (as a function of rescaled age), relative to final salary (expressed in constant earnings terms). The parameters k_1 and k_2 were estimated by least squares methods in *EViews*, taking account of the missing observations between the 8 central ages in the original NES data.

The polynomials in (3) satisfy the following criteria:

(4) $$\begin{cases} w_i(1) = 0 \quad \text{for } i = 1,2 \\ w_i(0) = -1 \ \text{ for } i = 1,2 \\ \int_0^1 w_2(y)\mathrm{dy} = 0 \\ \int_0^1 w_1(y) w_2(y)\mathrm{dy} = 0 \end{cases}$$

The first criterion ensures that the final salary is normalised on unity, i.e., $w(1) = 1$. This normalisation enables us to interpret our results relative to the outcomes that would be achieved under a comparable DB scheme. Recall that we wish to compare the DC pension with a DB benchmark that pays 2/3rds of final salary. Accordingly, $w(y) = 1$ indicates that the individual is earning a salary equal to final salary at age *y*; similarly, $w(y) = 1.1$ indicates that he/she is earning 10% above final salary at age *y*. The normalisation also simplifies comparison of the distributions of the pension ratio for different occupation and gender groups. So when we relate one occupation group to another it is helpful to assume that individuals end up on the same expected (normalised) final salary. Although a male professional is likely to earn a higher salary than a salesman, say, the pension ratio is independent of each occupation's final-salary benchmark, since the effect of the absolute salary level is cancelled out.

Each year, *t*, we assume that an individual's real earnings, $\overline{w}(x,t)$, grow in line with the real increase in national average earnings (*NAE*), adjusted for a promotional increase:

(5) $$\Delta \ln \overline{w}(x,t) = \Delta \ln NAE(t) + \ln\left(\frac{w\left(\frac{x+1-20}{40}\right)}{w\left(\frac{x-20}{40}\right)}\right) + \Delta \nu(t) + \Delta \varepsilon(t)$$

where

(6) $$\Delta \nu(t) = \nu(t) - \nu(t-1) = u(t)$$

The promotional increase has up to three components:

- a component that is common to all members of the individual's occupation of the same age (the second term on the right hand side of (5)),
- an idiosyncratic random component that persists over time (the third term in (5) which is defined in (6) as a random walk[14] with $u(t) \sim$ i.i.d. $N(0, \sigma_u^2)$)
- and an idiosyncratic random component that is transitory ($\varepsilon(t) \sim$ i.i.d. $N(0, \sigma_\varepsilon^2)$) which is uncorrelated with $u(t)$, but might be correlated with other variables such as asset returns, thereby allowing for the possibility of a correlation between shocks to human and financial capital (Campbell et al (2001)).[15]

In line with post-war UK experience, the annualised growth rate in real UK national average earnings is assumed to be 2% with a standard deviation of 2%. Further, given that we are modelling the average member of each occupation, we assume that there are no idiosyncratic components (either permanent or temporary) to the promotional increase.[16] We are primarily interested in comparing the systematic component of the promotional increase which differs substantially across occupations and between men

[14] Carroll (1997) and Gourinchas and Parker (2000) also model $\nu(t)$ as a random walk. This is consistent with the empirical evidence of Hubbard et al (1995) and Chamberlain and Hirano (1999) who estimate a first-order autocorrelation process and find an autocorrelation coefficient close to unity.

[15] Cocco, et al (1999, Table 3), however, find that the correlation between the transitory shocks to human and financial capital is statistically insignificant.

[16] This has the additional benefit of avoiding the problem of determining the size of σ_u^2 and σ_ε^2 which differ across occupations (Dickens (2000)), although not between males and females within the same occupation (inferred from the conclusions in Manning and Robinson (2004)).

and women in the same occupation.

The second criterion sets a common initial condition for each polynomial.[17] The negativity of $w_i(0)$ means that the parameters k_1 and k_2 have simple interpretations: they measure the gradient (average slope) and hump (degree of curvature) of the CSP, respectively. For this reason we propose to call them the gradient-factor (or G-factor) and the hump-factor (or H-factor), respectively. These factors are related to RCAS and PSA as follows:

(7) $$\text{RCAS} = \int_0^1 w(y)\mathrm{d}y = 1 - 0.5k_1$$

and, provided $k_2 > 0$:

(8) $$\text{PSA} = 20 + 40\frac{k_1 + 4k_2}{6k_2}$$

These results are proved in Appendix B. RCAS is negatively related to the G-factor (k_1). PSA is positively related to the G-factor and, if $k_1 < 0(> 0)$, positively (negatively) related to the H-factor (k_2).[18] While there is a one-to-one correspondence between the RCAS and the G-factor, indicating that the RCAS is an extremely good proxy for the G-factor, the same cannot be said of the PSA. The relationship between PSA and the H-factor is complicated by the PSA's dependence on k_1. Further, for a quadratic equation, the PSA as measured by (8) could differ significantly from the PSA implied by the raw data; in addition, the PSA is sensitive to the degree of polynomial fitted. Despite being less intuitive, the H-factor is therefore a more accurate summary measure of the curvature of the CSP than the PSA, although we will continue to make references to the PSA below.

The third criterion implies that the second-degree polynomial will have no effect on the accumulation of premiums when the growth rate in salary (in excess of the merit increases implied by the CSP) is equal every year to the rate of return on fund assets. This result is proved mathematically in Appendix C and is illustrated in Figure

[17] This is an arbitrary scaling condition. If we wished to rescale one of the polynomials then we would simply have to apply the reciprocal of the scaling factor to the relevant k_i coefficient.

[18] Tables 2 and 7 below show that k_1 is negative for most CSPs.

3 where we can see that although the addition of the hump changes the shape of the CSP, it does not affect the average salary over the full working lifetime of the individual (since the areas under the two curves are identical).

The fourth is an orthogonality criterion. When the coefficients of the polynomial are estimated sequentially, the second-order polynomial added will not significantly affect the values of the previously estimated coefficient of the first-order polynomial because $w_1(y)$ and $w_2(y)$ are orthogonal. Without these forms for the polynomials, the parameter k_1, would no longer be directly related to the general gradient or slope of the CSP, for example.

Having analysed the key features of a CSP, we can now investigate how they influence the pension outcome. From eqn (7), a lower value of k_1 (a lower, more negative G-factor) increases the RCAS and, *ceteris paribus*, increases the pension ratio: the reason is that if contributions are earnings-related, relatively higher contributions are invested earlier in the life of the scheme and this increases the size of the DC pension fund relative to the DB pension fund. This result holds irrespective of the relative sizes of the return on assets (r) and the growth rate in earnings (g).

By contrast, the impact of k_2 does depend on the relative sizes of r and g. If $r > g$, an increase in k_2 lowers the pension ratio. This is because a higher k_2, by increasing the curvature of the CSP, implies lower early salaries and higher later salaries (for the same k_1 and hence RCAS); this is clearly demonstrated in Fig. 3. When $r > g$, transferring income to the future implies a greater penalty for a DC pension (in terms of lower cumulative returns) than it does for a DB pension (in terms of lower final salary). The opposite result holds when $r < g$. The results in the previous two paragraphs are summarised in Table 1 and proved in Appendix D.

The results for k_2 hold irrespective of the sign of k_1. Corresponding results can be expressed in terms of the more intuitive (but less reliable) PSA feature of the CSP. However, in this case, the results are not independent of the sign of k_1. This is because a higher k_2 raises PSA if $k_1 < 0$, but lowers PSA if $k_1 > 0$ (see eqn (8)). Therefore if $r > g$ and $k_1 < 0$, an increase in PSA lowers the pension ratio, while if $r < g$ and $k_1 < 0$, an increase in PSA raises the pension ratio. The opposite results hold if $k_1 > 0$.

We are now in a position to examine how pension outcomes are determined for the different occupational groups listed at the beginning of this section, beginning first with those of males.

4. SIMULATION RESULTS FOR MALES

There are significant differences in the CSPs of the different male occupational groups listed in Figure 1, even though their shapes are broadly similar[19]. These differences are reflected in the RCAS and PSA measures shown in Table 2. We find that RCAS is highest for personal-service and manual workers (with values of 1.224 and 1.109, respectively), and lowest for managers and professionals (with values of 0.954 and 0.941, respectively). We also find that the PSA is lowest for personal-service workers (42.5 years) and highest for professionals and managers (49.3 and 48.3, respectively).

Table 3 shows the simulated median pension ratio for male workers across the four SAAs.[20] These results confirm our earlier 2001 findings for a 'typical' male worker, namely that equity-only and pension-fund-average strategies produce the highest median pension-ratios with the highest dispersions, and the bills-only and bills-bonds strategies produce the lowest median pension-ratios and dispersions across all occupational groups.

However, what is striking about the table is the wide dispersion of median pension ratios across occupations *for the same SAA*. To illustrate, for the equity-only strategy, the highest median pension ratio at 3.59 (for personal service workers) is 34% higher than that of the lowest median pension ratio at 2.68 (for professionals) *for the same contribution rate and asset returns*. The same occupational groups come top and bottom for all the other SAAs and although the proportionate differences are smaller, they are nevertheless still significant. The explanation is clear. Personal-service workers (and indeed manual workers as a whole group) have the highest RCAS (lowest

[19] Part of this similarity arises from restricting all the CSPs to be quadratic.

[20] All simulation results were based on 5000 Monte Carlo simulations of the PensionMetrics model.

k_1) and the lowest PSA (highest k_2), whereas professionals have the lowest RCAS and highest PSA (see Table 2). Indeed the rankings of median pension ratios over all occupational groups is very similar across the different SAAs, and again this follows from the relative sizes of RCAS and PSA.

Some occupational groups can end up with very similar median pension ratios across SAAs, however, even though they have very different RCASs and PSAs. An example in Table 3 is sales staff and plant operatives, and an examination of Table 2 shows how: sales staff have a low k_1 and a high k_2, while plant operatives have a high k_1 and a low k_2, and these various combinations happen to be such as to give almost identical pension ratios[21]. In general, the median pension ratio is more sensitive to changes in k_1 than k_2. However, sensitivity to k_2 increases the further r is from g. For example, in Table 3, the influence of k_2 is much smaller for the bills-bonds strategy where r is very close to g, than with the PFA strategy where r is much larger than g.

Table 4 shows the corresponding likely worst pension-ratio outcomes at the 95% confidence level. The ranking of outcomes across occupations is similar for all the SAAs, with the best outcome being for personal-service workers and the worst outcome being for professionals across all SAAs. The SAA has a key influence on extreme outcomes. To illustrate, the equity-only strategy, while producing the best median pension outcomes across all occupations, generates the second worst tail outcomes after T-bills. By contrast, the PFA strategy produce the least worst tail outcomes.

Our results so far indicate that a high pension outcome is, *ceteris paribus*, associated with occupations with a high RCAS and/or a low PSA, although these features tend to go together in any case. Thus, for example, manual workers and especially personal-service workers can anticipate relatively good pension outcomes (as measured by the their pension ratios) because their career salary profile has a high peak that occurs early, and managerial and professional workers can anticipate relatively poor pension outcomes because their career salary profiles have low peaks that occur late.

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[21] Eqn (D2) in Appendix D can be used to determine the combinations of k_1 and k_2 that give the same pension ratio.

We can gain further insight into the occupational differences by asking how contribution rates would differ across occupational groups if they are to achieve the same given prospective outcome. To illustrate, Table 5 shows the contributions required by each occupational group and for each SAA needed to give a 50% chance that the pension ratio exceeds unity. High-risk, high-return strategies such as 100% equities and the PFA require contribution rates well below 14%, whereas low-risk, low-return strategies, such as 100% T-bills and bills-bonds require contribution rates in excess of 14%. This clearly illustrates the so-called ‘reckless conservatism’ of investing in low return assets over long investment horizons. The table also shows the variation across occupational groups within the same SAA. For example, with 100% equities, the required contribution rate is 3.9% for personal-service workers, while for managers and professionals, it is 5.2%, 33% higher. With bills-bonds, on the other hand, the required rate for personal-service workers is 14.7%, while for professionals it is 19%, 29% higher.

Whatever SAA is chosen, non-manual workers have to contribute much more than manual workers to achieve the same probability of doing as well as in a DB scheme. The choice between DB and DC schemes therefore has major redistributive implications between occupational groups. Managerial and professional workers do relatively well under DB schemes, since they have a high salary near retirement relative to their career average salary (this corresponds to a low RCAS and high PSA), and they do relatively badly under DC schemes. By contrast, manual workers do relatively well under DC schemes and relatively badly under DB ones. A switch from DB to DC schemes thus implies significant transfers of wealth, and in particular from managerial and professional workers to manual workers, relative to the pension outcomes the same workers would have enjoyed under a DB scheme.

Table 6 shows the required contribution rates needed to achieve the same likely worst pension ratios as the PFA strategy. All other strategies require higher contribution rates. In other words, a well-financed and well-diversified investment strategy with a high equity weighting not only provides an adequate pension on average, it also provides the least costly way of avoiding extremely poor outcomes. The table also shows that within each SAA, there is very little variation of required contribution rates across occupational groups: this is consistent with the results in

Table 4.

5. SIMULATION RESULTS FOR FEMALES

Figure 2 shows that, as in the case of men, there are significant differences between the CSPs of different female occupations, although the differences are less than those for men. These differences are reflected in the RCAS and PSA values in Table 7: RCAS is highest for craft and managerial workers, and lowest for professionals; PSA is lowest for craft and other workers, and highest for professionals. By contrast with males, female RCASs are higher and PSAs are lower (since the k_1s and the k_2s are on average both lower than the male counterparts).

There are also significant cross-gender differences within the same occupational groups. For example, the RCAS of female personal-service workers is lower than that of their male colleagues, while female managers and professionals have higher RCASs than their male counterparts (cf Table 2).

Table 8 shows the simulated median pension-ratios for female workers. As with the male results, the equities-only and PFA strategies produce the highest and the T-bills-only and bills-bonds strategies produce the lowest median pension-ratios. However, there are significant cross-gender differences between the various occupations. For example, given an equity-only asset strategy, the two best performing female occupations are craft and other workers, whereas for men it is personal-service and technical workers. Female managers do particularly well in pension-ratio terms compared with their male counterparts. There are also some cross-gender similarities – for example, professional women do as relatively badly in terms of pension outcomes as their male counterparts. As in the case of males, the ranking of outcomes for the different occupations is broadly similar for each SAA. Table 9 shows the corresponding likely worst pension-ratio outcomes and the ranking across occupations for the various SAAs is very similar to Table 8, but, as in the case of males, the dispersion is much lower (cf Tables 3 and 4).

To evaluate how contribution rates would alter across occupational groups if they are all to achieve any given prospective outcome, Table 10 shows the contribution rates required by each occupational group needed to give a 50% chance that the female pension ratio exceeds unity. The required contribution rates are generally lower than the corresponding male rates across all SAAs, reflecting the generally higher female RCASs and lower PSAs (cf Table 5).

Table 11 shows the required contribution rates needed to achieve the same likely worst pension ratios as the PFA strategy. In this case, the female rates are in general slightly higher than the corresponding male rates across all SAAs (cf Table 6). This suggests that the shape of the female CSPs, while delivering better median outcomes than male CSPs, also deliver marginally worse tail outcomes.

Table 12 presents the k_1 and k_2 elasticities for the average male and female worker and confirms empirically the results in Table 1. The table shows clearly that:

- Lower values of k_1 increase the mean pension ratio. The male k_1 elasticities lie between -0.11 and -0.19 depending on the investment strategy. The female k_1 elasticities are higher in absolute terms and lie between -0.15 and -0.26. This indicates that a 1% reduction in k_1 has nearly a 40% greater impact in raising the female mean pension ratio than it has in raising the male pension ratio for a given SAA.
- If $r > g$ (i.e., $\theta = (1 + r)/(1 + g) > 1$), as in the case of the 100% equities and PFA strategies, lower values of k_2 increase the mean pension ratio. We find negative k_2 elasticities of -0.14 and -0.22 for males and -0.13 and -0.19 for females, depending on the investment strategy.
- If $r < g$ (i.e., $\theta < 1$), as in the case of 100% T-bills and mixed bills-bonds, lower values of k_2 reduce the mean pension ratio. The observed impact is much smaller than in the case where $r > g$, since θ is much closer to unity for these two SAAs.

6. CONCLUSIONS

In this paper, we have analysed the impact of occupation, gender and strategic asset allocation on DC pension plan outcomes. Our results indicate that the dispersion of DC pension outcomes across occupations depends primarily on the strategic asset allocation strategy chosen, with relatively large dispersions for equity-based strategies and (usually) much smaller ones for other strategies involving larger bond holdings. The extent to which the pension plan designer must take account of the policyholder's occupation therefore depends to a large extent on the asset strategy that the plan member chooses. This confirms the finding of our earlier 2001 paper which modelled the DC pension plan of a typical male worker.

We also found that there were wide differences in outcome across occupations for the same SAA. For example, with the equities-only strategy, the difference between the highest and lowest median pension ratio was 34% for men and 38% for women[22]. We explained these differences in terms of two key parameters explaining the shape of an individual's career salary profile, namely relative career average salary (RCAS) and peak service (PSA). DC plans benefit most those workers who have the highest career average salary relative to final salary and/or those whose salary peaks earliest in their careers.

These findings are quite unlike those from a conventional defined-benefit scheme. Everything else being equal, a DC plan member benefits more from having a higher career average salary and a lower peak salary age, whereas a DB plan member benefits more from a higher final salary. These differences imply that the choice of scheme has potentially substantial implied wealth transfers, and these transfers are particularly pronounced amongst male workers (who have larger differences in RCASs than female workers). For example, other things being equal, a move from a DB scheme to a DC scheme for all the workers in the same company implies a major transfer from male managerial and professional workers (since they are likely to have the highest relative final salaries) to male manual workers and to female workers (who tend to have lower relative final salaries, but higher RCASs and lower PSAs). It should

[22] Derived from Table 3 (column 1) and Table 8 (column 1), respectively.

be stressed that these transfers are *relative*: male managerial and professional workers, even with this switch of pension scheme, are likely to end up with larger *absolute* pensions than male manual workers and most female workers who are members of the same scheme.

Furthermore, there are significant differences between the career salary profiles of male and female workers within the same occupation, which suggests that key aspects of scheme design (in particular contribution rates) will be gender specific. Of particular interest is the finding that the female mean pension ratio is generally higher for the various SAAs than the corresponding male mean. For example, with the equities-only strategy, female managerial workers receive a 45% higher median pension ratio than their male counterparts, while for sales staff the difference is lower at 13%[23]. These results are a direct consequence of the fact that women tend to have higher RCASs than men.

The clear message of our study is that an employee will have been very poorly advised if his or her occupation and gender are not taken into account by those designing their DC pension plan.[24] [25]

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[23] Derived from Table 3 (column 1) and Table 8 (column 1), respectively.

[24] We should be aware of certain weaknesses in our underlying assumptions. For example, we have assumed that individuals remain in employment for their whole careers. In reality, individuals face unemployment risk and hence earnings risk. However, this will impact considerably more on the DB pension than on the DC pension. There are two reasons for this. First, every time a worker changes jobs they experience a portability loss on their DB pension. The pension is based on the leaving salary which is likely to be less than the final salary (even if the leaving salary is uprated to the retirement date to account for inflation, it is uprated by less than the increase in earnings). As reported in Blake and Orszag (1997), a typical UK worker changing jobs 6 or 7 times in a career suffers a portability loss of around 30% of the final salary pension of a worker with the same salary history who stays his/her whole career with the same employer. Second, the DB pension, depending as it does on the final salary or the average salary in the final three years, is susceptible to earnings risk near retirement. Both these factors bias our analysis against DC schemes. When we also take into account our finding that a well-diversified asset allocation with a high equity weighting can, for the same cost as a DB scheme, generate a DC pension that is on average higher than a DB pension and also has good downside protection, then we can conclude that DC schemes do provide a feasible alternative to DB schemes if they are appropriately designed. Samwick and Skinner (2004) reach the same conclusion for 401(k) DC plans in the US.

[25] As a final comment, we have shown the importance of the shape of CSPs on the pension outcomes in

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DC schemes. Yet we have had to construct the CSPs using just 8 observations, typically one observation for each 10-year age interval. In addition, these observations are snapshots at a point in time and not what we really need which is the earnings of a single occupational cohort as it ages over time. The New Earnings Survey is constructing a panel dataset, but this only started in 1975 and so full career histories for single cohorts are not yet available in the UK.

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APPENDIX A: PROPERTIES OF THE PENSIONMETRICS ASSET RETURNS MODELS

The properties of the real returns on the securities used in the analysis together with earnings growth are given in the following table:

	Mean (%)	Standard deviation (%)	Correlation with UK earnings growth(%)
UK T-bills	1.28	4.04	21.10
UK equities	10.37	27.11	-5.44
UK bonds	1.55	13.95	-34.38
UK property	4.48	10.45	36.23
US equities	8.97	21.16	4.45
US bonds	2.13	16.96	-1.44
UK earnings growth	2.09	2.06	100

The mean returns in the first column are gross returns; we assume, in our model, that an annual management fee of 1% is deducted from gross returns. The correlation matrix for the returns is presented in the following table:

	UK T-bills	UK equities	UK bonds	UK property	US equities	US bonds
UK T-bills	1	-0.0612	0.2563	0.272	0.0679	0.2603
UK equities	-0.0612	1	0.5441	0.1854	0.4814	0.1568
UK bonds	0.2563	0.5441	1	0.2016	0.2335	0.3046
UK property	0.272	0.1854	0.2016	1	0.0561	-0.0358
US equities	0.0679	0.4814	0.2335	0.0561	1	0.6818
US bonds	0.2603	0.1568	0.3046	-0.0358	0.6818	1

APPENDIX B: PROOF OF EQUATIONS (7) AND (8)

Integrating equation (2) taking into account (3) and (4) gives:

$$(\mathrm{B1}) \qquad \begin{aligned} \mathrm{RCAS} &= \int_0^1 w(y)\mathrm{d}y \\ &= \int_0^1 \left(1 + k_1\left(-1 + y\right)\right)\ \mathrm{d}y \\ &= \left[y + k_1\left(-y + 0.5y^2\right)\right]_0^1 \\ &= 1 - 0.5k_1 \end{aligned}$$

which is the same as equation (7). ■

Substituting from (3), the CSP function can be rewritten:

$$(\mathrm{B2}) \qquad w(y) = 1 + k_1(-1 + y) + k_2(-1 + 4y - 3y^2)$$

Differentiating (B2) with respect to *y* and setting to zero, we get:

$$(\mathrm{B3}) \qquad w'(y) = k_1 + 4k_2 - 6k_2 y = 0$$

from which equation (8) immediately follows, provided $k_2 > 0$. ■

APPENDIX C: PROOF THAT THE VALUE OF THE PENSION FUND AT RETIREMENT IS INDEPENDENT OF THE DEGREE OF CURVATURE OF THE CSP WHEN THE RATE OF RETURN ON ASSETS AND THE GROWTH RATE IN EARNINGS ARE EQUALISED

For a male worker, let:

r = rate of return on assets held in the pension fund (assumed constant)

g = growth rate in salary (assumed constant)

$\theta = (1 + r)/(1 + g)$

c = contribution rate into the pension fund (assumed to be a constant proportion of salary)

$s(x)$ = salary at age x

F = value of pension fund at retirement.

Then the value of the pension fund at retirement is given by:

$$(\text{C1}) \quad F = c\sum_{x=20}^{59} s(x)(1+r)^{60-x}$$

$$= c\sum_{x=20}^{59} \frac{w\left(\frac{x-20}{40}\right)}{w(0)} s(20)(1+g)^{x-20}(1+r)^{60-x}$$

$$= c\sum_{x=20}^{59} \left(\frac{w\left(\frac{60-20}{40}\right)}{w(0)} s(20)(1+g)^{60-20} \right) \frac{w\left(\frac{x-20}{40}\right)}{w\left(\frac{60-20}{40}\right)} (1+g)^{x-60}(1+r)^{60-x}$$

$$= c \times s(60) \times \sum_{x=20}^{59} w\left(\frac{x-20}{40}\right)\theta^{60-x}$$

$$(\text{C2}) \quad \doteq 40 \times c \times s(60) \times \int_0^1 w(y)\theta^{40(1-y)}\mathrm{d}y$$

If $r = g$, then $\theta = 1$ and $F = 40 \times c \times s(60) \times \text{RCAS} = F_1$, say, by equation (B1). Note that this is independent of k_2. Furthermore:

$$(\text{C3}) \quad r \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} g \Rightarrow F \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} F_1. \quad \blacksquare$$

APPENDIX D: PROOF OF THE RESULTS IN TABLE 1

Theorem: Using the same notation as in Appendix C, suppose $F(k_1 < 0)$ and $F(k_1 = 0)$ are the values of the fund for (a given) $k_1 < 0$ and $k_1 = 0$, respectively, and for $k_2 = 0$. Then $F(k_1 < 0) > F(k_1 = 0)$, irrespective of the relative sizes of *r* and *g*.

Proof: Using integration rather than summation, the last row of (C1) can be evaluated as follows. For $k_2 = 0$:

$$\text{(D1)} \quad \begin{aligned} F(k_1 < 0) &= c \times s(60) \times \int_{20}^{60} w\left(\frac{x-20}{40}\right) \theta^{60-x} \mathrm{d}x \\ &= 40 \times c \times s(60) \times \int_0^1 w(y) \theta^{40(1-y)} \mathrm{d}y \\ &= 40 \times c \times s(60) \times \int_0^1 f(y)\big(1 + k_1(-1+y)\big) \mathrm{d}y \\ &= 40 \times c \times s(60) \times \int_0^1 f(y) \mathrm{d}y \\ &\quad + 40 \times c \times s(60) \times k_1 \times \int_0^1 f(y)(-1+y) \mathrm{d}y \\ &= F(k_1 = 0) + \{F(k_1 < 0) - F(k_1 = 0)\} \end{aligned}$$

where $f(y) = \theta^{40(1-y)}$. Since $f(y) > 0$ and $(-1+y) < 0$ for 0 < *y* < 1, then $\int_0^1 f(y)(-1+y)\mathrm{d}y < 0$. Hence if $k_1 < 0$, then $\{F(k_1 < 0) - F(k_1 = 0)\} > 0$, for all values of *r* and *g*. ■

Theorem: Suppose $F(k_2 = 0)$ is the value of the fund for a given $k_1 (< 0)$ and for $k_2 = 0$ and $F_2(k_2 > 0)$ is the value of the fund for the same $k_1 (< 0)$, for a given $k_2 (> 0)$. The corresponding CSPs are depicted in Fig. 3 for the cases $k_1 = -0.1,\ k_2 = 0.0$, and $k_1 = -0.1,\ k_2 = 0.2$. Both CSPs have the same RCAS (see (B1) and the third criterion in (4)). If $r > (<) g$, then $F(k_2 > 0) < (>) F(k_2 = 0)$.

Proof: Suppose $r > g$, in which case $\theta > 1$. Then from (C2) we have:

$$\text{(D2)} \quad F(k_2>0)=40\times c\times s(60)\times\int_0^1 w(y)\theta^{40(1-y)}\mathrm{d}y$$
$$=40\times c\times s(60)\times\int_0^1 \theta^{40(1-y)}\left(1+k_1(-1+y)+k_2\left(-1+4y-3y^2\right)\right)\mathrm{d}y$$
$$=40\times c\times s(60)\times\int_0^1 f(y)\left(1+k_1(-1+y)\right)\mathrm{d}y$$
$$+40\times c\times s(60)\times k_2\times\int_0^1 f(y)\left(-1+4y-3y^2\right)\mathrm{d}y$$
$$=F(k_2=0)+\left\{F(k_2>0)-F(k_2=0)\right\}$$

where $f(y)=\theta^{40(1-y)}$ is a decreasing function of y (i.e., $f'(y)<0$).

Using integration by parts, the second integral on the penultimate line of (D2) is evaluated as follows:

$$\text{(D3)} \quad \int_0^1 f(y)\left(-1+4y-3y^2\right)\mathrm{d}y$$
$$=\left[f(y)\left(-y+2y^2-y^3\right)\right]_0^1-\int_0^1 f'(y)\left(-y+2y^2-y^3\right)\mathrm{d}y$$
$$=0+\int_0^1 f'(y)y(y-1)^2\,\mathrm{d}y$$
$$<0$$

since $f'(y)<0$ and $y(y-1)^2>0$ for $0 < y < 1$. Hence if $k_2>0$ and $\theta>1$, then $\left\{F(k_2>0)-F(k_2=0)\right\}<0$.

Conversely if $r<g$ then $\theta<1$ and $f(y)=\theta^{40(1-y)}$ is an increasing function of y, so that $F(k_2>0)>F(k_2=0)$. ■

The above proofs relate to the pension fund at retirement, rather than the pension ratio at retirement which is the focus of the main text. If the annuity rate at retirement is independent of asset returns, then the above proofs are both necessary and sufficient for the proving comparable results for the pension ratio. In practice, the correlation will not be zero (in particular, the annuity yield is likely to be negatively correlated with the return on bonds at the retirement date), although we conjecture that it will be small. So we must conclude that the above theorems, while correct for the pension fund, only hold approximately for the pension ratio.

Table 1: The Relationships Between the Polynomial Coefficients of the Career Salary Profile, the Return on Assets, the Growth Rate in Earnings and the Pension Ratio

1	Regardless of the values of r and g, then relative to k_1 = 0, a negative (positive) k_1 will (by increasing (reducing) RCAS) increase (reduce) the ratio of the mean value of the pension fund to final salary and hence the pension ratio.[a]
2	If $r > g$, then relative to k_2 = 0, a negative (positive) k_2 will (by reducing (increasing) PSA) increase (reduce) the ratio of the mean value of the pension fund to final salary and hence the pension ratio.[b]
3	If $r < g$, then relative to k_2 = 0, a positive (negative) k_2 will (by reducing (increasing) PSA) increase (reduce) the ratio of the mean value of the pension fund to final salary and hence the pension ratio.[b]

Notes:

[a] This follows because $\int_0^1 f(y)w_1(y)\,dy < 0 \quad \forall\theta = (1+r)/(1+g)$.

[b] This follows because $\int_0^1 f(y)w_2(y)\,dy \begin{cases} < 0 & \forall\theta > 1 \\ > 0 & \forall\theta < 1 \end{cases}$

Proof: see Appendix D.

Table 2: Male Career and Salary Profiles: Parameters and Key Features

Occupation	k_1	k_2	Relative career average salary	Peak salary age
All	-0.2520	0.6557	1.126	44.10
Manual	-0.2171	0.5095	1.109	43.83
Non-Manual	0.0434	0.4976	0.978	47.25
Managerial	0.0922	0.3810	0.954	48.28
Professional	0.1176	0.3029	0.941	49.25
Clerical	-0.1183	0.3348	1.059	44.31
Technical	-0.1808	0.4240	1.090	43.82
Craft	-0.2067	0.5557	1.103	44.19
Personal	-0.4479	0.7180	1.224	42.51
Sales	-0.1375	0.5396	1.069	44.97
Plant Operatives	-0.0944	0.3363	1.047	44.80
Others	-0.1707	0.3913	1.085	43.76

Table 3: Male Median Pension Ratios

	Equities only	PFA	T-bills only	Bills-bonds
All	3.23	2.58	0.87	0.88
Manual	3.25	2.58	0.85	0.86
Non-Manual	2.72	2.18	0.76	0.77
Managerial	2.69	2.15	0.74	0.75
Professional	2.68	2.14	0.73	0.74
Clerical	3.14	2.49	0.82	0.83
Technical	3.22	2.56	0.84	0.85
Craft	3.19	2.55	0.85	0.86
Personal	3.59	2.86	0.94	0.95
Sales	3.06	2.45	0.83	0.84
Plant Operatives	3.09	2.46	0.81	0.82
Others	3.21	2.56	0.84	0.85

Table 4: Male Likely Worst Pension Ratios (95% Confidence Level)

	Equities only	PFA	T-bills only	Bills-bonds
All	0.62	0.95	0.57	0.67
Manual	0.61	0.94	0.56	0.65
Non-Manual	0.54	0.82	0.50	0.59
Managerial	0.53	0.80	0.49	0.57
Professional	0.53	0.80	0.48	0.56
Clerical	0.59	0.90	0.54	0.62
Technical	0.60	0.93	0.55	0.64
Craft	0.61	0.93	0.56	0.65
Personal	0.67	1.03	0.62	0.72
Sales	0.59	0.90	0.55	0.63
Plant Operatives	0.58	0.89	0.53	0.62
Others	0.60	0.92	0.55	0.64

Table 5: Percentage Contribution Rate Needed to Give a 50% Chance that the Male Pension Ratio Exceeds Unity

	Equities only	PFA	T-bills only	Bills-bonds
All	4.3	5.4	16.1	15.9
Manual	4.3	5.4	16.4	16.2
Non-Manual	5.2	6.4	18.5	18.3
Managerial	5.2	6.5	19.0	18.8
Professional	5.2	6.5	19.3	19.0
Clerical	4.5	5.6	17.2	17.0
Technical	4.3	5.5	16.7	16.5
Craft	4.4	5.5	16.5	16.2
Personal	3.9	4.9	14.8	14.7
Sales	4.6	5.7	17.0	16.8
Plant Operatives	4.5	5.7	17.4	17.1
Others	4.4	5.5	16.8	16.6

Table 6: Percentage Contribution Rate Needed to Achieve Same Likely Worst Male Pension Ratio as the PFA Strategy (95% Confidence Level)

	Equities only	PFA	T-bills only	Bills-bonds
All	21.44	14.00	23.11	19.88
Manual	21.53	14.00	23.28	20.06
Non-Manual	21.11	14.00	22.80	19.55
Managerial	21.15	14.00	23.00	19.71
Professional	21.15	14.00	23.14	19.85
Clerical	21.50	14.00	23.42	20.20
Technical	21.59	14.00	23.39	20.17
Craft	21.52	14.00	23.26	20.04
Personal	21.65	14.00	23.31	20.12
Sales	21.36	14.00	23.13	19.89
Plant Operatives	21.47	14.00	23.40	20.17
Others	21.56	14.00	23.38	20.17

Table 7: Female Career and Salary Profiles: Parameters and Key Features

Occupation	k_1	k_2	Relative career average salary	Peak salary age
All	-0.3721	0.6393	1.186	42.79
Manual	-0.2147	0.3475	1.107	42.55
Non-Manual	-0.2966	0.6144	1.148	43.45
Managerial	-0.6172	0.7508	1.309	41.19
Professional	-0.0576	0.3614	1.029	45.60
Clerical	-0.1764	0.3989	1.088	43.72
Technical	-0.3610	0.4720	1.180	41.57
Craft	-0.6728	0.4917	1.336	37.54
Personal	-0.2680	0.3923	1.134	42.11
Sales	-0.2798	0.3202	1.140	40.84
Plant Operatives	-0.2077	0.2527	1.104	41.19
Others	-0.3152	0.2366	1.158	37.79

Table 8: Female Median Pension Ratios

	Equities only	PFA	T-bills only	Bills-bonds
All	3.48	2.77	0.91	0.92
Manual	3.33	2.64	0.85	0.86
Non-Manual	3.34	2.66	0.89	0.90
Managerial	3.91	3.11	1.01	1.02
Professional	3.01	2.39	0.79	0.80
Clerical	3.22	2.56	0.84	0.85
Technical	3.55	2.82	0.91	0.92
Craft	4.16	3.29	1.02	1.03
Personal	3.41	2.70	0.87	0.88
Sales	3.46	2.75	0.88	0.89
Plant Operatives	3.36	2.66	0.85	0.86
Others	3.59	2.83	0.89	0.90

Table 9: Female Likely Worst Pension Ratios (95% Confidence Level)

	Equities only	PFA	T-bills only	Bills-bonds
All	0.65	1.00	0.60	0.70
Manual	0.61	0.94	0.56	0.65
Non-Manual	0.63	0.97	0.58	0.68
Managerial	0.71	1.10	0.66	0.76
Professional	0.57	0.87	0.52	0.61
Clerical	0.60	0.92	0.55	0.64
Technical	0.65	1.00	0.60	0.69
Craft	0.73	1.14	0.67	0.77
Personal	0.63	0.97	0.57	0.66
Sales	0.63	0.97	0.58	0.66
Plant Operatives	0.61	0.95	0.56	0.64
Others	0.64	0.99	0.58	0.67

Table 10: Percentage Contribution Rate Needed to Give a 50% Chance that the Female Pension Ratio Exceeds Unity

	Equities only	PFA	T-bills only	Bills-bonds
All	4.0	5.1	15.3	15.1
Manual	4.2	5.3	16.4	16.3
Non-Manual	4.2	5.3	15.8	15.6
Managerial	3.6	4.5	13.9	13.7
Professional	4.7	5.8	17.7	17.4
Clerical	4.3	5.5	16.7	16.5
Technical	3.9	5.0	15.4	15.3
Craft	3.4	4.3	13.7	13.5
Personal	4.1	5.2	16.1	15.9
Sales	4.0	5.1	16.0	15.8
Plant Operatives	4.2	5.3	16.5	16.3
Others	3.9	4.9	15.8	15.6

Table 11: Percentage Contribution Rate Needed to Achieve Same Likely Worst Female Pension Ratio as the PFA Strategy (95% Confidence Level)

	Equities only	PFA	T-bills only	Bills-bonds
All	21.63	14.00	23.31	20.12
Manual	21.64	14.00	23.56	20.41
Non-Manual	21.53	14.00	23.23	20.01
Managerial	21.61	14.00	23.31	20.19
Professional	21.42	14.00	23.38	20.12
Clerical	21.56	14.00	23.38	20.17
Technical	21.71	14.00	23.54	20.41
Craft	21.80	14.00	23.75	20.76
Personal	21.64	14.00	23.56	20.42
Sales	21.55	14.00	23.67	20.55
Plant Operatives	21.54	14.00	23.73	20.59
Others	21.58	14.00	23.84	20.77

Table 12: Sensitivity Analysis of the Quadratic Coefficients on the Mean Pension Ratio of All Male Workers and All Female Workers

	Equities only	PFA	T-bills only	Bills-bonds
Mean value of θ [a]	1.0823	1.0551	0.9907	0.9922
All Male Workers				
Original parameters: $k_1 = -0.251973$, $k_2 = 0.655672$				
Mean	4.338462	2.297334	0.65641	0.641311
Original parameters except: $k_1 = -0.254493$ (i.e., lowered by 1%)				
Mean	4.464343	2.399766	0.705933	0.693149
Elasticity (%)	-0.1908	-0.1660	-0.1082	-0.1083
Original parameters except: $k_2 = 0.649115$ (i.e., lowered by 1%)				
Mean	4.347896	2.300598	0.656354	0.641263
Elasticity (%)	-0.2174	-0.1421	0.0085	0.0074
All Female Workers				
Original parameters: $k_1 = -0.372147$, $k_2 = 0.639317$				
Mean	4.756855	2.487339	0.690149	0.674333
Original parameters except: $k_1 = -0.3758684$ (i.e., lowered by 1%)				
Mean	4.769083	2.492971	0.691198	0.675359
Elasticity (%)	-0.2571	-0.2264	-0.1520	-0.1522
Original parameters except: $k_2 = 0.632924$ (i.e., lowered by 1%)				
Mean	4.766053	2.490522	0.690095	0.674286
Elasticity (%)	-0.1934	-0.1279	0.0078	0.0069

Note: [a] $\theta = (1 + r)/(1 + g)$, where r = rate of return on assets held in the pension fund and g = growth rate in salary

Figure 1: Career Salary Profiles for Male Workers

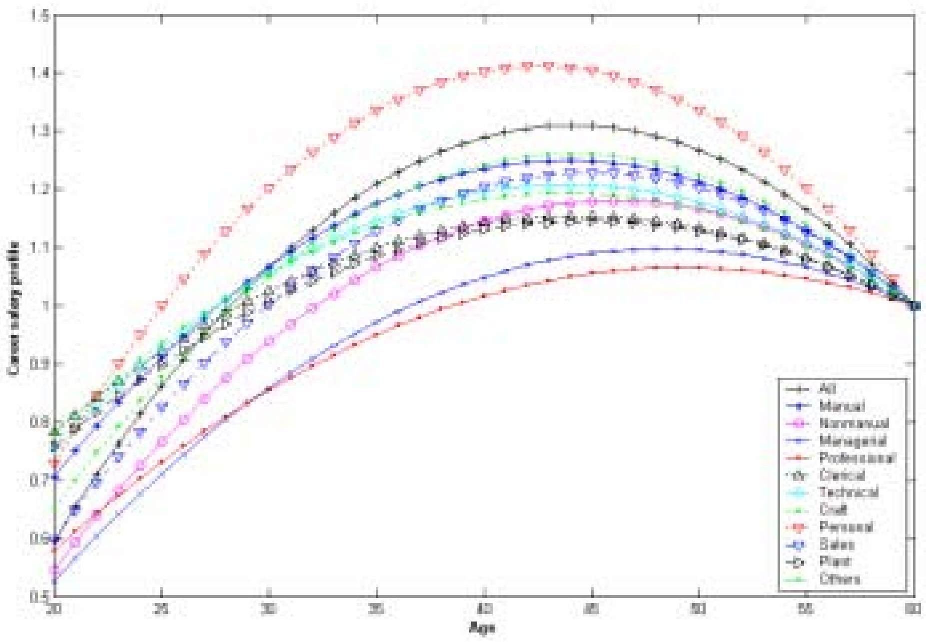

Figure 2: Career Salary Profiles for Female Workers

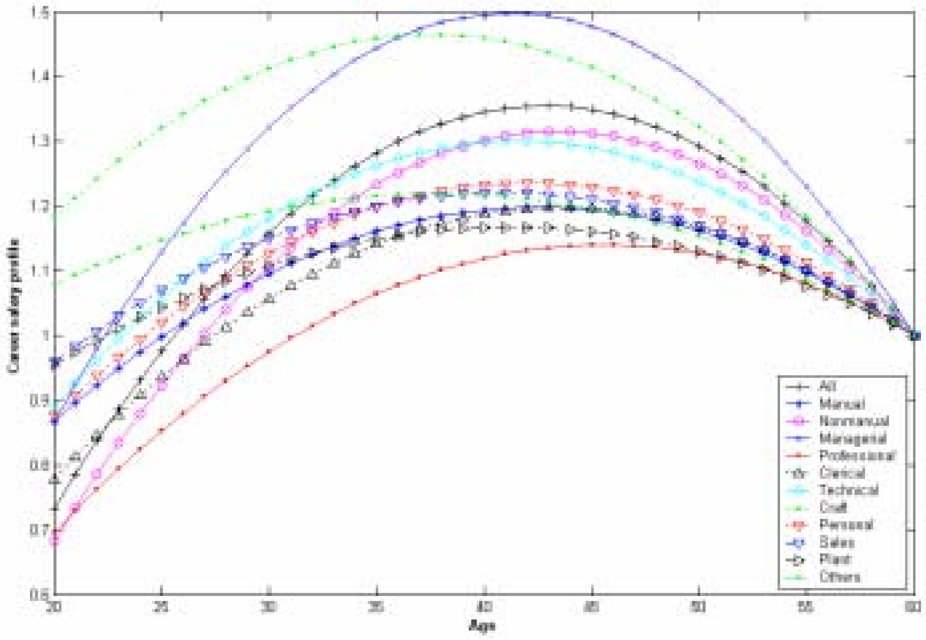

Figure 3 Construction of a Career Salary Profile using Basis Polynomials