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

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Abstract

Using data on historical returns on international financial assets, the paper simulates pension fund and pension replacement ratios, building up frequency distributions of these ratios for individuals saving in a defined contribution pension plan in different countries. These frequency distributions illustrate the risk in the pension replacement ratio faced by an individual who saves in a typical defined contribution pension scheme.

JEL Classification: E62, G14, H55

Keywords: Risks, Defined contribution pension schemes, pension replacement ratio.

1. Introduction

Around the world there has been a trend away from unfunded pay-as-you-go and funded defined benefit schemes towards funded defined contribution schemes.[2] In a defined contribution (DC) scheme, an individual builds up his or her own pension fund to provide an income during retirement. Examples of such schemes are the USA's 401(k) scheme, the UK's personal and stakeholder pensions, Germany's Reister plans, and Australia's Superannuation Guarantee. Individual pension savings plans exist in Austria, Czech Republic, Denmark, Greece, Finland, Ireland, Netherlands, Slovenia and Spain; a number of countries, such as Estonia, Latvia, Lithuania, Hungary, Poland, Slovakia and Sweden, have switched part of their social security pension system into private funded schemes.[3] Governments may compel individuals to invest in such schemes or may encourage it through providing tax incentives. At retirement it is possible to convert the pension fund into an income stream through the purchase of an annuity and in some countries, such as the UK, this is compulsory.

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? A public policy maker would have additional questions about efficiency, redistribution and the appropriate way to manage the transition to a DC scheme from existing schemes, but this paper will concentrate on these first two questions. Ideally we should conduct a comparative analysis of the mean and variance of the pension under a DC scheme with alternatives, but we shall follow many existing studies in concentrating on DC schemes alone.

The approach we use to answer these questions is to use historical data to calculate hypothetical DC pensions. We pose the counter-factual

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[2] James (1997), Poterba, Venti and Wise (1998), Miles and Timmermann (1999),
[3] Economic Policy Committee and the European Commission (DG ECFIN) (2006).

conditional: what pension would someone have achieved if they had been able to invest in one of the pension schemes currently available and earned the returns on their investment which actually occurred over the twentieth century? Burtless (2003) has addressed this question using data from the period 1927-2001 for France, Germany, Japan, the UK and the USA; this is up-dated for the USA to draw on data for the period 1872-2008 in Burtless (2007). Shiller (2006) analyses USA data for the period 1871-2004. Samwick and Skinner (2004) and Poterba, Rauh, Venti and Wise (2007) have compared simulated wealth accumulations from DB and DC pension plans emphasising the importance of incorporating earnings histories into the simulated savings plans. Samwick and Skinner (2004) assume that the log of earnings follow a random walk with age-related drift. Poterba et al (2007) use earnings histories from the US's Health and Retirement Study which are randomly assigned to individuals in their simulated pension plans. Basu and Drew (2007) have examined alternative risk measures in simulated DC plans for Australia. Both Burtless and Shiller discuss the merits of relative investment strategies and it is possible to extend this approach further, using either historical data or simulations based on the observed first two moments of returns data. Blake, Cairns and Dowd (2001) estimate the riskiness of defined contribution pension plans during the accumulation phase and find that they are extremely risky relative to a defined benefit alternative.

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 size of the pension fund relative to final labour income (which we call the *fund ratio*) or the size of the resulting pension income to final labour income (which Diamond, 1977, refers to as the *replacement ratio*). From the perspective of consumer choice – presumably 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. Despite this, Burtless (2003) does not use data on earnings in his international simulations, and this makes cross-country comparisons problematic, especially if wages and returns are correlated in the long run. In our analysis we will incorporate country specific historical wage data alongside the historical returns data to calculate fund ratios and replacement ratios and extend the analysis to a total of sixteen countries.

Benzoni, Collin-Dufresne and Goldstein (2007) analyse this problem theoretically, taking into account that wages are correlated with investment returns in the long run (strictly speaking that the dividend and wage series are cointegrated). Their conclusion is that young investors should short equities early on in the lifecycle: since wages and equity returns are correlated in the long run this effectively allowing investors to insure against the whole economy doing badly. In practice it is difficult to see how signficant 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 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, 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 all of the updated data available in Dimson, Marsh and Staunton (2002) except for the data from South Africa.

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. As we write, we appear to be in the largest financial crisis since the 1930s, face the possibility of an influenza epidemic, 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).[4] We might note that there are at least two further reasons for consumers' expenditure (as opposed to consumption) to change upon retirement: the elimination of work-related expenditure (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 discussion so far assumes that we wish to compare the retirement income to final labour income. If a pensioner annuitizes his pension wealth then this is the appropriate assumption. Cannon and Tonks (2008) note

[4] Notice that some age-related expenditures are discrete rather than continuous choice variables, providing a further reason for discontinuity at retirement.

that annuitisation is unusual in many countries and that this may be due to rational reasons or irrational ones. Combined with the observation that many countries have very thin annuity markets, this suggests that we should look at a different metric of pension wealth, namely the pension *fund ratio*, which is the ratio of pension wealth to final labour income. Note that this is related to the replacement ratio by[5]

$$\text{(1)} \qquad \text{Replacement ratio}_t = \text{Annuity rate}_t \times \text{Fund ratio}_t$$

We have indexed 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 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 continuously in employment during that time earning a labour income y_k in year k.[6] Then someone retiring at time t will have a pension fund equal to

[5] 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).
[6] An additional problem is that the individual may have a broken work history: this is particularly likely for women who withdraw from the labour force to care for family members, but also may be true for men who may be employed. This consideration affects both the average size of pension and the risk. We abstract from this possibility to concentrate on the investment-risk in the pension.

(2) $$\text{Pension Fund}_t = s\sum_{i=1}^{40} y_{t-i}\prod_{j=1}^{i}\left(1 + r_{t-j}\right).$$

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}.[7] We report the *Fund Ratio* which is simply

(3) $$\text{Fund Ratio}_t \equiv \frac{\text{Pension Fund}_t}{\text{Final Net Labour Income}_t} = \frac{s\sum_{i=1}^{40} y_{t-i}\prod_{j=1}^{i}\left(1 + r_{t-j}\right)}{\left(1-s\right)y_{t-1}}$$

where by "net" labour income we mean labour income after deduction of pension contributions, not taxes. Indeed we ignore taxation altogether: in DC schemes around the world typically pension contributions are tax deductible and it is for such a scenario that we wish to produce simulations.

In all of our simulations we shall assume that the savings rate s is 10 per cent. This figure is probably lower than people ought to be saving and higher than they actually are (certainly this characterisation would not be particularly controversial in the U.K.). 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 depends upon bond and equity yields, respectively r_t^B and r_t^E. In principle it would also be possible to invest in cash (which would yield much lower rates of return) or property (for which we do not have data). If a proportion θ is invested in equity then the overall return is

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

[7] This formula suggests 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.

where c^E and c^B are respectively the annual management charges for managing an equity or bond portfolio. We do not have international or historical data for these charges, and these charges tend to depend upon the type of investment fund. There is some evidence that more actively managed funds on average tend to beat the market index but that this improvement in return is compensated by higher charges so that there is relatively little improvement in what matters for the saver, which is $r_t^E - c^E$ (Malkiel, 1995; Sandler, 2002). "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. These charges are consistent with the estimates of charges in the U.K. found by Chapman (1999). In many countries annual charges are augmented by an initial charge of up to 5 per cent (Franks, Mayer & da Silva, 2003). This would mean that a savings rate of 10 per cent would translate to only 9.5 per cent of income going into the fund. In our analysis below, however, we assume no initial charge since such charges are sometimes reduced for long-term investments.

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 "lifestyle" 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.[8] The lifestyle 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; Booth and Yakoubov, 2000; Hibbert and Mowbray, 2002; Viceira, 2009).

We consider two different models of labour income. In the first, a representative worker is assumed to be just that: so labour income just

[8] Shiller (2006) refers to this as a "life-cycle" fund and considers a wider range of possibilities, all of which tend to have slightly fewer stocks in the portfolio earlier

equals the national average labour income. In practice individuals wages tend to be correlated to 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 level off (obviously some exceptional individuals' earnings continue to rise quickly after this, but not for most people). Following Miles (1997) we use the following formula for an individual's wages

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

where $\overline{y}_t$ is the national average wage. When combined with economy-wide annual real wage growth of 2% this results in a series similar to that of Disney and Emmerson (2005) or many of the earnings profiles in Poterba, Rauh, Venti and Wise (2007). Miles (1999) summarises results from other countries and suggests that they are similar.

With the assumptions made so far and with data on wages, bond yield and equity yields we can calculate the hypothetical fund ratios that individuals could have obtained by investing in a tax deductible DC pension scheme. We report our results for this in Section 3. However, it would also be interesting to know about their pension incomes. To calculate the replacement ratio would require annuity rates, for which data are not generally available.[9] We therefore construct hypothetical annuity rates for each country in each year. Ideally such an exercise would be based upon the actuarial projections used in the relevant country in the relevant year.

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on: compared with Shiller's funds, ours would be characterised as more "aggressive".

[9] Data on historical annuity rates across countries is sparse. A historical series of US Annuity rates 1928-95 is provided by Warshawsky (1998) in Mitchell et al (1998), although this appears to have some missing observations. Cannon and Tonks (2008) provide UK data for the voluntary market for 1957-2007 and the compulsory market for 1994 – 2007. Bateman, Kingston and Piggott provide data for Australia 1986-1996. We do not know of historical series for any other countries.

However, except for the U.K. and the U.S.A. it would be very difficult to do this, partly because the thinness of annuity markets mean that very little actuarial information is published.[10] Therefore we use the following method:

For any given country suppose that in a given year t data are available on the probability of dying within a year for someone aged x (the data will be for the population as a whole, not just the select group of people buying private pensions). We denote this probability $q_{x,s}$ and assume that data are available for $s \in \left\{t, t-1, \ldots, t-T\right\}$. A simple but relatively reliable method of projecting mortality improvements into the future would be

$$(6) \qquad \mathrm{E}\left[q_{x,t+i} \middle| \mathrm{I}_t\right] = \exp\left\{\hat{\beta}_{0,x} + \hat{\beta}_{1,x}\left(t+i\right)\right\} \qquad i > 0$$

where the parameters $\hat{\beta}_{0,x}$ and $\hat{\beta}_{1,x}$ are the OLS estimates from the regression

$$(7) \qquad \ln q_{x,s} = \beta_{0,x} + \beta_{1,x} s + \varepsilon_s \qquad s = \left\{t-T, \ldots, t\right\}$$

Then the expected probability of a 65-year old man (who is purchasing a pension in year t) surviving to at least age k would be

$$(8) \qquad S_{t,k} \equiv \prod_{i=0}^{k-65}\left(1 - \hat{q}_{t+i,65+i}\right) \qquad k > 65$$

and a pension paying one unit per year would be priced as

$$(9) \qquad a_{65,t} \equiv \sum_{k=66}^{100} S_{t,k}\left(1+\rho\right)^{65-k}$$

[10] In some countries the relevant information is so sparse that actuaries use actuarial data from another country and then make adjustments to compensate for differences in life expectancy: e.g., until recently Canada used U.S.A. data.

The projection method for the survival probabilities outlined here would probably not be used today by actuaries, nor is it precisely the same as that used by U.K. actuaries over the relevant period (Cannon and Tonks, 2004). However, it is a reasonable simplification of actuarial methods for the 20th Century. As a projection method it is increasingly unreliable for ages greater than about 80 – but this does not matter too much since payments made to people surviving that long are heavily discounted and contribute only a small proportion of $a_{65,t}$.

If annuities were actuarially priced then the annuity rate would just be $1/a_{65,t}$. In practice it is usually less than this because of transaction costs, selection effects and the risk faced by the pension provider in projecting life expectancy. Cannon and Tonks (2008) show that the actual annuity rate is often in the region of $0.9/a_{65,t}$, reflecting a "money's worth" of annuities less than one. In our simulations below we assume a money's worth of one (ie actuarial pricing), noting that this will provide an *overestimate* of the replacement ratio. This means that the replacement ratio that we report in Section 6 is calculated using

(10) $$\text{Replacement Ratio}_t \equiv \frac{\text{Fund Ratio}_t}{a_{65,t}}$$

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. (we omit South Africa due to problems with the other data that we need). 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 was obtained from Mitchell (1998)'s collection of a variety of data series showing indices of labour earnings: as Mitchell makes clear, these involving small differences in definitions and from both official and unofficial sources. To bring the wage series up to date we use data from the *OECD Main Economic Indicators* or the *Yearbook of Labour Statistics*. The data we use are a mixture of weekly, monthly or annual wages, sometimes referring to the whole economy and sometimes (particularly in the early 20th Century) to manufacturing alone. To produce a single time series for each country we splice the different series together. German data are unavailable for the hyperinflation of the 1920s, Japanese data are unavailable for 1901-1936, Dutch and Norwegian data for 1901-1932, Spanish data for 1901-63 and Swiss data for 1901-1930. In all these 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).

The resulting wage series for each country are only a crude estimate of the actual wages series, however, it is difficult to see how we could improve upon them given our secondary data sources. Since scholars such as Maddison and Mitchell have spent lifetimes collecting these data we doubt that better data are easily available. We also believe that the series we are using are probably adequate for our purposes, certainly to measure the broad differences over time and space.

With the data discussed we are able to calculate hypothetical pension-fund ratios. To calculate the *synthetic* annuity rates we need in addition interest rate data and mortality data. Ideally we would use the term structure of interest rates for the interest rate, but this is not available for most countries (especially if we want real interest rates). Instead we use an interest rate based on government bond yield data from the IMF's

International Financial Statistics.[11] Mortality information was taken from the *Human Mortality Database* (data downloaded August 2008). For the UK we use mortality data drawn from England and Wales alone: we also use these data for Ireland since Irish mortality data are unavailable.

2.3 Preliminary Discussion of the Data

Since the purpose of this paper is to examine how fund ratios and replacement ratios are influenced by the interactions of wages and investment returns, we briefly discuss the relationship between these underlying variables.

The simplest measure would be to look at the correlation coefficient on the raw data. This statistic is reported in the first row of Table 1.[12] We also make two adjustments to this statistic. First, we smooth the data to remove high frequency variation:[13] we do this in the second row where the correlations remain high: the correlation between equity returns and wage growth is 0.17, so high investment returns on a pension fund will tend to be accompanied by higher wage growth. This justifies the suspicion that the effect of high investment returns on the fund ratio will tend to be over-estimated if we do not account for the likely accompanying faster wage growth.

[Table 1 about here]

[11] Dimson, Marsh and Staunton (2007) include data on bond returns, but not on the coupon yield.

[12] Since the sample size is 1537, the conventional test for statistical significance of the correlation coefficient would require a correlation coefficient 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.

[13] We smoothed each country's data series individually using a cubic spline where the number and position of knots was chosen by the procedure in OX version 5 (Doornik, 2007). Alternative smoothing procedures are unlikely to give results which are much different and we do not consider them because this analysis is only for preliminary descriptive statistics. For completeness Table 1 also reports the correlation of the smoothed and raw data.

Secondly we calculate analogous correlation coefficients using the formula[14]

$$(10) \qquad r_{\text{Fixed effects}} \equiv \frac{\sum_{i,t}\left(y_{it}-\overline{y}_i-\overline{y}_t+\overline{\overline{y}}\right)\left(x_{it}-\overline{x}_i-\overline{x}_t+\overline{\overline{x}}\right)}{\sqrt{\sum_{i,t}\left(x_{it}-\overline{x}_i-\overline{x}_t+\overline{\overline{x}}\right)^2\sum_{i,t}\left(y_{it}-\overline{y}_i-\overline{y}_t+\overline{\overline{y}}\right)^2}}$$

where $\overline{y}_i$ is the within-group mean, $\overline{y}_t$ is the within-period mean and $\overline{\overline{y}}$ is the whole-sample mean. It can be seen from the fourth row in Table 1 that having smoothed the data and controlled for the fixed effects there is no correlation between equity and wages, suggesting that the long-run correlation is a between-group rather than within group phenomenon. However, there is still substantial within-group short-run correlation and it remains to be seen how important this is for the fund ratio.

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 a decent government pension, one would not want the fund ratio to be much lower than ten.

[Figure 1 about here]

Figure 1 shows the fund ratios for the all-equity and lifestyle 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

[14] In fact the formula is slightly more complicated than this because we have an imbalanced panel. The easiest way to calculate these correlations is to use a standard software package to run two panel regressions, respectively of y_{it} on x_{it} and of x_{it} on y_{it} and then take the geometric mean of the two parameter estimates.

in these graphs. The striking feature about this graph is that the actual historical fund ratio appears to be too low for nearly all countries in nearly all time periods. This is despite the fact that the pension fund is invested in equity for most of the accumulation phase, only gradually moving to bonds towards the end of the period.

[Table 2 about here]

We present the same calculations differently in Table 2. Panel A of this table reports for the four alternative investment strategies, the median fund ratio for all sixteen countries averaged over the time series for that country. On average all countries have fund ratios considerably lower than sixteen. 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 lifestyle 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 of the table 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 lifestyle 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 lifestyle 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 lifestyle 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 the lifestyle strategy would have substantially beaten the all-equity strategy for someone retiring in several years (notably 1974 and 2002). This may suggest that the lifestyle strategy has some advantages in insuring downside risk in particularly bad periods.[15]

So Shiller's conclusion that a lifestyle investment strategy does not provide adequate insurance against downside risk cannot be generalised to all countries.

An important contention of this paper is that historical wage data should be used alongside historical investment returns. To guage how important this actually is we repeated all of our analysis without historical wage data but under the assumption that average 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.

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[15] Burtless does not compute the lifestyle 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 lifestyle strategy would have beaten the all-equity strategy in those years and that it will do so again for 2008-2010.

[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 we calculate no fund ratios in this range when using historical data. We also report these results in Panel C of Table 2: the median fund ratios are much higher, often by a factor of about two.[16] 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 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 have associated low equity returns and the effect of the latter is sufficiently strong to result in low fund ratios.

A final question that we consider in this question is how our calculations are affected by our assumptions about investment charges. Table 3 reports our analysis for the equity-only investment strategy with two variants on the model above. In the first three columns we report median fund ratios when annual investment charges are 2 per cent (as used earlier), 1 per cent and 0.3 per cent. Annual charges of 1 per cent may be feasible if there is government regulation or economies of scale. UK personal pensions often have 1 per cent charges. We include figures for 0.3 per cent because Shiller (2006) quotes USA social security actuaries as providing this figure. Bateman, Kingston and Piggot (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

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[16] The lower deciles are also much higher.

aiming for management charges of 0.33 per cent. With these lower charges the figures look much better with fund ratios being about 50 per cent higher, increasing from 9.81 per cent, with a 2 per cent management change, to 14.12 per cent with a 0.3 per cent fee; although the downside risk would remain considerable.

[Table 3 about here]

4. Simulation Analysis

We have calculated fund ratios using historical data for sixteen countries for the period 1948-2007. However, our 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 each country. In each case we estimate the following VAR by OLS:

$$\text{(11)} \qquad \mathbf{x}_t = \boldsymbol{\mu} + \boldsymbol{\pi}_1 \mathbf{x}_{t-1} + \boldsymbol{\pi}_2 \mathbf{x}_{t-2} + \boldsymbol{\varepsilon}_t \qquad \mathbf{x}_t \equiv \begin{pmatrix} r_t^B & r_t^E & \Delta \ln w_t \end{pmatrix}'$$

We then use the estimated parameters to simulate the joint behaviour of investment returns and wages.[17] These simulated returns were 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 (11), however, we need to address the issue of parameter constancy. In Figure 1 we graphed the time series behaviour of the fund ratios and these graphs suggest that there may be considerable

[17] None of these variables are obviously trending over the period so we did not include a trend. 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.

instability in the underlying data generating processes. If we were to plot the histograms of the fund ratios, many would be 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 4 shows the probability distributions from the simulations based on just the last sub-period for the years 1980 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 all of the simulations are shown in Table 4. 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 4.

Although for each strategy there is significant upside potential, according to Panel A of Table 4 over the whole sample period 1902-2007, for the 50:50 equity:bond strategy there is a ten per cent probability of getting a fund ratio of 3.3 or less for the UK and and of 4.9 or less for the US, but a ten per cent probability of getting only less than 1.6 for France, 1.4 for Italy and 1.2 for Japan. The other panels in Table 4 consider three sub-sets of the sample period: the post-war period, 1948-2007; the Golden Age and Stagflation, 1948-1978; and the 1980s 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 post-1978, than pre-1978.

5. Annuity rates and replacement ratios

We have now calculated hypothetical historical fund ratios and simulated their distribution. We now turn to the question of what sort of income these 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.

[Figure 5 about here]

Figure 5 illustrates our hypothetical annuity rates, using two different interest rate assumptions. Ideally we should have used historical values of the term structure, but no such data exist, with the exception of the UK and USA and even these countries do not have data for the entire post war period. To maintain consistency across countries we used the medium-long term government bond rate.[18] This is the appropriate method to calculate a pension income that would be constant in nominal terms. Since there is considerable variation in inflation, this means that such annuity rates are not comparing like for like in real terms. To calculate the pension income that might have been obtained in real terms we assume a constant real interest rate of 2 per cent roughly equal to the average real bond yield in Dimson, Marsh and Staunton (2007).

[Figure 6 about here]

[Table 5 about here]

We match up the resulting hypothetical annuity rates with the pension fund ratios we calculated in Section 4: the resulting replacement ratios are illustrated in Figure 6 and summarised in Table 5. From the right hand columns of Panel A in Table 5 for nominal annuities, the median replacement ratio appears more that satisfactory, with an average value across countries of greater than unity: implying an income in retirement

[18] We note that many actuarial texts calculate the value of an annuity using a constant medium term bond rate.

more than necessary for income smoothing. Some countries, noticeably the US, UK and Australia have very high simulated median replacement ratios. Even the numbers for the lowest decile, suggest high replacement ratios, so that individuals in the worst-performing economy (Japan) would have a ten percent probability of ending up with a replacement ratio of 0.32. However, these values are largely due to the generous initial replacement ratios which can be obtained by buying nominal annuities in periods of high inflation: the income from these would decline rapidly in real terms and we report them primarily for purposes of comparison. The replacement ratios obtained from buying real annuities are lower, although on average across economies the median is 0.86. However the lowest decile of replacement ratios based on real annuity payments are much lower, with individuals in France, Italy and Spain facing a ten percent probability of having a real replacement ratio of 0.25, 0.20 and 0.17 respectively.

Recall also that these are hypothetical historical rates. Figure 5 shows that annuity rates have tended to trend down as life expectancy has trended up. The real annuity rates that we calculated for 2007 range from 6.4 per cent (Australia) to 7.7 per cent (Denmark). Such annuity rates are based on population mortality figures and the assumption of actuarially fair pricing. To give an idea of how much this biases annuity rates up, note that our calculated figure for the UK is 7.0 per cent: in reality the annuity rate for a 65-year old man in the UK in 2007 was 4.5 per cent.[19]

It might seem surprising that given the low fund ratios that we identified in Figure 1 and Table 4, the replacement ratios in Figure 6 and Table 5 are not lower. But recall from Table 1, that bond and equity returns are less than perfectly correlated, and the annuity rates that we have simulated are

[19] This is for an RPI-linked annuity purchased in the compulsory-purchase market (ie a pension annuity bought with a tax-deductible pension fund). We calculate this as the average of seven annuity providers for December 2007. It assumes a "healthy" individual (higher rates would be available for men with certain health conditions or who were smokers). Note that real bond yields were much lower than 2 per cent at the time of writing: however, if we calculated the real annuity using our method and an interest rate of 1 per cent the result would still be 6.2%, much higher than the rate observed in reality.

determined by the bond rate. This low correlation between equities and bonds acts as a natural hedge in the annuitization process: when fund values are high due to high equity returns, the annuity rate will be low, reducing the replacement ratio. Conversely when fund values at retirement are low, the annuity rate and hence the replacement ratio will be relatively high.

6. Conclusions

This paper has examined the pension fund and replacement ratios for all of the major developed countries over the twentieth century. Our analysis has 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.

A crucial extension of the existing literature has been to analyse the relationship between investment returns and wage growth, which we have done through the use of both historical data and simulations. An economy might have high returns because of a successful period of development, in which case wage growth would also tend to be high. Prima facie it is not clear whether the combination of high wage growth and high returns will result in high or low fund ratios because the two effects have opposite effects on the fund ratio. Figure 2 shows that the effect of high returns tends to dominate the fast wage growth so that "successful" economies tend to have higher fund ratios.

We have found that there is considerable variation in fund ratios across both time and country. There is some evidence that countries keenest on individual DC pension accounts have the highest fund ratios (eg the UK, the USA), but all investors in all countries face considerable downside risk.

To construct hypothetical replacement ratios we have also estimated hypothetical annuity rates. If individuals purchased annuities that made payments constant in nominal terms then the initial incomes would be satisfactory, but would decline over time in real terms. If individuals purchased real annuities then over the post war period the pension income would have been unsatisfactory: the median replacement ratios we calculated are only around unity and these are based on population mortality and actuarially fair pricing. There is considerable downside risk, evidenced by the lowest decile of the replacement ratios being considerably less than the median.

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Figure 1: Hypothetical fund ratios obtained from lifestyle (dotted line) and equity (solid line) investment strategies

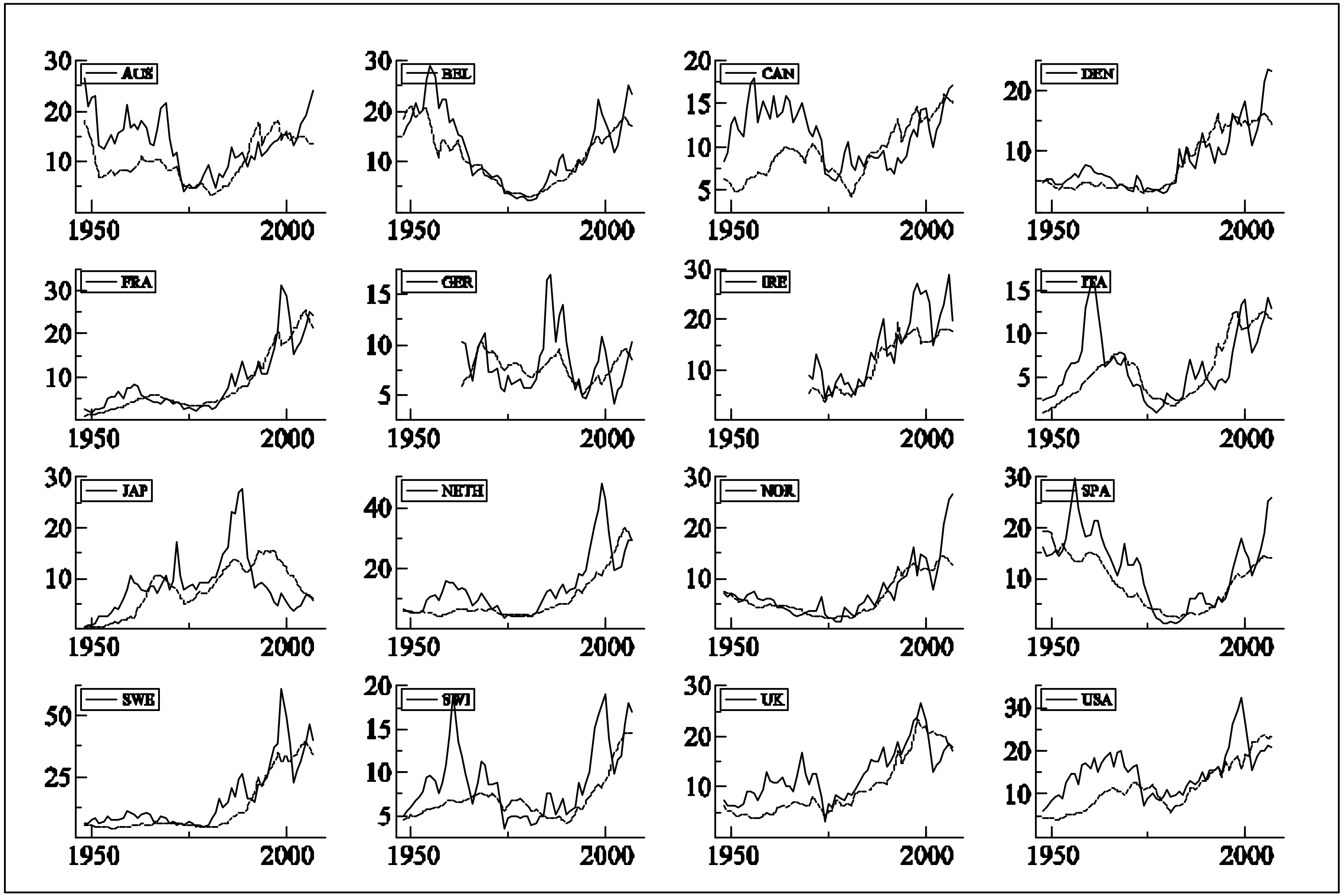


Figure 2: Fund ratios (equity investment strategy) and average equity returns: historical wage data

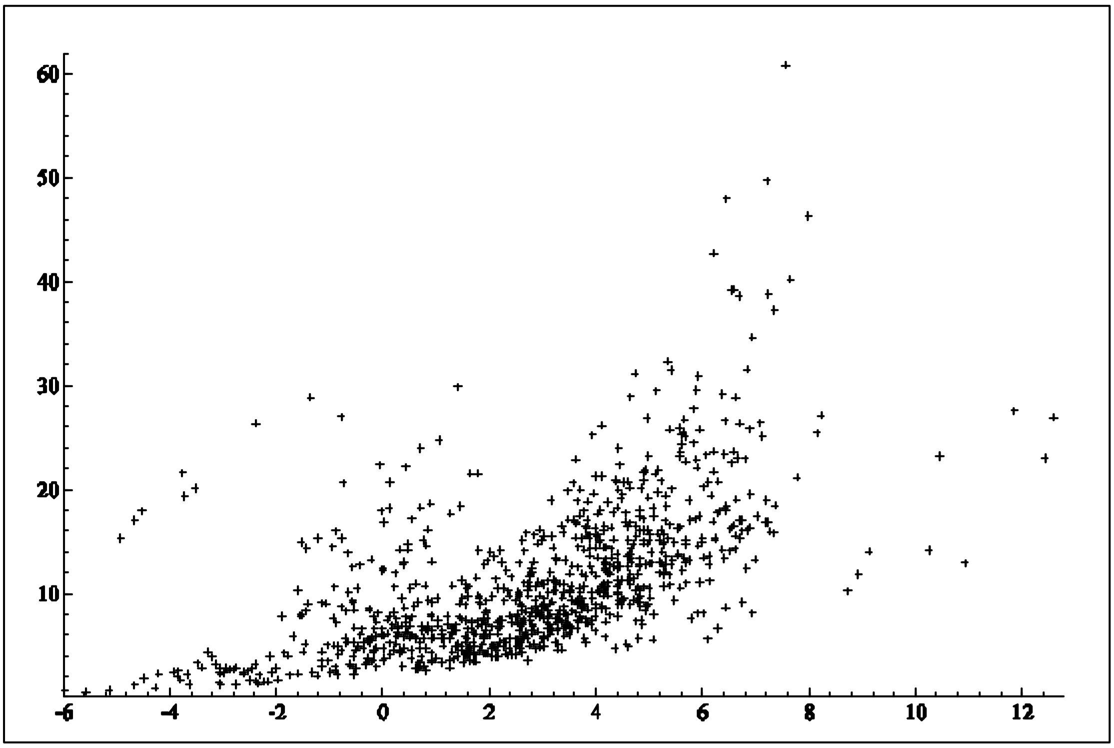


Figure 3: Fund ratios (equity investment strategy) and average equity returns: constant 1.5% annual real wage growth

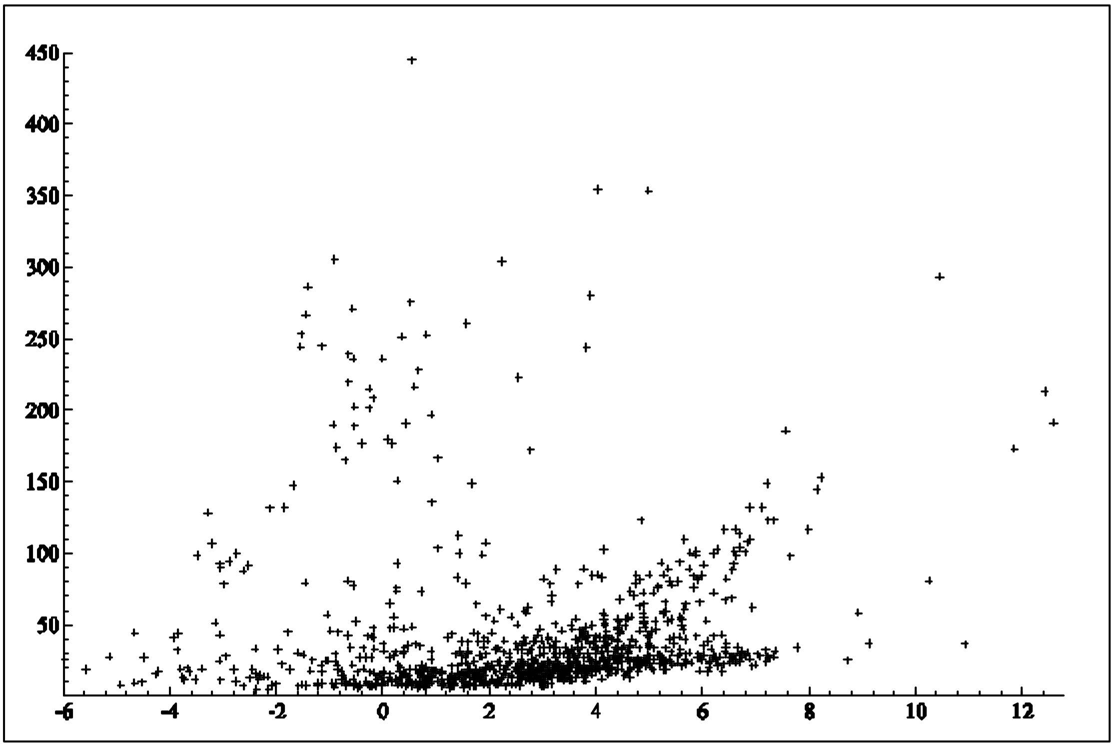


Figure 4: Densities of simulated fund ratios for equity strategy (solid line) and lifestyle strategy (dotted line) (densities truncated at 160)

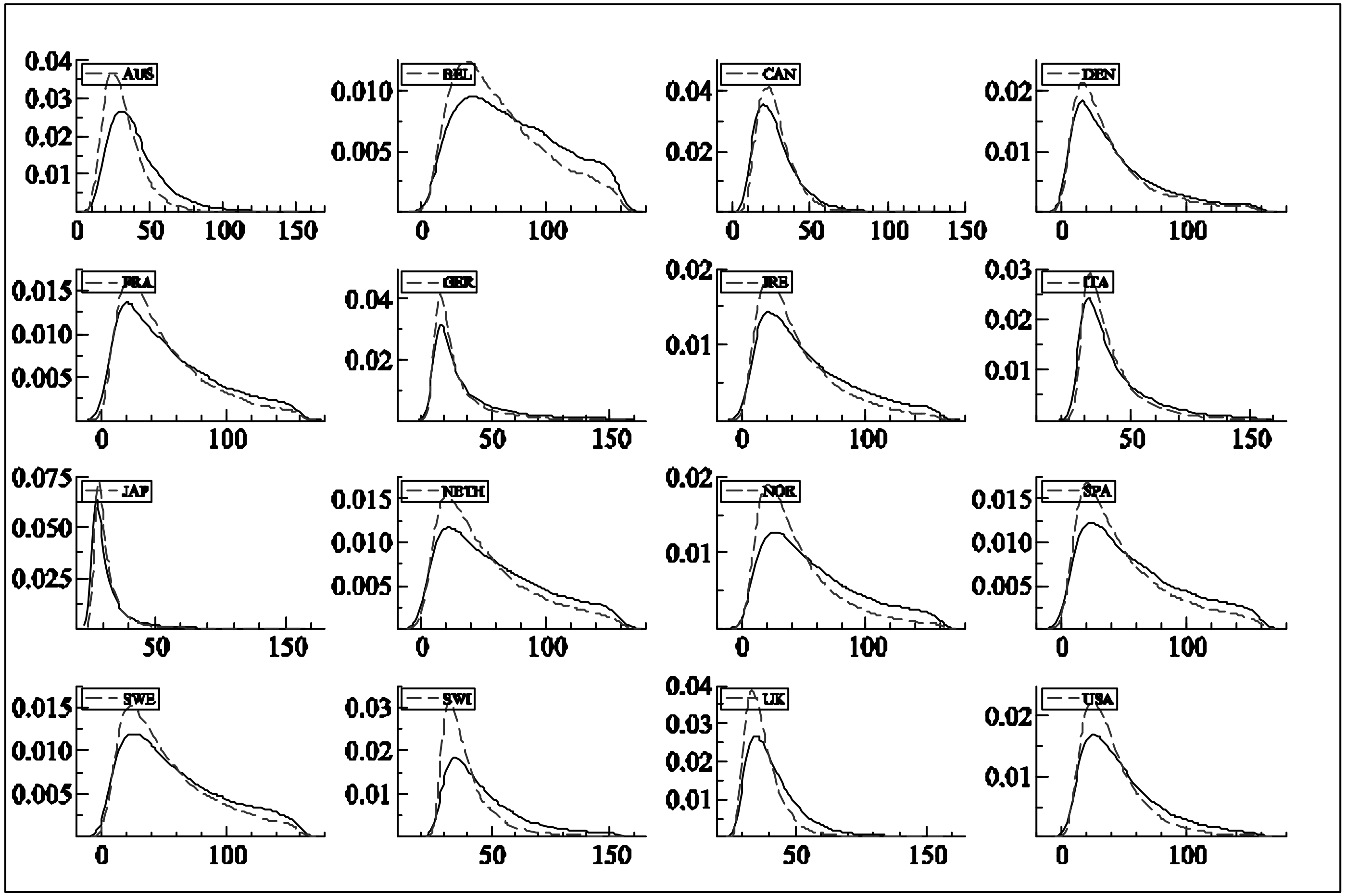


Figure 5: Hypothetical nominal (solid line) and real (dotted line) annuity rates

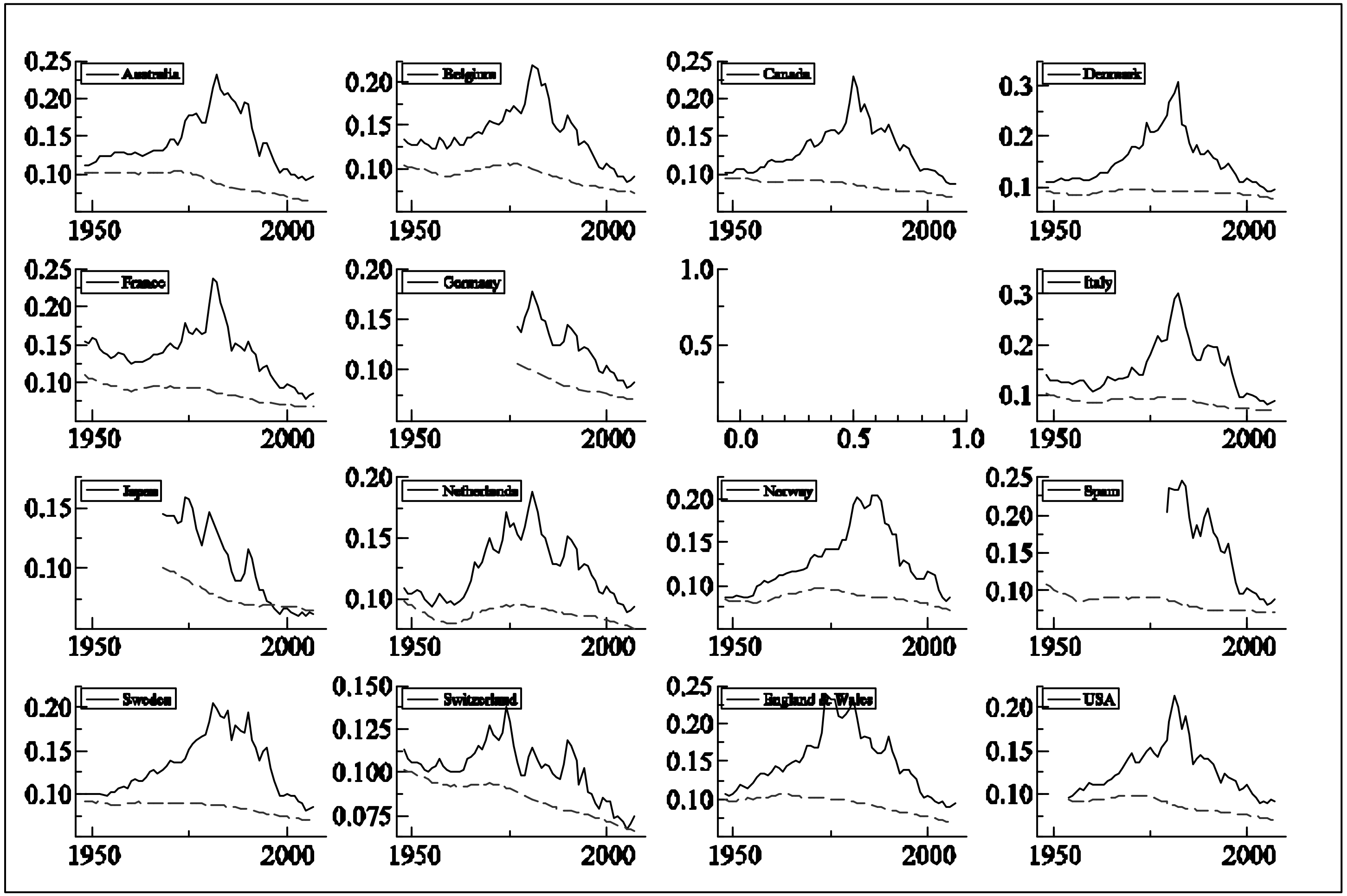
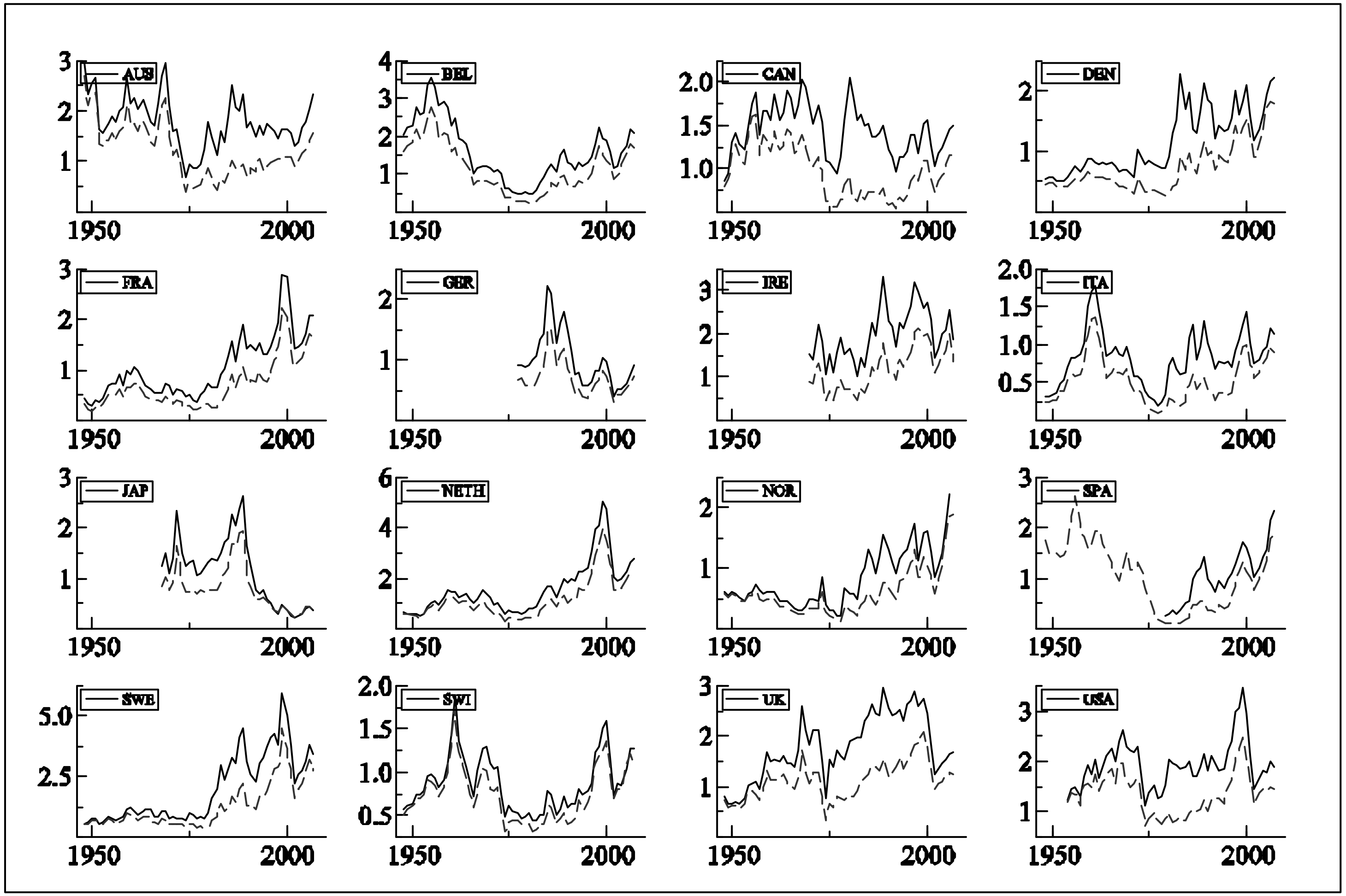


Figure 6: Hypothetical replacement ratios with nominal (solid line) and real (dotted line) annuities



Tables

Table 1: Preliminary analysis of underlying data series

Correlations between real bond returns, real equity returns and real wage growth			
	Bonds and equity	Bonds and wages	Wages and equity
Raw data	0.358	0.166	0.055
Smoothed data	0.302	0.060	0.172
Raw data, fixed effects	0.335	0.183	0.106
Smoothed data, fixed effects	0.099	0.089	0.001
Correlations between raw and unsmoothed data			
	Bond returns	Equity returns	Wage growth
	0.504	0.124	0.462

nb fixed effects refers to both country and year fixed effects.

Table 2: Summary statistics of hypothetical 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	Lifestyle	Bond	Equity	50:50	Lifestyle	Bond	Equity	50:50	Lifestyle
Australia	3.86	13.66	8.27	9.24	2.05	6.70	3.66	4.95	6.55	29.71	14.90	18.39
Belgium	6.86	11.04	9.39	10.16	2.52	3.14	2.95	3.70	7.14	14.06	11.14	11.77
Canada	4.04	11.52	7.47	9.19	2.72	7.29	4.62	5.71	6.30	23.73	13.10	19.71
Denmark	4.27	6.38	5.22	4.86	2.56	3.62	3.14	3.75	9.83	18.32	13.65	17.17
France	2.74	5.37	3.79	5.05	1.29	2.55	2.43	2.25	12.26	44.65	33.04	42.69
Germany*	4.26	7.35	5.35	7.76	2.40	5.55	4.12	6.10	10.65	20.42	16.32	21.52
Ireland*	6.38	13.26	9.91	13.56	1.95	6.49	3.75	5.10	25.01	77.38	51.68	70.52
Italy	2.42	5.45	4.05	5.08	1.16	2.23	1.55	1.90	8.79	39.67	37.13	40.88
Japan	2.69	8.00	4.88	8.09	0.61	2.49	1.33	0.76	11.36	173.38	40.76	59.61
Netherlands	4.28	11.57	7.15	6.13	1.98	4.55	3.13	4.59	6.48	24.47	11.52	17.01
Norway	4.04	5.85	5.22	4.60	2.06	2.70	2.81	2.43	7.72	10.55	9.28	8.99
Spain	6.59	12.76	9.97	9.04	1.72	2.09	2.01	2.87	11.23	23.07	18.01	23.24
Sweden	3.54	9.42	6.13	5.45	2.37	5.61	3.61	4.09	7.29	23.60	11.48	17.82
Switzerland	4.55	8.33	6.45	6.53	3.44	4.88	4.46	4.73	7.11	12.89	10.01	11.58
UK	4.16	11.76	6.26	6.88	2.37	6.52	4.64	4.37	7.07	34.02	16.64	29.20
USA	3.42	15.18	7.66	10.94	2.82	8.92	5.25	5.07	5.70	27.42	12.72	20.63

*Germany 1963-2007, Ireland 1970-2007

Table 3: Hypothetical fund ratios with different assumptions about investment management charges (all-equity strategy)

	2% annual charge	1% annual charge	0.3% annual charge
Australia	13.66	17.25	20.23
Belgium	11.04	13.62	15.87
Canada	11.52	14.51	17.07
Denmark	6.38	7.85	9.13
France	5.37	6.32	7.13
Germany*	7.35	9.10	10.61
Ireland*	13.26	16.31	18.95
Italy	5.45	6.37	7.20
Japan	8.00	9.59	10.53
Netherlands	11.57	14.21	16.45
Norway	5.85	7.25	8.46
Spain	12.76	16.27	19.25
Sweden	9.42	11.67	13.62
Switzerland	8.33	10.34	11.99
UK	11.76	14.49	16.86
USA	15.18	19.12	22.61
Average	9.81	12.14	14.12

*Germany 1963-2007, Ireland 1970-2007

Table 4: Simulated Fund Ratios

		Aust	Belg	Can	Den	Fr	Ger	Ire	Italy	Japan	Neth	Nor	Sp	Swe	Switz	UK	USA
Panel A: WHOLE PERIOD (1902-2007)																	
	Equity	9.3	3.8	6.2	3.5	1.9	1.8	5.0	1.6	1.6	3.3	2.7	3.1	5.4	3.0	5.0	6.3
Lower decile	50:50	4.8	3.8	4.5	3.2	1.6	1.9	3.5	1.4	1.2	2.8	2.6	3.2	4.3	3.0	3.3	4.9
	Lifestyle	5.8	3.7	4.8	3.3	1.6	1.8	3.9	1.4	1.1	2.9	2.6	3.1	4.5	3.1	3.6	5.0
	Equity	23.2	13.7	15.1	9.8	8.0	8.2	13.3	6.4	8.0	10.0	7.8	12.6	19.1	7.9	12.9	15.2
Median	50:50	10.2	8.9	8.5	7.0	5.0	6.0	7.4	4.4	5.2	6.1	5.8	8.7	9.6	5.9	7.3	8.6
	Lifestyle	14.0	10.5	10.6	7.7	5.7	6.2	9.0	4.6	5.6	7.1	6.1	9.9	12.3	6.5	8.9	10.4
Panel B: POST WAR (1948-2007)																	
	Equity	6.3	6.0	8.5	4.5	4.3	3.2	6.4	2.0	4.2	5.0	2.5	1.9	6.4	5.7	7.3	11.3
Lower decile	50:50	3.6	4.8	5.7	3.8	4.7	3.9	4.3	2.4	5.5	3.3	2.6	1.9	4.0	4.6	4.4	7.0
	Lifestyle	4.1	5.2	6.2	3.9	4.5	3.6	4.9	2.3	4.3	3.7	2.5	2.0	4.6	4.9	5.1	8.0
	Equity	17.2	24.9	16.7	13.0	16.2	14.9	18.4	10.8	11.6	18.2	8.6	10.9	22.4	16.0	17.9	24.2
Median	50:50	8.1	13.1	10.5	9.3	11.3	9.2	9.4	7.9	9.0	8.1	6.2	6.1	9.8	8.7	8.5	11.9
	Lifestyle	10.6	17.1	12.3	10.3	12.8	10.9	11.8	8.6	9.3	11.0	6.5	7.3	13.4	10.8	11.2	15.9
Panel C: GOLDEN AGE & STAGFLATION 1948-1978																	
	Equity	3.3	3.1	5.7	3.0	3.2	1.7	4.0	0.9	6.4	3.0	0.8	0.6	4.0	4.2	4.0	7.3
Lower decile	50:50	2.0	2.6	3.4	2.5	3.0	2.5	2.5	1.2	4.9	2.1	1.4	0.7	2.6	3.5	2.4	4.3
	Lifestyle	2.2	2.7	3.8	2.5	3.0	2.4	2.8	1.2	4.3	2.2	1.3	0.8	2.8	3.8	2.7	4.8
	Equity	9.1	6.6	11.4	4.3	9.6	6.8	8.4	4.8	16.7	6.8	1.6	2.2	6.2	8.9	10.1	14.0
Median	50:50	3.8	4.1	4.8	3.2	5.8	5.2	4.1	3.3	7.7	3.3	2.0	1.8	3.2	5.5	4.2	5.7
	Lifestyle	4.8	4.7	6.3	3.4	6.7	5.5	4.9	3.6	9.4	4.0	1.7	1.8	3.8	6.3	5.4	7.7

Panel D: 1980 ONWARDS

Lower decile	Equity	21.0	30.3	13.6	10.8	14.8	3.6	15.2	8.2	2.8	16.8	17.9	17.2	18.1	12.6	12.8	16.7
	50:50	16.8	22.7	18.5	11.9	16.9	4.1	14.3	12.1	5.9	13.6	14.0	13.3	18.4	9.0	10.8	17.2
	Lifestyle	17.8	24.2	15.4	10.8	14.9	3.7	13.9	9.8	4.4	14.1	14.2	14.4	16.8	9.9	11.4	16.2
Median	Equity	36.7	101.1	25.4	37.9	57.3	17.4	51.0	26.3	8.5	76.1	61.0	73.0	72.5	37.3	28.3	42.4
	50:50	25.2	42.8	26.7	28.5	36.7	11.6	30.6	23.8	11.0	30.7	25.9	30.2	38.1	16.1	18.5	30.0
	Lifestyle	29.2	65.2	25.6	31.6	43.8	12.8	37.3	24.1	9.6	47.1	37.4	44.9	50.3	22.9	22.3	35.0

Table 5: Summary statistics of hypothetical replacement ratios

	Panel A: Nominal annuity		Panel B: Real annuity	
	Lower decile	Median	Lower decile	Median
Australia	1.13	1.73	0.57	1.10
Belgium	0.59	1.39	0.33	0.95
Canada	1.06	1.48	0.62	0.93
Denmark	0.58	0.89	0.34	0.57
France	0.43	0.82	0.25	0.51
Germany*	0.57	0.91	0.41	0.64
Ireland*	1.35	1.93	0.63	1.12
Italy	0.34	0.82	0.20	0.48
Japan*	0.29	1.22	0.32	0.74
Netherlands	0.62	1.31	0.43	0.96
Norway*	0.33	0.61	0.25	0.50
Spain*	0.34	1.04	0.17	1.14
Sweden	0.74	1.17	0.50	0.84
Switzerland	0.50	0.80	0.41	0.71
UK	0.79	1.68	0.65	1.13
USA	1.41	1.90	0.83	1.37
Averages	0.69	1.23	0.43	0.86

* Germany 1977-2007, Japan 1968-2007, Norway 1948-2006, Spain 1979-2007; Ireland based on England & Wales mortality