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International Evidence

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The Value and Risk of Defined Contribution Pension Schemes: International Evidence

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The Value and Risk of Defined Contribution Pension Schemes: International Evidence

Abstract

We use historical data on investment returns and labour income from sixteen countries to quantify the value and risk of defined contribution pension plans, building frequency distributions of pension fund and pension replacement ratios for each country. We show that pension risk is substantial, and find that pension fund ratios are lower and less variable than when the correlation between wage growth and investment returns is ignored: typically halving the median pension fund ratio. We also show that an all-equity fund is the dominant investment strategy across all countries, although sometimes a life-cycle strategy insures against downside risk.

JEL Classification: E62, G14, H55

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1. Introduction

The primary purpose of a pension is to ensure that an individual's consumption does not fall after the retiring from work: ideally the pension achieves this by providing an income in retirement which is similar to previous labour income. Indeed the *pension replacement ratio* should be close to unity if the pension is to smooth consumption effectively. The determinants of the pension replacement ratio are the returns on investment – in both the accumulation and decumulation phases of the pension – as well as the determinants of labour income. Importantly, investment returns and labour income are both risky and correlated. In this paper we use a large data set of both variables to measure the overall effect on the riskiness of a personal pension. We find that DC pension fund ratio are lower on average and less variable than they appear to be when the correlation between wage growth and investment returns is ignored. Using the realised wage growth rate and implementing its correlation with investment returns, instead of assuming a constant growth rate, halves the median DC fund ratio.

Where countries rely upon a state pension system or an occupational pension system, the risk attached to pensions is borne respectively by the taxpayer or the employer. In addition governments frequently provide a degree of insurance to occupational schemes.[1] But around the world there has been a trend towards funded defined contribution (DC) personal pension schemes.[2] In a DC scheme, an individual builds up his or her own pension fund to provide an

[1] Examples of explicit government insurance of occupational pension schemes are the *Pension Benefit Guaranty Corporation* in the U.S.A. and the *Pension Protection Fund* in the U.K. Within the E.U. governments are required to provide a minimal level of insurance of occupational pensions through the European Insolvency Directive (80/987), as interpreted by the European Court of Justice (case C278/05).

[2] James (1997), Poterba, Venti and Wise (1998), Miles and Timmermann (1999).

income during retirement, and bears the pension risks.[3] Governments may compel individuals to invest in such schemes or may encourage them to do so through providing tax incentives. At retirement the pension fund may be converted into an income stream through annuitization, which may be compulsory, or there may be limits on the amounts of the fund that can be decumulated.

Regardless of these details, the individual's personal pension does not receive the sort of guarantees which are found in state or occupational pensions. From the perspective of an individual pensioner, the important questions that this move to DC raises are: how well is such a scheme likely to perform and how much risk is there in such a scheme (Turner, 2006)?[4]

Our approach to answering these questions is to use historical data to calculate hypothetical DC pensions. We pose the counter-factual conditional: what pension would someone have achieved if they had been able to invest a DC pension scheme and earned the investment returns which actually occurred over the twentieth century?[5] Our methodology follows previous work, but using many more data. Burtless (2003) addressed this question using data from the period 1927-2001 for France, Germany, Japan, the UK and the USA, but

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[3] Examples of such schemes are the USA's 401(k) pension plans, the UK's personal pensions and proposed National Employment Savings Trust (NEST), Germany's Riester plans, Australia's Superannuation system and New Zealand's KiwiSaver scheme. Individual pension savings plans also exist in Austria, Czech Republic, Denmark, Greece, Finland, Ireland, Netherlands, Slovenia and Spain (Economic Policy Committee and the European Commission (DG ECFIN), 2006).

[4] State and occupational pensions are not risk free and ideally we should compare the risk of a DC scheme with that of the alternatives. Such an exercise is beyond the scope of the present paper.

[5] MacDonald and Cairns (2009) examine feedback effects from DC plan accumulation to the labour market.

without using actual wage data;[6] this is up-dated for the USA in Burtless (2007). Shiller (2006) analyses USA data for the period 1871-2004. Samwick and Skinner (2004) and Poterba *et al* (2007) compare simulated wealth accumulations from DB and DC pension plans emphasising the importance of incorporating earnings histories. Basu and Drew (2010) examine alternative risk measures in simulated DC plans for Australia. Vidal-Meliá, Domínguez-Fabián and Devesa-Carpio (2006) simulate the risks in a notional DC scheme. Blake, Cairns and Dowd (2001) estimate the riskiness of DC pension plans during the accumulation phase and find that they are much riskier than a DB alternative. Cocco and Lopes (2011) compare the risks in DC and DB schemes, and find that workers select into schemes that are optimal for them given their characteristics.

The appropriate metric for measuring pension fund investment performance is not the absolute size of an individual's pension fund at retirement but either the *replacement ratio* or possibly the size of the pension fund relative to final labour income (the *fund ratio*). From the perspective of a consumer who has some desire to smooth consumption – the replacement ratio makes sense. However, there is also a macroeconomic reason for choosing these variables: economies which have high investment returns will tend to be "successful" economies and thus also have high wage growth. Scaling the pension by final labour income goes some way to distinguishing having a successful pension from living in a successful economy. Previous studies which have not used actual wage data do not take this issue into account.

Benzoni, Collin-Dufresne and Goldstein (2007) analyse this problem theoretically, allowing for the dividend and wage series being cointegrated in the long-run. Their conclusion

[6] For his comparison of international replacement rates, Burtless (2003) simulates distributions assuming the lifetime path of real earnings for each country matches the age-earnings profile of employed U.S. men in 1995, and grows at 1.5 per cent per year.

is that young investors should short equities early on in the lifecycle. Since wages and equity returns are correlated over the longer term this effectively allows investors to insure against the whole economy doing badly. In practice it is difficult to see how significant numbers of savers could follow such a policy, since no financial institution could provide such insurance on a wide scale. Consistent with the idea that investors should hedge against poor performance of their domestic economy, Burtless (2007) provides historical evidence that savers would do better to invest most – or indeed all – of their pension fund abroad, but we do not consider this international diversification issue further here.

Using historical data on 20th Century returns for the UK and an historical annuity rate series for the period 1957-2002, Cannon and Tonks (2004) showed that the annual variation in hypothetical pension funds would be partially hedged by variation in the annuity rate. Since annuity rates are generally unavailable for most countries, we complement our hypothetical pension funds with annuity rates constructed from historical bond yields and actuarial data. Our analysis is conducted for sixteen countries using the updated data available in Dimson, Marsh and Staunton (2002).

Throughout the paper we do not assume utility maximisation but that individuals have a constant savings rate. The reasons for this are both pragmatic and theoretical. Pragmatically, to introduce optimisation would be to write a longer (or another) paper. Theoretically, we are uncertain how any individual could work out the optimal strategy. Disney and Emmerson (2004) suggest that government policy on pensions alone is so changeable that it is impossible to predict what it will be over a lifetime. The time frame of our analysis begins with someone entering the labour market in 1909, who would face two world wars, at least one financial crisis (depending on his nationality), the rise of extreme nationalist political movements and an influenza pandemic. During the gestation of this paper, we have experienced the largest financial crisis since the 1930s, the possibility of an influenza epidemic (which then failed to occur), the resurgence of far right political parties in European elections and the uncertain challenges of climate change. *Plus ça change, plus c'est la même chose*.

The rest of the paper is organised as follows. In section 2 we describe our analytical framework, our data sources and the relationship between investment returns and labour income. Section 3 calculates hypothetical pension-fund ratios and Section 4 extends the analysis to provide frequency distributions for these ratios. In Section 5 we estimate replacement ratios for hypothetical individuals retiring in the twentieth century. Section 6 concludes.

2. Method and Data

2.1 Fund Ratios and Replacement Ratios

Diamond (1977) introduces the concept of a pension *replacement ratio*, defined as the ratio of the pension income to labour income (net of pension contributions) in the final year of employment. If the savings rate is 10 per cent and pension income is 60 per cent of labour income, then the pension replacement ratio is 60/90 = 2/3 and Diamond suggests that this replacement ratio might be appropriate.

In fact the optimal value of the replacement ratio is unclear. In a simple utility-maximising framework where agents only wish to smooth consumption flows, the optimal ratio would be one. However, this result does not follow if agents also obtain utility from leisure and if utility is not additively separable in consumption and leisure: because leisure increases discretely at the point of retirement we should also expect consumption to fall discretely (assuming that the two goods are substitutes at the margin).[7] There are two further reasons for consumers' expenditure (as opposed to consumption) to change upon retirement: the elimination of work-related spending (such as commuting) and variation in the real value of consumption (arising both because the budget shares of goods change and because retired individuals typically face different prices due to favourable price discrimination). The UK's Pension Commission (2004) suggests a range of benchmark replacement ratios from 80 per cent for low earners, 67 per cent for median earners, and 50 per cent for top earners.

The replacement ratio compares retirement income to final labour income, and if a pensioner annuitizes his pension wealth then this is the appropriate assumption. However, Cannon and Tonks (2008) note that many countries have thin annuity markets, and this suggests that we should look at a different metric of pension wealth, namely the pension *fund ratio*. This is related to the replacement ratio by[8]

$$\text{(1)} \qquad \textit{replacement ratio}_t = \textit{annuity rate}_t \times \textit{fund ratio}_t$$

We index all of the variables by t to emphasise that we re-calculate these figures for every year. Note that all of our calculations are done individually for each country: throughout this section all formulae are country specific but for notational tidiness we do not include a country index.

Equation (1) suggests that the optimal pension fund ratio might be the optimal replacement ratio divided by the annuity rate. Since annuity rates for a 65-year old male would

[7] Some age-related expenditures are discrete rather than continuous choice variables, providing a further explanation for discontinuity at retirement.

[8] By the annuity rate we mean the ratio of the annual income to the single premium paid for an annuity. This is the reciprocal of the value of an annuity paying one unit per year (the latter is denoted *a* in standard actuarial notation).

typically be in the range of 5-10 per cent, then a target replacement ratio of 0.8 would suggest an optimal pension fund ratio of between 8 to 16. In our analysis we assume that an individual saves for his pension from ages 25 to 65 and is in employment during that time earning a labour income y_k in year k.[9] Then someone retiring at time t will have a pension fund equal to

$$\text{(2)} \qquad pension\ fund_t = s\sum_{i=1}^{40} y_{t-i} \prod_{j=1}^{i} (1+r_{t-j})$$

where s is the savings rate from labour income and every year the entire value of the fund (including previous years' returns which are re-invested) earns a rate of return r_{t-j}.[10] We report the *fund ratio* as

$$\text{(3)} \qquad fund\ ratio_t = \frac{pension\ fund_t}{final\ net\ labour\ income_t} = \frac{s\sum_{i=1}^{40} y_{t-i} \prod_{j=1}^{i} (1+r_{t-j})}{(1-s)\,y_{t-1}}$$

where "net" labour income means labour income after deduction of pension contributions, not taxes. In developed countries, savings through a pension scheme typically receives a favourable tax treatment, and Dilnot and Johnson (1994) and Antolin, Pugh and Stewart (2008) compare tax systems across countries. They document that the most common tax system for pension savings is the exempt-exempt-taxed (EET) model (deductibility of pension contributions from taxable income; no tax on investment income of the pension fund; but taxation charged on withdrawals at retirement). In terms of our simulations, the fact that investment returns on fund

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[9] An additional problem is that the individual may have a broken work history. We augment our analysis with estimates for the effect of unemployment, but other issues (such as problems for women who withdraw from the labour force to care for family members) are beyond the scope of this paper.

[10] This formula assumes that pension contributions are made at the beginning of the year, whereas in fact contributions are likely to be made continuously (or at least monthly) throughout the year, but we are unable to model this since we do not have intra-year data.

assets are exempt from tax (i.e. the middle "E"), is the most important, since our results all depend upon that assumption in a highly non-linear fashion. Nearly all of the countries in our sample satisfy this requirement.[11] We do not explicitly allow for the detailed myriad of differences within the broad EET model, and this acts as a caveat on our comparisons between countries.[12]

In our simulations we assume that the savings rate s is 10 per cent. The UK's Office for National Statistics (2008) reports that contribution rates into occupational DC schemes are 8.8 per cent of salary per annum (made up of 3 per cent contributions from members and 5.5 per cent from employers).[13] Note that doubling the savings rate would more than double the Fund Ratio since s appears in both the numerator and denominator of equation (3).

The rate of return on pension assets depends upon bond and equity yields, respectively r_t^B and r_t^E. If a proportion θ is invested in equity then the overall return is

$$(4) \qquad r_t = \theta(r_t^E - c^E) + (1-\theta)(r_t^B - c^B)$$

where c^E and c^B are respectively the annual management charges for managing an equity or bond portfolio. There is some evidence that actively managed funds outperform the market index, but that this improvement is offset by higher charges (Malkiel, 1995; Sandler, 2002).

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[11] Of the countries that do not, both Australia and Sweden had EET systems prior to recent changes in the nineteen nineties; in Denmark since 1984 real investment returns have been taxed above a threshold; in Belgium, fund income is taxed depending on the asset class in which the fund is invested.

[12] Yoo and Serres (2004) provide estimates of the net tax cost of pension contributions across countries on the basis of contributions made in 2000.

[13] According to the Personal Accounts Delivery Authority (2009), the UK's proposed individual-based DC Personal Accounts (renamed NEST) recommends a contribution rate of 8 per cent per annum (made up of 3 per cent from employers, 4 per cent from employees, and 1 per cent tax rebate).

"Index" or "tracker" funds have relatively low annual charges, and we assume 2 per cent for equity and 1 per cent for bonds in most of our analysis, consistent with the reported charges in Chapman (1999) and Whitehouse (2000).

We consider four different investment rules: (a) invest entirely in equity for the whole forty years; (b) invest entirely in bonds for the whole forty years; (c) manage the portfolio so that in every year half is in equity and half in bonds; (d) a "life-cycle" scheme where everything is invested in equity for the first 28 years and everything in bonds for the last three years – in the intervening nine years the fund is gradually moved from equity to bonds.[14] The life-cycle scheme approximates to the suggested rule of many fund managers, who argue that it is too risky to hold equity towards the end of the accumulation phase of a pension (Schooley and Worden, 1999).

We model labour income with a single representative worker, so labour income equals the national average labour income. In practice individuals wages tend to be correlated with age. Using data for individuals born between 1921 and 1925, Disney and Emmerson (2005) estimate that real wages in the UK rise relatively quickly until an individual is about 40 years old and then typically level off. Following Miles (1997) we use the following formula for an individual's wages

$$y_{age,t} = \bar{y}_t \exp\left\{0.05\, age - 0.0006\, age^2\right\} \qquad (5)$$

where $\bar{y}_t$ is a wage purged of age effects, which we refer to as the *underlying wage*. When combined with economy-wide annual real wage growth of 2 per cent this results in a series

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[14] Shiller (2006) considers a wider range of life-cycle schemes, all of which have fewer stocks in the portfolio earlier on: compared with Shiller's funds, ours would be characterised as more "aggressive". In the United Kingdom this sort of scheme is called a *lifestyle* scheme rather than a *life-cycle* scheme.

similar to that of Disney and Emmerson (2005), many of the earnings profiles in Poterba, *et al* (2007) and to the series from other countries (Miles, 1999).

To implement equation (5) we need the underlying wage $\bar{y}_t$. Unfortunately the only variable available is the national average wage, so it is necessary to estimate $\bar{y}_t$. For consistency with equation (5) we use the following procedure. We denote the proportion of males of a given age as $\phi_{age,t}$ (for simplicity we only consider males in the range 18-65). Multiplying equation (5) by $\phi_{age,t}$ and summing across ages, we get

$$(6) \qquad y_t = \sum_{age} \phi_{age,t} y_{age,t} = \bar{y}_t \sum_{age} \phi_{age,t} \exp\left\{0.05\, age - 0.0006\, age^2\right\}$$

where the first equality follows from the definition of the average wage. From this we can infer

$$(7) \qquad \bar{y}_t = \frac{y_t}{\sum_{age} \phi_{age,t} \exp\left\{0.05\, age - 0.0006\, age^2\right\}}$$

Surprisingly, this adjustment makes little difference, since $\bar{y}_t$ and y_t are highly correlated. The explanation is that an individual's wage relative to the underlying wage is maximised at about 42 years old.[15] The average age of workers is never very far from this maximum, where the function $0.05\, age - 0.0006\, age^2$ is approximately flat. Furthermore, since the function is symmetric about 42, an increase in the proportion of workers above 42 which is offset by a similar reduction in the proportion of workers below 42 has no effect at all on the ratio of the

[15] The worker's wage relative to age-independent wages is falling after age 42. But the worker's real wage is not falling since the age-independent wage is typically rising. When underlying real wage growth is about 2 per cent per annum an individual worker's wage is rising until about age 50 and thereafter approximately flat.

average wage to the underlying wage. Empirically, when we feed the population data into equation (7) the denominator is almost constant over time for every country we analyse.

So far we have assumed that the individual is continuously in work, but many workers face unemployment risk. We supplement our analysis with a further set of simulations assuming that individuals' unemployment probabilities mirror the economy's unemployment rate. This is a crude adjustment for an individual's unemployment risk, but it is arguably an improvement on the literature which makes no allowance for such events. Writing the unemployment rate as u_t, we assume that an individual makes no pension contributions when unemployed and hence the equation for the fund ratio becomes

$$\text{(8)} \qquad \textit{fund ratio}'_t = \frac{s\sum_{i=1}^{40}(1-u_{t-i})\, y_{t-i}\prod_{j=1}^{i}(1+r_{t-j})}{(1-s)\, y_{t-1}}$$

Notice that in the denominator of this definition we use labour income without any adjustment for unemployment: the interpretation of this fund ratio is the pension fund divided by the wage that a worker would have received had he been working.

To calculate a pension replacement ratio we multiply the pension fund ratio by an appropriate annuity rate. Since annuity rates across countries are not readily available, we impute annuity rates from bond yields and mortality rates.[16] We use the bond yield on medium to long-term government bonds, and convert these bond yields to annuity rates by using just one set of mortality tables for every country and year: the mortality table chosen was the UK's PMA92 life tables for pensioners. The formula used to calculate the value of an annuity in country *i* in year *t* for a 65-year old male is then

[16] Many actuarial texts calculate the value of an annuity using a constant medium term bond rate.

(9) $$a_{i,t} = \sum_{j=65}^{110} \pi_{UK92,j} \left(1+\rho_{i,t+j-65}\right)^{-j}$$

where $p_{\cdot,j}$ is the one-year survival probability for a male aged *j*, and ρ is the relevant yield to maturity. Cannon and Tonks (2008) show that annuities in the UK are typically priced about 12 per cent higher than their actuarially fair value, but since there is only limited data on annuity loadings across countries and in different time periods, we assume annuities to be fairly priced. This means that the replacement ratio that we report in Section 5 is calculated using

(10) $$replacement\ ratio_{i,t} = \frac{fund\ ratio_{i,t}}{a_{i,t}}$$

Because we wish to see the effect of yields varying with wages and returns we contrast this with the replacement ratio that would result if each country's annuity rate were constant over time:

(11) $$replacement\ ratio'_{i,t} = \frac{fund\ ratio_{i,t}}{T^{-1}\sum_t a_{i,t}}$$

2.2. Data Sources

We obtained equity and bond returns for a cross-section of international financial markets from Dimson, Marsh, and Staunton (2002), who present a comprehensive and consistent analysis of investment returns for equities, bonds, bills, currencies and inflation for the period 1900-2000. From their study we use the data from Australia, Belgium, Canada, Denmark, France, Germany, the Republic of Ireland, Italy, Japan, the Netherlands, Norway, Spain, Sweden, Switzerland, the U.K. and the U.S.A. Since the publication of the 2002 book the data have been up-dated to 2008 and extended to include Norway and are available from Ibbotson Associates. Most of our data on earnings growth and unemployment was obtained from Mitchell (1998)'s collection of a variety of historical data about the labour markets in different countries.[17] The advantage of using Mitchell (1998) for data up to the 1990s is that it relies upon the judgement of a highly respected economic historian and removes any possibility of selection bias in the data.[18] The vast majority of Mitchell's data is taken from data provided by government statistical agencies, and they are perhaps best described as "semi-official". To bring the wage series up to date we use data from the *OECD Main Economic Indicators* (since Swiss data were not in the OECD MEI we took recent Swiss data from the Swiss Federal Statistics website). It is difficult to make judgements about the absolute or relative accuracy of the earlier data and there are a variety of trade-offs: data from the USA may be of high quality but they cover a large and heterogeneous country; data from a small country such as Norway appears to be of high quality and suffers less from heterogeneity; data from the UK is high quality and very comprehensive (British Labour Statistics, 1971) but is affected by changes in definition and scope.[19] The data we use sometimes refer to the whole economy and sometimes (particularly in the early 20th Century) to manufacturing alone. Where possible we rely entirely on data for male workers for manufacturing or the economy as a whole (agricultural wages are generally excluded). Wage data of any sort is unavailable in Mitchell (1998) for some of the earlier years for some

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[17] As a robustness check, we repeated the analysis for four countries where more recent and significantly revised data happened to be available, referring to: *Historical Statistics of the United States* (Carter *et al*, 2006) which reports data supplied by Robert Margo; *Historical Statistics of Canada* (which is available on line); Grytten's (2009) data on Norway; and Prado's (2010) data for Sweden.

[18] We ignore very small changes in definitions (such as small changes in scope of coverage). Where series are created from more than one index we splice series based on the overlap year. Occasional missing years are interpolated in the fund-ratio analysis: the biggest problem is that of obtaining unemployment during the Second World War, where we have had to interpolate for several countries. In one or two cases, series are joined without there being an overlap: in these cases we use the best available alternative series to determine the splice (either an alternative wage series or, in one case growth in nominal GDP per capita).

[19] A similar problem applies to France: see Annuaire Statistique de la France: Résumé Rétrospectif (1966).

countries. We do not attempt to model wages for Germany before 1923 nor Ireland before 1921. Japanese data are unavailable for 1901-1936, Dutch data for 1901-1926, Spanish data for 1901-63 and Swiss data for 1901-1930. In these four latter cases we assume that in the missing years wages grow in line with GDP per capita using Maddison's *Statistics on World Population, GDP and Per Capita GDP, 1-2006 AD* (these data are available on the web and are discussed in Maddison, 2007).[20] We realise that per capita GDP growth is only a very poor proxy for wage growth and so only use it when no other source is available and in our results we draw attention to when these less satisfactory data are available. In years for which both nominal GDP growth and nominal wage growth are available, the correlations between these two variables are: Netherlands 0.66; Spain 0.73; Switzerland 0.59; Japan 0.68. The final complication is that countries differ on whether they report hourly, daily wages or annual wages. Since the length of working year may vary over time, the annual and hourly series will typically behave differently, especially in the long run. The length of the working year is determined by a combination of institutional factors and workers' preferences: one oft-mentioned stylised fact is that increased productivity is taken partly in leisure in European countries, whereas the labour supply per person has declined less in the USA. Conceptually it is not clear whether we should prefer hourly wages or annual wages. In terms of the data available to us there is little that we can do about this, so we ignore this issue and merely report the wage series we are using for each country. With the data discussed we are able to calculate hypothetical fund ratios both with and without unemployment risk. To calculate the pension replacement ratios we use government bond yield data taken from the IMF's *International Financial Statistics*.[21]

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[20] In addition we do not have data for Norway from Mitchell for the three years 1908-1910, but we infer these from Grytten (2009).

[21] Dimson, Marsh and Staunton (2007) include data on bond returns, but not on bond yields.

2.3 Preliminary Discussion of the Data

We start by discussing the relationship between these wages and investment returns. The first row of Table 1 reports the correlation coefficient on the raw data: all data are in real terms.[22] This suggests moderate correlations between equity and bond returns and bond returns and wages, but that wages and equity returns are not correlated. Part of the reason for this is that equity returns and wage growth are not perfectly synchronised: for example, good news for the economy's future prospects may result in immediate changes in the stock market but the effect on wages will occur later (i.e. stock returns are a leading indicator). A simple method which partially addresses this problem is to smooth each country's data series and look at the correlations between the smoothed series.[23] After smoothing, there is a negligible correlation between bond returns and wages but a small and significant correlation between wages and equity returns. For equity returns to insure the fund ratio against fast wage growth we need a positive correlation and this is *prima facie* evidence that equity returns will act as a partial hedge.

[Table 1 about here]

In Table 1 we also report additional information to illustrate the variation in correlations across time and between countries. If we confine ourselves to correlations in the complete data set for just the post-war period then the notable difference is that bond returns have a much lower correlation with wages. The final panel of Table 1 demonstrates the large variety of correlations between the three variables within each country.

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[22] Since the sample size is 1,404, the conventional test for statistical significance of the correlation coefficient would require it to be greater than about 0.05: in fact there is likely to be heteroskedasticity and residual correlation; so this critical value is not valid.

[23] The series is smoothed using a natural cubic spline with a roughness penalty using the algorithm in *Ox* (Doornik, 2009).

3. Fund Ratio Calculations

In this section we report our calculations for fund ratios and discuss how these vary across time, country and investment strategy. Recall that a ball-park annuity rate for a 65-year old man is 5 per cent, suggesting that for a target replacement ratio of 0.8, the desired fund ratio should be about sixteen. Even allowing for higher annuity rates and receipt of an adequate first-tier government pension, one would not want the fund ratio to be much lower than ten.

[Figure 1 about here]

Figure 1 shows the pension fund ratios for the all-equity and life-cycle investment strategies for all sixteen countries. Note that, because of the large cross-country variation in fund ratios we use different scales for the vertical axes in these graphs. The striking feature about this graph is that the actual historical pension fund ratio appears to be low for nearly all countries in nearly all time periods for both the all-equity and life-cycle strategies. It does appear that the volatility of fund ratios is lower for the life-cycle strategy reflecting the asset allocation of the pension fund being invested in equity for most of the accumulation phase of the life-cycle strategy, only gradually moving to bonds towards the end of the period.

[Table 2 about here]

We present the same calculations in more detail in Table 2. Panel A reports for the four alternative investment strategies, the median fund ratio for all sixteen countries averaged over the time series for that country. All countries have median fund ratios considerably lower than sixteen for each asset allocation strategy. The average value across all countries of the median fund ratio for the all-equity strategy is only 8.99. The all-equity strategy dominates the all-bond and the 50:50 bond:equity strategy for each country. Except for Germany and Ireland the equity strategy also has a higher average than the alternative life-cycle investments (although these figures are not strictly comparable since they are not calculated for the full period). Among the countries with average fund ratios greater than ten are all of the Anglo-Saxon countries (Australia, Canada, Ireland, the UK and the USA) and only two continental European countries (Belgium and Spain). There is considerable downside risk for all four types of investment strategy. Panel B provides the lower decile fund ratio. With the possible exception of the USA using the all-equity strategy, these figures are much too low for comfort, suggesting considerable risk that the pension fund will be inadequate. While our analysis confirms that of Shiller (2006) that the life-cycle investment strategy does not provide adequate insurance compared to the all-equity strategy for the USA, we do find that there are six countries where the life-cycle investment strategy provides a lower decile which is greater than or approximately equal to the all-equity strategy (Belgium, Denmark, Germany, Netherlands, Spain, Switzerland). Of the 923 country-year observations for which we calculate a fund ratio, the life-cycle investment strategy fund ratio is significantly greater (more than ten per cent more) than the all-equity one in 23 per cent of cases. These are predominantly concentrated in Japan and continental European countries. Even in the USA there are several years (notably someone retiring in 1974 and 2002) when the life-cycle strategy would have substantially beaten the all-equity strategy, suggesting that the life-cycle strategy has some advantages in insuring downside risk in particularly bad periods.[24] Shiller's (2006) conclusion that a life-cycle investment strategy does not provide adequate insurance against downside risk cannot be generalised to all countries.

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[24] Burtless (2003) does not compute the life-cycle investment strategy so we cannot make a direct comparison, but it is notable that the all-equity strategy performed particularly badly for someone retiring during World War One, its immediate aftermath or in the crash of 1930. We conjecture that the life-cycle strategy would have beaten the all-equity strategy in those years and for 2008-2010.

An important contention of this paper is that historical wage data should be used alongside historical investment returns in assessing the value of pension funds. To gauge how important this actually is we repeated all of our analysis under the assumption that underlying real wages grew at exactly 1.5 per cent per year. This is the assumption made by Burtless (2003) – in fact the average wage growth for all of our countries over the period 1908-2007 is 1.6 per cent. An individual's wage is still related to the average wage using equation (5). To illustrate this graphically, Figures 2 and 3 provide simple cross-plots of the fund ratios (all-equity strategy) against the corresponding 40-year average real equity return (net of charges) for all country-year observations.

[Figures 2 and 3 about here (one above the other to facilitate comparison)]

As might be expected there is a strong positive and possibly log-linear relationship in both cases. However, there are marked differences in the graphs: the vertical scales are dramatically different. Even if we were to remove the substantial number of apparent outliers from Figure 3, there would still be significant numbers of fund ratios in the range 60-100, whereas it can be seen from Figure 2 that our calculations produce no fund ratios in this range when using historical wage data. We also report these results in Panel C of Table 2: the median fund ratios with the constant wage growth are much higher, often by a factor of about two.[25] The implication of comparing the median fund ratios in Panels A and C, is that, as we established in Table 1, equity returns and wage growth in a particular country, and over a particular time period, is correlated. This means that the accumulated savings in a pension fund needed to sustain a target replacement ratio will be affected by both the equity returns and the growth in wages. Economies that experience low wage growth over particular time-periods have

[25] The lower deciles are also much higher.

associated low equity returns over those same periods, and the effect of the latter is sufficiently strong to result in substantially lower fund ratios.

The final source of risk that we take into account is the effect of unemployment. Figure 4 shows the time-series plots for each country for a life-cycle investment strategy both without unemployment (the same as in Figure 1) and with unemployment risk as measured by equation (8).[26] The interesting feature about these figures is that the difference is small: including an adjustment for unemployment only reduces the median fund ratio by about five per cent.[27] Partly this is because unemployment has been low for much of the period for which we have data, but it is also because we are only measuring the effect of macroeconomic unemployment risk on the average pension. Since unemployment is a binary variable, an individual's experience of unemployment will differ from the average much more than an individual's wage might differ from the average wage.[28] This brings us back to the conceptual issue of our definition of pension risk: although individuals who are particularly unlucky in their working life or particularly prone to unemployment are likely to have poor pensions, this is not a failing in the pension *per se*, but a failing in some other part of the economy: the labour market.

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[26] We have insufficient data to perform calculations for France and Spain, but to facilitate comparison of graphs by eye we retain the same arrangement of each country's graph.

[27] This is the average reduction in median fund ratio for all countries and time periods in which relevant data are available. The reduction does not vary much between countries and the largest reduction is for Ireland (9 per cent). In additional analysis not reported here we also see whether the unemployment adjustment makes a big impact on the downside risk by looking at the effect on the lower decile. The reduction for this statistic is about nine percentage points with the largest reduction being for Denmark (16 percentage points).

[28] In addition to this, an individual's unemployment status may be more serially correlated than aggregate unemployment, due either to heterogeneity in workers or scarring. We are unable to model this in a representative agent framework.

[Figure 4 about here]

Our calculations have assumed annual management charges of 2 per cent for equities and 1 per cent for bonds. In fact pension schemes in some countries such as the UK and the Netherlands often have charges of 1 per cent or lower. Shiller (2006) quotes USA social security actuaries as suggesting charges of figures for 0.3 per cent. Bateman, Kingston and Piggott (2001) quote annual management charges of between 0.4 and 1.8 per cent in the Australian pension industry, and the Pension Commission (2005) notes that the Swedish pension scheme is aiming for management charges of 0.33 per cent. With these lower charges the pension fund ratios are considerably higher, with the all-equity strategy increasing from a median of 8.99 (Table 2 second column), to 11.05 with a 1 per cent per cent management change, and to 12.84 with a 0.3 per cent fee; although the downside risk would remain considerable.

4. Simulation Analysis

So far we have calculated fund ratios using realised historical data for sixteen countries for the period 1948-2007. However, these calculated ratios are not independent since they use overlapping data on investment returns and wages. To address this problem we conduct a simulation analysis for equity returns, bond returns and wage growth for each country. In each case we estimate the following VAR by OLS:

$$\mathbf{x}_t = \mu + \pi_1 \mathbf{x}_{t-1} + \pi_2 \mathbf{x}_{t-2} + \varepsilon_t \qquad \mathbf{x}_t \equiv \left(r_t^B \quad r_t^E \quad \Delta \ln w_t \right)' \tag{12}$$

We then use the estimated parameters to simulate the joint behaviour of financial returns and wages.[29] These simulated returns are then used to calculate fund ratios assuming individuals' wages to be determined by the aggregate wage multiplied by the formula in (5) and annual charges to be 2 per cent on equity and 1 per cent on bonds as above. Before estimating equation (12), however, we first address the issue of parameter constancy. The time series behaviour of fund ratios in Figure 1 suggests that there may be considerable instability in the underlying data generating processes. Many of the histograms of the fund ratios are bi-modal, further evidence that there might be structural changes in each country's data series. For this reason we supplement the simulation analysis based on the whole period with simulations based on sub-periods.

[Figure 5 about here]

Figure 5 is a box plot comparing the inter-quartile ranges (and 5th and 95th centiles) of the simulated probability distributions of pension fund ratios from the simulations based on data from just the last sub-period for the years 1979 onwards, where the density plots are truncated at values of 160 (a small number of simulations produced fund ratios much higher than this). The median and lower decile fund ratios from the three simulations (all-equity; 50:50 bond:equity and life-cycle) are shown in Table 3. It can be seen that the all-equity investment strategy appears to dominate the other two: the relatively rare instances where this is not the case are shaded in Table 3.

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[29] None of these variables are obviously trending over the period. Using the Akaike or Schwartz criteria alone we would typically have chosen only one lag in the VAR, but such models evidenced considerable residual autocorrelation, which was absent or highly attenuated in models with two lags. Excess kurtosis in the residuals was ignored at the estimation phase but incorporated into the simulation through bootstrapping. Evidence for heteroskedasticity - probably ARCH - was ignored on the grounds that we had too little data to model it.

[Table 3 about here]

The median pension fund ratio across the three alternative asset allocation strategies is typically lower than the recommended value of 16 that we suggested in Section 2.1. The average median value across countries for the all-equity strategy is 10.7. Although for each strategy there is significant upside potential, according to Panel A over the whole data sample period 1902-2007, for the all-equity strategy there is a ten per cent probability of getting a fund ratio of 8.4 or less for Australia and of 5.9 or less for the US, but a ten per cent probability of getting less than 1.9 for France, 2.9 for Germany, 1.7 for Italy and Japan. The other panels in Table 3 consider simulations based on data from three sub-sets of the sample period: the post-war period, 1948-2007; the Golden Age and Stagflation, 1948-1978; and 1979-onwards. We can see from Panel B that for most countries the higher financial returns in the post-war years resulted in higher average fund ratios and lower downside risk, than over the whole of the 20th century from the numbers in Panel A, although there are some exceptions, such as Australia and Spain. Dividing the post-war period into the two sub-periods before and after 1978, we can see from Panel C that with the exception of Japan the average fund ratios are much higher using data from the post-1978 period, than from pre-1978.

5. Annuity rates and replacement ratios

We now turn to the question of what sort of income these accumulated pension funds could provide. To do this we construct hypothetical annuity rates using the method described in Section 2.1 and match these to the fund ratios calculated in section 3. Table 4 illustrates the median and lower decile pension replacement ratios resulting from calculating the replacement ratio in equation (10). Given the wide range in fund ratios, it is unsurprising that the median replacement ratios are often only about a half and the lower decile much lower.

[Table 4 about here]

To measure the extent to which movements in yields (and hence movements in annuity rates) are likely to hedge movements in the fund ratio, we calculate the ratio of the standard deviation of the replacement ratio (from equation 10) to the ratio of the standard deviation of the replacement ratio with annuity rates held constant (from equation 11): the results are reported in Table 4, column 4. For every county except Canada the ratio is less than one and it is typically about 0.8. This suggests that the movements in yields typically act as some form of hedge. But there are two caveats to this. First, movements in yields are partially driven by inflation and high yields may inadequately protect against future inflation. Second, column 3 reports the lower decile pension replacement ratio calculated from equation (11), with a constant annuity rate. If movements in yields were an effective hedge against downside risk, then we should expect column 3 to have lower numbers (more downside risk) than column 2. While this is the case for Canada, Denmark, Ireland, Sweden, the U.K. and the U.S.A., there are many countries where either the lower deciles are the same or the lower decile is actually lower for a constant annuity rate. In the latter category we find Japan, whose interest rates have been low due to the "lost decade", but also Australia, Germany and Spain. This suggests that even if annuity rates may act as a partial hedge to variation in the fund ratio, this co-movement does not insure particularly well against downside risk.

6. Conclusions

We have examined pension fund and pension replacement ratios for all of the major developed countries over the twentieth century. Our analysis calculated fund ratios in two ways: constructing hypothetical fund ratios using historical data and simulating fund ratios using the estimated behaviour of investment returns and wages. By examining the properties of these ratios across a wide range of developed capital markets we may better assess the risks in such pension schemes, since in effect we are examining the properties of 16 "independent" economies.[30]

We have found that there is considerable variation in fund ratios across both time and country, and all investors in all countries face considerable downside risk. We computed the pension fund ratios under alternative investment allocation strategies, and found that median values of pension fund ratio has an average value across countries of 8.99 for the all-equity strategy, which is low and only just above the lower bound of the optimal fund ratio that we identified in Section 2.1. Evidence from median values of the fund ratio is that an all-equity strategy always dominates all-bonds, and the 50:50 bond-equity, but that life-cycle is sometimes better than all-equity, and for some countries provides better downside risk protection.

We have extended the existing literature to analyse the relationship between investment returns and wage growth. We find that wage growth and investment returns tend to be positively correlated, which is unsurprising as a country experiencing a successful period of development would usually have both high wage growth and high investment returns. Since we are interested in the ratio of the pension fund to the final wage, a positive correlation in wages and returns means that the two variables might hedge each other.[31] Since the pension fund ratio is a non-linear function of wages and returns, the wage-returns correlation affects not just the variance but also the expected value of the pension (or any other measure of central tendency

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[30] Clearly these economies are not completely independent as witnessed by the recent credit crisis. However, for much of the 20th century various types of exchange controls has meant that international capital markets were effectively segmented.

[31] Intuitively, the variable of interest is the *ratio* of pension fund to final wage, so positive correlation tends to reduce the variance of the ratio. Since wages also appear in the numerator the overall effect is more complicated.

such as the median). If the positive correlation is ignored the pension fund ratio will have a higher variance and will also be higher on average. We found that the effect of assuming the average constant growth rate of wages rather than using the realised wage growth rate, more than doubles the median fund ratio. In measuring pension risk we are primarily interested in the possibility that the pension is too low. *Prima facie* the overall effect of wage-return correlation on downside risk is unclear.

To construct hypothetical replacement ratios we have also estimated hypothetical annuity rates based on bond yields (holding mortality constant). If individuals purchased nominal annuities then the initial pension incomes would be satisfactory, with an average median value of the replacement ratio across countries of 1.23, which is high; but these nominal annuities would decline over time in real terms. If instead individuals purchased real annuities, then the pension income would have been less satisfactory: the median replacement ratios we calculated are below unity and these are based on population mortality and actuarially fair pricing. There is considerable downside risk: some countries such as France, Italy and Spain face a ten percent probability of having a real replacement ratio of 0.25, 0.20 and 0.17 respectively.

The effect of bond yields on annuity rates would reduce the risk in the hypothetical replacement ratios, where risk is measured by standard deviation. This is because of the joint correlation between equity returns, bond returns and bond yields. In the present value model there is an inverse relationship between values and discount rates. Hence when equity markets are high, bond yields are low, so high pension fund values convert into a relatively small annuity. Conversely depressed equity markets are typically associated with high bond yields, which provides for a relatively high annuity incomes. So the distribution of replacement ratios is smoothed by the bond and equity correlations. However, this hedge is not particularly good at reducing downside risk (as measured by the lower decile).

References

Annuaire Statistique de la France: Résumé Rétrospectif (1966).

Antolin, P., C. Pugh, and F. Stewart (2008), "Forms of Benefit Payment at Retirement", OECD Working Papers on Insurance and Private Pensions, No. 26.

Basu, A. K., and M.E. Drew (2010) "The appropriateness of default investment options in defined contribution plans: Australian evidence," *Pacific-Basin Finance Journal*, 18(3): 290-305.

Bateman, H., G. Kingston, and J. Piggott (2001) *Forced Saving: Mandating Private Retirement Incomes* (Cambridge University Press, 2001)

Benzoni, L., P. Collin-Dufresne and R.S. Goldstein (2007) "Portfolio Choice Over the Life-Cycle when the Stock and Labor Markets are Cointegrated" *FRB of Chicago Working Paper No. 2007-11*

Blake, D., A.J.G. Cairns and K. Dowd (2001) Pensionmetrics: stochastic pension plan design and value-at-risk during the accumulation phase", *Insurance: Mathematics and Economics*, 29(2): 187-215

British Labour Statistics: Historical Abstract 1886-1968 (1971) Department of Employment: HMSO.

Burtless, G. (2003) "What do we know about the risk of individual account pensions? Evidence from industrial countries," *American Economic Review*, 93(2): 354-359.

Burtless, G. (2007) "International investment for retirement savers: historical evidence on risk and returns," Center for Retirement Research at Boston College, Working Paper.

Cannon, E. and I. Tonks, (2004) "UK Annuity Rates and Pension Replacement Ratios 1957-2002," *Geneva Papers*, 29(3): 371-393.

Cannon, E. and I. Tonks (2008) *Annuity Markets* (Oxford University Press, Oxford).

Carter, S. and others (2006) *Historical Statistics of the United States* (New York and Cambridge: Cambridge University Press).

Chapman, J. (1999) "Persistency and charges: exposing the big hitters," *Money Management*, 72-75.

Cocco, J. F. and Lopes, P. (2011), Defined Benefit or Defined Contribution? A Study of Pension Choices. *Journal of Risk and Insurance*, 78 forthcoming

Diamond, P. A. (1977) "A Framework for Social Security Analysis," *Journal of Public Economics*, 8: 275-298.

Dimson, E., P. Marsh, and M. Staunton (2002) *Triumph of the Optimists: 101 Years of Global Investment Returns* (Princeton University Press).

Dilnot, A. and P. Johnson (1994) *The Taxation of Private Pensions* (Institute for Fiscal Studies, London)

Disney, R. and C. Emmerson, (2005) "Public Pension Reform in the UK: what effect on the financial well being of current and future pensioners," *Fiscal Studies*, 26(1): 55-82.

Doornik, Jurgen A. (2009) Ox 6: An Object-oriented Matrix Programming Language (London: Timberlake Consultants).

Economic Policy Committee and the European Commission (DG ECFIN) (2006) “The impact of ageing on public expenditure:” *Special Report 1/2006*

Feinstein, C.H. (1972) *National income, expenditure and output of the United Kingdom, 1855-1965* (London: Cambridge University Press).

Grytten, O.H. (2009) “Purchasing Power of Labour: Norwegian Real Wages, 1726-2006” *Scandinavian Economic History Review*, 57(1): 48-87.

Historical Statistics of Canada (1983/1999) http://www.statcan.gc.ca/

Human Mortality Database. University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany). Available at www.mortality.org or www.humanmortality.de (data downloaded August, 2008).

International Labour Office *Yearbook of Labour Statistics* 1990-2002.

James, E. (1997) “New Systems for Old Age” World Bank, Working Paper

MacDonald, B.-J. and Cairns, A. J. G. (2009), Getting Feedback on Defined Contribution Pension Plans. *Journal of Risk and Insurance*, 76: 385–417

Maddison *Statistics on World Population, GDP and GDP Per Capita, 1-2006 AD.* Available from the Groningen Growth & Development Centre (can be downloaded from http://ggdc.net/maddison/).

Maddison, A. (2007) Contours of the World Economy, 1-2030 AD: Essays in Macroeconomic History (Oxford: Oxford University Press)

Malkiel, B.G. (1995) “Returns from Investing in Equity Mutual Funds 1971 to 1991”, *Journal of Finance*, 50(2): 549-572.

Miles, D. (1997) “A Household Level Study of the Determinants of Income and Consumption,” *Economic Journal*, 107: 1-26.

Miles, D. (1999) “Modelling the impact of demographic change upon the economy” *Economic Journal*, 109: 1-37.

Miles, D. and A. Timmerman (1999) “Costing pension reform: Risk sharing and transition costs in the reform of pension systems in Europe”, *Economic Policy*, 253-286

Mitchell, B.R. (1988) *British Historical Statistics* (Cambridge University Press).

Mitchell, B.R. (1998) International Historical Statistics: Europe; The Americas; Africa, Asiana and Oceania; 1750- (Basingstoke: Macmillan)

Office for National Statistics (2008) Occupational Pension Schemes Annual Report 2007 Edition, No. 15.

Pension Commission (2004) *Pensions: Challenges and Choices: The First Report of the Pensions Commission* (The Stationery Office).

Pension Commission (2005) *A New Pension Settlement for the Twenty-First Century: The Second Report of the Pensions Commission* (The Stationery Office).

Personal Accounts Delivery Authority (2009) Building personal accounts: designing an investment approach, May 2009

Poterba, J.M., S.F. Venti and D.A. Wise (1998), "401(k) plans and future patterns of retirement savings", *American Economic Review*, 88(2): 179-184

Poterba, J., J. Rauh, S. Venti and D. Wise (2007) "Defined contribution plans, defined benefit plans, and the accumulation of retirement wealth", *Journal of Public Economics,* 91(10): 2062-2086.

Prado, S. (2010) "Nominal and real wages of manufacturing workers, 1860–2007" in Edvinsson, R., Jacobson, T., and Waldenström, D. (editors) *Exchange rates, prices, and wages, 1277–2008* (Sveriges Riksbank).

Samwick, A. and J. Skinner, (2004) "How will 401(k) plans affect retirement income?" *American Economic Review*, 94, 329–343.

Sandler, R. (2002) "Medium and Long-Term Retail Savings in the UK: A Review", (HM Treasury).

Schooley, D.K., and D. D. Worden (1999) "Investors' Asset Allocations versus Life-Cycle Funds", *Financial Analysts Journal*, 55(5): 37-43.

Shiller, R.J. (2006) "Life-cycle personal accounts proposal for Social Security: An evaluation of President Bush's proposal" *Journal of Policy Modeling, 28*: 427-44.

Turner, A. (2006), "Pensions, risks and capital markets" *Journal of Risk and Insurance*, 73: 559–574.

Vidal-Meliá, C., Domínguez-Fabián, I. and Enrique Devesa-Carpio, J. (2006), "Subjective Economic Risk to Beneficiaries in Notional Defined Contribution Accounts", *Journal of Risk and Insurance,* 73: 489–515.

Whitehouse, E. (2000), *Administrative Charges for Funded Pensions: An International Comparison and Assessment*, Pension Reform Primer Series, World Bank Social Protection Discussion Paper 0016.

Yoo, K-Y and A. de Serres (2004) "Tax treatment of private pension savings in OECD countries and the net tax cost per unit of contribution to tax-favoured schemes", OECD Economics Department Working Papers No. 406.

Figure 1: Hypothetical pension fund ratios obtained from life-cycle (dotted line) and equity (solid line) investment strategies

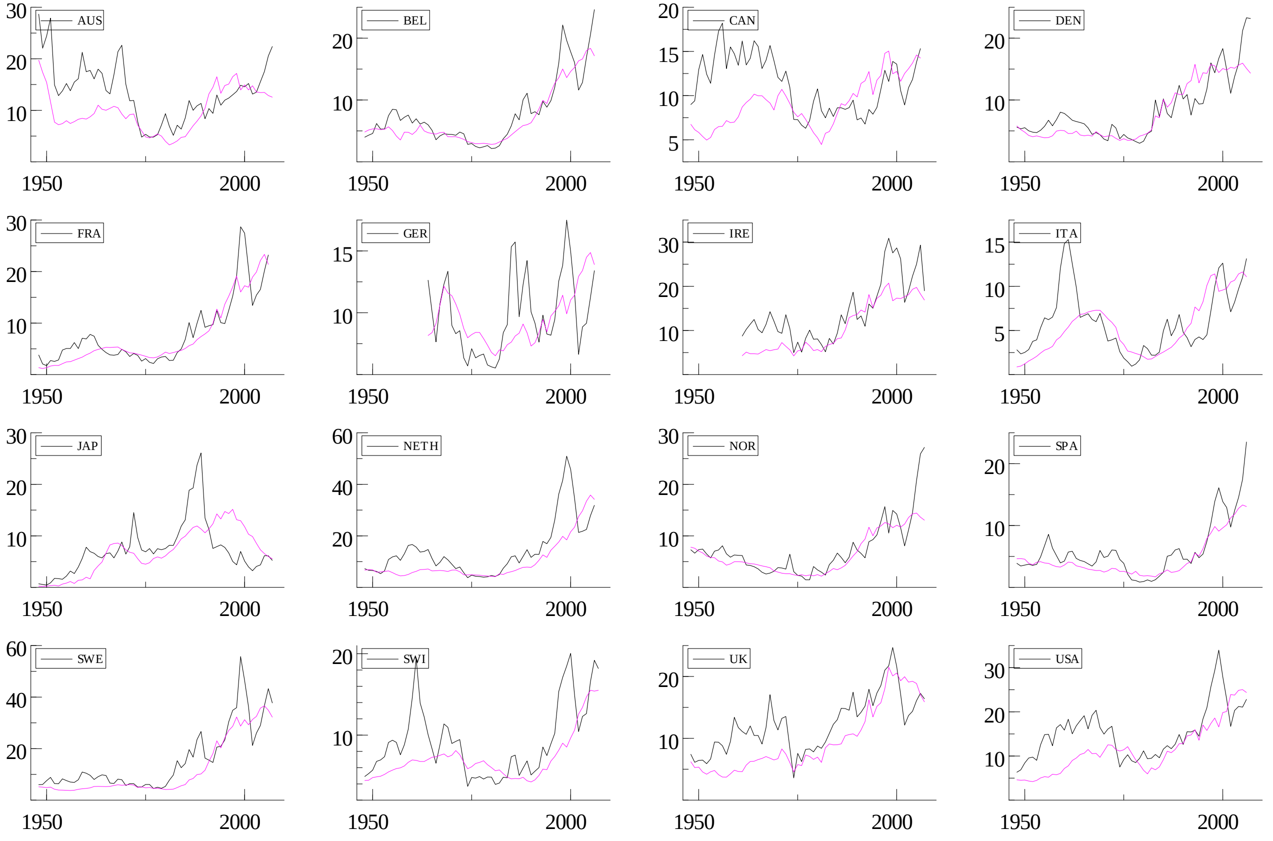


Figure 2: Pension fund ratios (equity investment strategy) and average equity returns: historical wage data

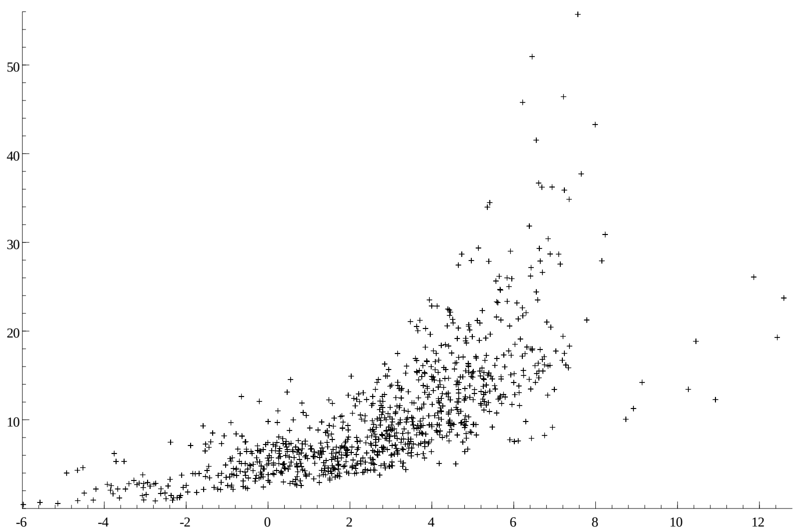
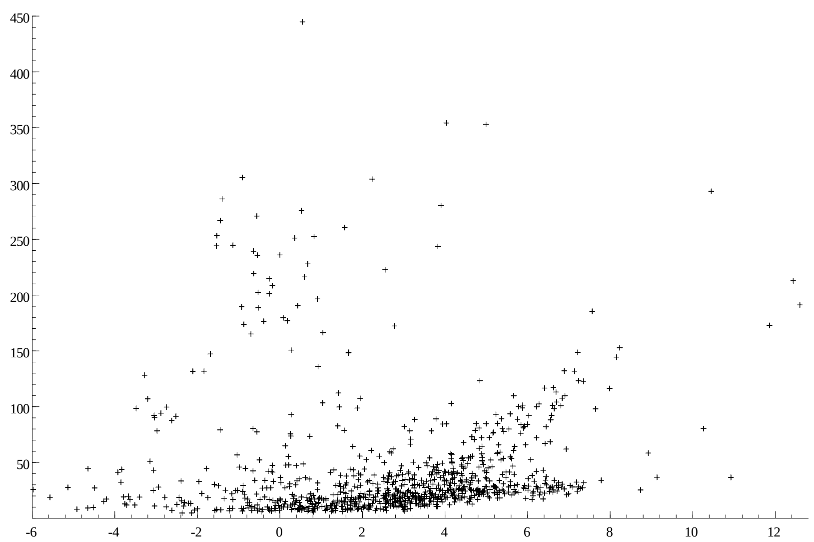


Figure 3: Pension fund ratios (equity investment strategy) and average equity returns: constant 1.5% annual real wage growth



Figures 2 and 3 provide cross-plots of pension fund ratios against the corresponding 40-year average real equity return for all country-year observations. Figure 2 uses actual historical wage data for each country, whereas Figure 3 assumes a constant annual real wage growth of 1.5%

Figure 4: The effect of unemployment risk: hypothetical pension fund ratios obtained from life-cycle investment strategies, with unemployment risk (dotted line) and without unemployment risk (solid line)

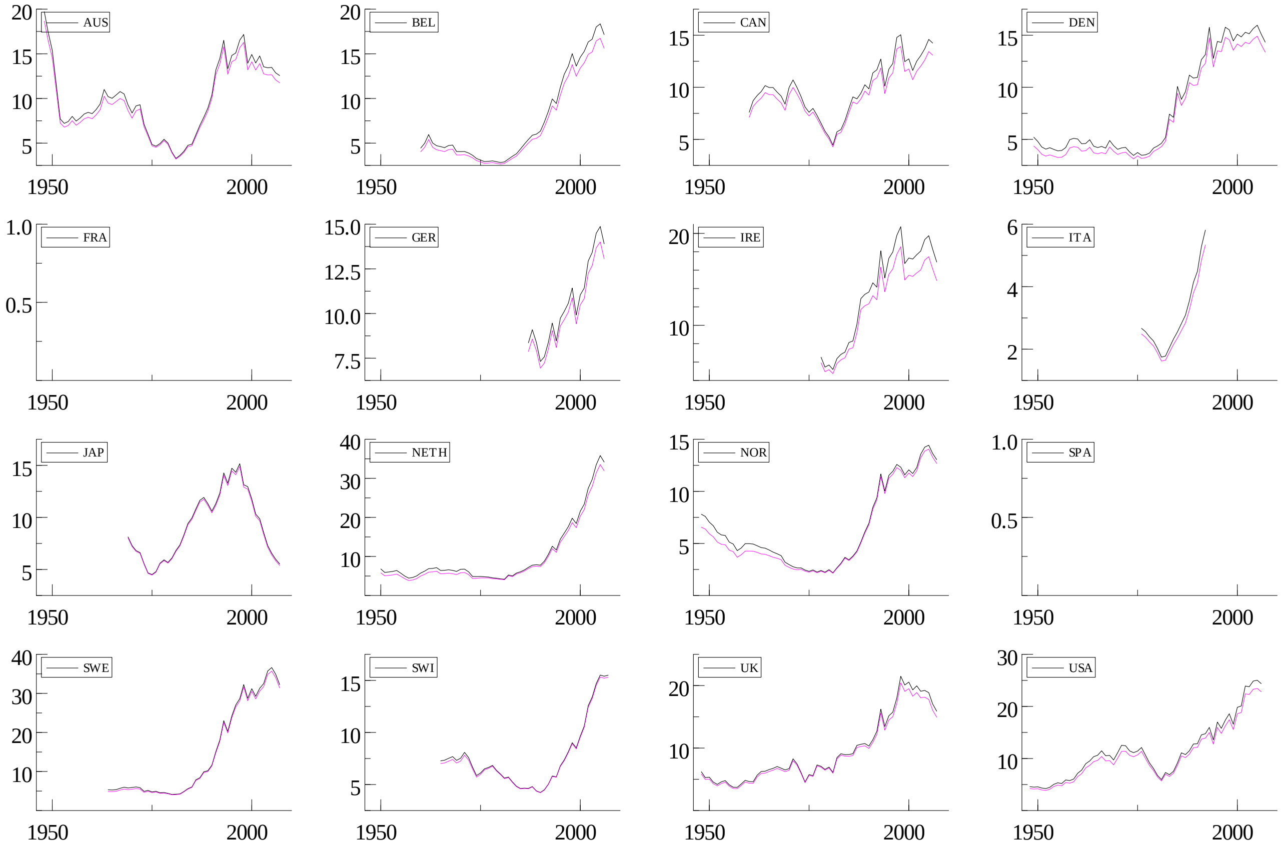


Figure 5: Simulated pension fund ratios for life-cycle strategy (inter-quartile range, 5th and 95th centiles)

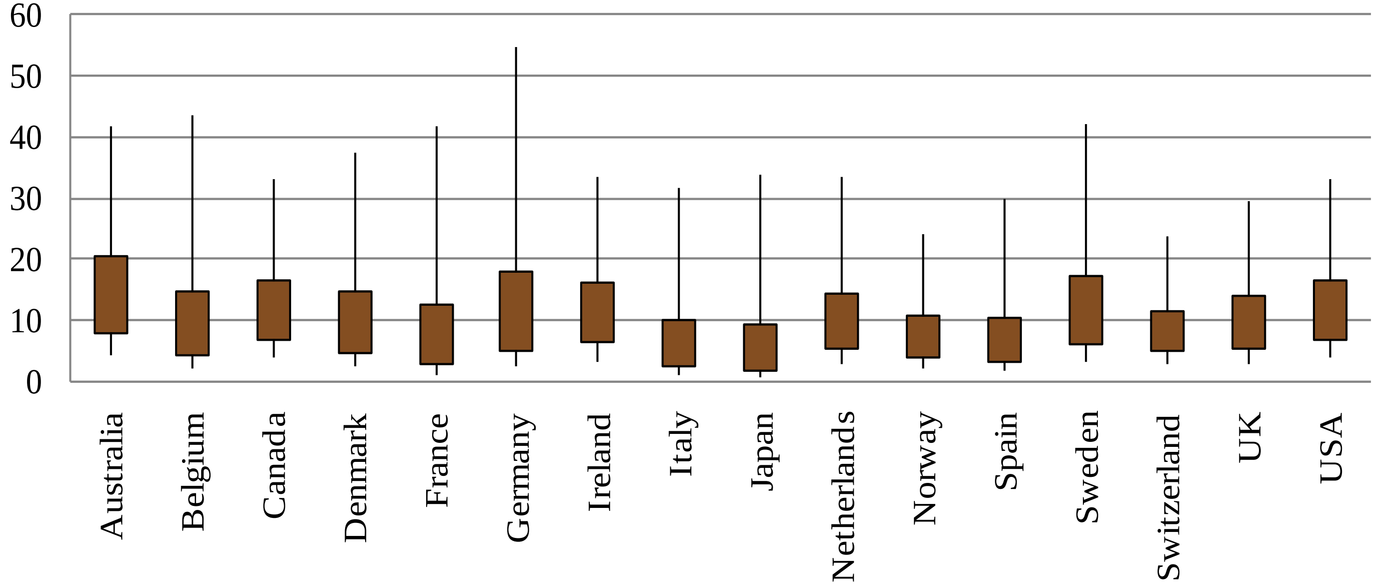


Figure 5 compares the inter-quartile ranges (and 5th and 95th centiles) of the simulated probability distributions of pension fund ratios by country from simulations based on data from 1979 onwards.

Table 1: Correlations between real bond returns, real equity returns and real wages

	Bonds and equity	Bonds and wages	Wages and equity
Complete data set (all countries, all observations)			
Raw data	0.332	0.228	0.037
Smoothed data	0.269	-0.021	0.126
Post-war data (all countries, 1948-2007)			
Raw data	0.311	0.045	0.079
Individual countries (raw data, all time periods)			
Australia	0.340	-0.066	0.148
Belgium	0.256	-0.123	0.268
Canada	0.175	-0.092	0.177
Denmark	0.541	-0.087	-0.030
France	0.387	-0.081	0.447
Germany*	0.304	0.178	-0.120
Ireland*	0.441	0.152	0.246
Italy	0.422	0.043	0.427
Japan†	0.324	0.438	0.266
Netherlands†	0.105	-0.209	-0.089
Norway	0.202	-0.148	0.134
Spain‡	0.608	0.029	0.032
Sweden	0.189	-0.073	0.305
Switzerland†	0.368	-0.083	0.446
UK	0.546	0.106	0.228
USA	0.223	-0.021	0.150

This table reports correlations between real equity returns, real bond yields and real wages for both raw and smoothed data. *Germany 1923-2007, Ireland 1921-2007. †Some pre WW2 wage data missing and inferred from GDP data. ‡ Wage data missing until 1963: data inferred from GDP data

Table 2: Summary statistics of hypothetical pension fund ratios by country, 1948-2007

	Using historical returns and historical wages								Historical returns, 1.5% wage growth			
	Panel A: Country's Median Fund Ratio				Panel B: Country's Lower Decile Fund Ratio				Panel C: Country's Median Fund Ratio			
	Bond	Equity	50:50	Life-cycle	Bond	Equity	50:50	Life-cycle	Bond	Equity	50:50	Life-cycle
Australia	3.86	13.36	8.33	9.29	2.11	6.26	3.50	4.83	6.55	29.71	14.90	18.39
Belgium	3.33	6.28	5.08	4.97	2.35	2.63	2.65	3.09	7.05	14.01	10.98	11.70
Canada	4.07	11.40	7.55	9.11	2.79	7.30	4.72	5.78	6.17	23.48	12.79	19.42
Denmark	4.41	6.73	5.42	5.01	2.62	3.73	3.19	3.89	9.83	18.32	13.65	17.17
France	2.61	5.07	3.59	4.71	1.15	2.71	2.38	2.06	11.71	44.56	32.82	42.42
Germany*	5.22	9.16	7.56	8.73	2.60	6.28	4.37	7.33	10.65	20.42	16.32	21.53
Ireland*	3.73	12.11	6.89	7.35	2.13	7.20	4.24	4.95	12.64	49.95	27.73	45.12
Italy	2.29	5.23	3.72	4.87	1.01	2.21	1.63	1.79	8.69	41.23	37.08	42.45
Japan†	2.71	6.69	4.63	6.74	0.54	1.75	1.00	0.62	11.36	173.38	40.76	59.61
Netherlands†	4.40	11.86	7.47	6.55	2.00	4.54	3.03	4.72	6.48	24.28	11.44	16.88
Norway	4.13	6.26	5.44	4.96	2.11	2.76	2.92	2.45	7.72	10.55	9.28	8.99
Spain‡	3.37	4.81	4.27	3.49	1.41	1.24	1.36	2.19	11.21	22.08	17.95	23.17
Sweden	3.55	9.62	6.02	5.48	2.39	5.68	3.67	4.18	7.29	23.60	11.48	17.82
Switzerland†	4.50	8.42	6.37	6.58	3.47	4.78	4.44	4.63	7.11	12.89	10.01	11.58
UK	4.06	11.88	6.41	7.07	2.48	6.65	4.72	4.57	7.07	34.02	16.64	29.20
USA	3.43	14.96	7.67	10.64	2.82	9.01	5.29	4.95	5.69	27.40	12.70	20.48
Average	3.73	8.99	6.03	6.60	2.12	4.67	3.32	3.88	8.58	35.62	18.53	25.37

This table reports summary statistics for the calculated pension fund ratios using realised historical data for each country over the period 1948-2007 for four alternative investment strategies. Panel A reports each country's median fund ratio, Panel B reports the lower decile fund ratio. Panel C reports the median fund ratio under the assumption that real wages grew at 1.5 per cent per year. *Germany 1963-2007, Ireland 1970-2007. †Some pre WW2 wage data missing and inferred from GDP data. ‡ Wage data missing until 1963: data inferred from GDP data.

Table 3: Summary statistics of simulated pension fund ratios

		Aust	Belg	Can	Den	Fr	Ger	Ire	Italy	Japan	Neth	Nor	Sp	Swe	Switz	UK	USA
WHOLE PERIOD (1902-2007)																	
Lower decile	Equity	8.4	2.9	5.9	3.3	1.9	2.9	5.4	1.7	1.7	4.0	2.6	1.9	4.3	3.6	4.9	5.9
	50:50	4.5	2.8	4.5	3.0	1.6	3.9	3.8	1.5	1.2	3.5	2.5	2.1	3.8	3.6	3.3	4.7
	Lifestyle	5.3	2.8	4.8	3.1	1.6	3.2	4.2	1.5	1.0	3.6	2.5	2.1	3.9	3.6	3.6	4.9
Median	Equity	20.4	10.0	14.6	10.3	8.0	12.3	13.9	6.8	5.8	11.8	7.7	7.1	14.2	9.3	12.5	15.4
	50:50	9.3	6.7	8.6	7.3	5.1	8.4	8.3	4.4	4.0	7.3	5.9	4.9	8.2	6.7	7.1	8.6
	Lifestyle	12.7	7.7	10.3	8.2	5.7	9.2	9.9	4.7	4.1	8.4	6.2	5.4	9.9	7.4	8.6	10.7
POST WAR (1948-2007)																	
Lower decile	Equity	6.3	4.5	8.2	4.8	3.6	3.7	6.3	2.1	3.8	5.4	2.9	1.8	6.8	5.4	6.6	11.0
	50:50	3.5	4.1	5.8	4.1	4.1	4.7	4.3	2.5	4.4	3.6	2.9	1.8	4.2	4.6	4.4	7.3
	Lifestyle	3.9	4.2	6.2	4.2	3.9	4.2	4.8	2.5	3.6	3.9	2.8	1.9	4.8	4.7	5.0	8.1
Median	Equity	16.9	13.9	15.7	14.6	13.3	14.1	18.9	9.4	9.7	20.0	8.8	8.7	21.9	15.6	17.4	23.2
	50:50	8.1	8.7	9.8	10.1	9.6	9.6	9.6	7.2	8.0	8.9	6.6	4.9	9.8	8.6	8.4	12.3
	Lifestyle	10.6	10.3	11.6	11.5	10.6	10.8	12.0	7.6	7.9	12.1	6.8	5.9	13.2	10.7	11.0	15.8
GOLDEN AGE & STAGFLATION 1948-1978																	
Lower decile	Equity	2.9	2.6	5.9	3.0	2.7	2.5	4.2	0.9	4.8	3.3	0.9	0.9	4.1	3.1	3.9	7.2
	50:50	1.8	2.4	3.6	2.6	2.7	2.9	2.8	1.2	3.2	2.2	1.5	1.0	2.6	3.0	2.6	4.3
	Lifestyle	1.9	2.4	4.0	2.6	2.7	2.8	3.0	1.2	2.9	2.3	1.3	1.0	2.8	3.1	2.8	4.8
Median	Equity	9.0	4.9	11.1	4.7	7.4	8.1	9.1	4.2	12.6	7.2	2.0	2.5	6.2	8.0	11.9	13.6
	50:50	3.7	3.4	4.8	3.4	4.9	5.5	4.3	3.2	6.3	3.5	2.1	1.8	3.3	5.1	4.8	5.6
	Lifestyle	4.7	3.7	6.3	3.6	5.5	6.1	5.3	3.3	7.3	4.2	1.9	1.9	3.9	5.8	6.3	7.7
1980 ONWARDS																	
Lower decile	Equity	19.0	18.9	11.6	9.8	19.7	9.7	18.8	8.1	1.8	16.8	16.0	8.8	13.4	14.1	11.3	19.5
	50:50	15.9	16.1	15.4	10.4	19.4	11.1	14.2	10.6	4.3	14.3	15.6	8.7	15.2	9.4	10.3	20.1
	Lifestyle	16.4	16.6	13.3	9.7	17.8	9.4	15.5	9.2	3.2	14.3	14.1	8.7	13.0	10.6	10.5	19.0
Median	Equity	30.3	63.9	22.2	33.6	61.0	34.2	58.9	20.9	6.1	86.4	49.4	33.7	57.6	39.6	28.9	48.1
	50:50	22.7	32.4	24.0	24.3	34.4	20.7	30.6	19.8	8.7	34.7	26.5	18.6	33.0	17.1	19.3	33.2
	Lifestyle	25.0	44.5	22.8	27.6	44.3	24.8	40.8	19.2	7.4	53.5	33.8	23.5	41.0	24.5	23.0	39.5

This table reports summary statistics of simulated pension fund ratios for each country for various time periods calculated from equation (12).

Table 4: Summary statistics of hypothetical pension replacement ratios

	Pension Replacement Ratio		Constant Annuity Rate	Comparison of Risk
	Median	Lower Decile	Lower Decile	Ratio of St Dev
Australia	0.91	0.65	0.55	0.86
Belgium	0.49	0.38	0.34	0.73
Canada	1.02	0.47	0.63	1.06
Denmark	0.68	0.40	0.49	0.81
France	0.55	0.21	0.24	0.71
Germany*	0.96	0.81	0.76	0.62
Ireland	1.36	0.56	0.65	0.62
Italy	0.55	0.22	0.23	0.75
Japan*	0.82	0.50	0.06	0.54
Netherlands	0.65	0.46	0.47	0.79
Norway*	0.42	0.27	0.26	0.87
Spain*	0.67	0.39	0.31	0.55
Sweden	0.64	0.34	0.46	0.85
Switzerland	0.51	0.37	0.37	0.81
UK	1.15	0.36	0.53	0.84
USA	1.22	0.32	0.49	0.97

This table reports the median and lower decile pension replacement ratios for each country. The results in column 1 and 2 are calculated from the replacement ratio in equation (10). The result in column 3 is from the calculation in equation (11). * Germany 1977-2007, Japan 1968-2007, Norway 1948-2006, Spain 1979-2007