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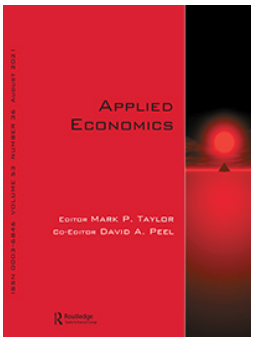

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ABSTRACT

The asset allocation decision is one of the most important decisions made by defined benefit pension schemes, with a major effect on the scheme contribution rate, funding ratio and financial position of the sponsoring company. We investigate the determinants of the equity allocation of UK pension funds using a panel of 1,304 observations on 125 companies that were members of the FTSE 100 over the 2003–2019 period. We find that seven variables have a significant effect on the allocation between equities and bonds – maturity (as measured by the effective duration of scheme liabilities), default risk, leverage of the sponsor, size of the sponsor (or the scheme), whether the scheme is closed to future contributions, whether the scheme has significant overseas liabilities, and a time trend. Our sensitivity analysis finds that the biggest effects on the asset allocation come from scheme maturity, the scheme's funding ratio and a time trend.

KEYWORDS

Pension fund asset allocation; pension scheme maturity; effective duration; defined benefit pension schemes; risk shifting

JEL CLASSIFICATION

G23; G32; J32

I. Introduction

The asset allocation of defined benefit (DB) pension schemes is one of the most important decisions taken by such schemes. It has a major effect on their investment performance, which then affects the scheme's funding ratio and contribution rates. While they are separate legal entities, since the employer (sponsor) is responsible for any surplus or deficit on their DB scheme, it is now generally accepted that the assets and liabilities of DB pension schemes are effectively consolidated with those of their sponsor. Therefore, a DB scheme affects its corporate sponsor in many different ways, including leverage, mergers and acquisitions, dividends, capital expenditure, share price and credit rating.[1]

DB pension scheme asset allocation has been the subject of a very active debate by trustees, actuaries, fiduciary managers, sponsors, fund managers, academics and regulators. A common solution, e.g. 60% equities and 40% bonds, does not prevail, and there is considerable variation in the asset allocations of UK DB pension schemes. This is the first study of the determinants of the equity-bond allocation of UK pension funds. The results for other countries do not necessarily apply to the UK due to institutional differences. The asset allocation decision is affected by UK pension legislation, the requirements of the Pension Regulator and UK institutions such as the Pension Protection Fund (Yuan and Lui 2016); as well as by the different circumstances of each scheme.[2] A better understanding of the determinants of asset allocation within the UK context will help both those making this decision, and those regulating and insuring pension schemes, as well as investors in DB scheme sponsors.

We study the determinants of the percentage of funds invested in equities by the DB pension schemes of FTSE 100 companies for the 2003–2019 period. We analyse the effects of ten explanatory variables on the equity allocation, while previous studies for other countries have

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[1]Leverage (Bartram 2016; Shivdasani and Stefanescu 2010), mergers and acquisitions (Cocco and Volpin 2013; Chang, Kang, and Zhang 2012; Meijdam 2012; Sudarsanam and Appadu 2015), dividends (Bunn and Trivedi 2005; Liu and Tonks 2010), capital expenditure (Bartram 2017; Campbell, Dhaliwal, and Schwartz 2012; Chaudhry, Yong, and Veld 2017; Dambra 2014; Kubick, Lockhart, and Robinson 2014; Phan and Hegde 2013; Rauh 2006), CAPM beta (Jin, Merton, and Bodie 2006), share price (Castro-Gonzalez 2012; Chen et al. 2014; Chen 2015; Feldstein and Mørck 1983; Feldstein and Seligman 1981; Franzoni 2009; Franzoni and Marin 2006a, 2006b; Liu and Tonks 2013 ; Nakajima and Sasaki 2010; Phan and Hegde 2013), and credit rating (Cardinale 2007; Carroll and Niehaus 1998; Gallagher and McKillop 2010a, 2010b; McKillop and Pogue 2009; Maher 1987, 1996; Martin and Henderson 1983; Wang, Wu, and Zhang 2013; Watson Wyatt 2005).

[2]There are no legal limits on the asset allocations of UK pension funds. However, the annual levy payable to the Pension Protection Fund rises with the riskiness of the asset allocation.

used only a few explanatory variables. This is the first study of the effects of non-linear default risk, leverage, cash flow volatility, size of the sponsor (or scheme) and maturity on the asset allocation of UK schemes. In addition to the six explanatory variables that have been used in previous research on the asset allocation decision for various countries, we also include four new variables – scheme closure to new contributions, overseas pension liabilities, a time trend and equity returns exceeding bond returns. This is also the first study to measure the maturity of DB pension schemes using effective duration, which we argue is the best available measure of scheme maturity. We find that UK DB scheme asset allocations vary in response to eight factors in ways that are largely consistent with prior expectations. Our results indicate that the large variations in pension scheme asset allocation observed in practice are due to differences in the circumstances of both sponsors and schemes. There is no single 'correct' asset allocation where one size fits all, e.g. 60% equities and 40% bonds.

The rest of this article is structured as follows. Section 2 reviews the literature on the determinants of the pension fund asset allocation. Section 3 discusses the measurement of the maturity of pension scheme liabilities, and in section 4 we describe our empirical model. Sample selection, data sources and descriptive statistics are contained in section 5. Section 6 presents our empirical results, and section 7 concludes.

Literature review

Theory indicates that three factors affect the asset allocation of DB pension schemes. The tax arbitrage strategies of Black (1980) and Tepper (1981) imply 100% investment in bonds, while the under-priced default insurance model of Sharpe (1976) leads to 100% investment in equities. In the presence of risk sharing between the scheme's sponsor and members the optimal asset allocation is indeterminate; depending on the risk sharing proportions and the sensitivity of total remuneration and the value of the sponsor's pension call option to changes in asset volatility (Sutcliffe 2016, pp. 219–221). Pension schemes are usually affected by more than one of these three factors, making it difficult to predict the optimal asset allocation. The empirical evidence for the influence of these three factors is limited, and only tax arbitrage has been researched. Thomas (1988) and Frank (2002) found some modest US evidence in favour of the tax arbitrage strategy, while, Bartram (2018) found no evidence for the tax arbitrage strategy for the US. In the UK Boots moved to 100% bonds in 2000 (Ralfe, Speed, and Palin 2004) in accordance with tax arbitrage motive.

In addition to these three factors, a pension fund's asset allocation may be affected by the default risk of the sponsor, and this has been examined empirically by research on the opposing motives of risk management and risk shifting. Risk management implies a negative relationship between sponsor default risk and the equity proportion of the pension fund, while risk shifting implies a positive relationship (Rauh 2009). There have been many empirical studies of risk shifting versus risk management for the US, and to a lesser extent the UK. In these studies, most have used the scheme's funding ratio as a reverse proxy for default risk. For the US, the evidence is mixed, with an equal number of studies supporting the two alternative hypotheses,[3] while the smaller number of studies for the UK mostly support risk shifting.[4]

A further influence on a pension fund's asset allocation is the degree to which the asset allocation is re-balanced in response to price changes. Unless the asset allocation is fully re-balanced, a rise or fall in the equity market (relative to the other assets held by the fund) automatically changes the equity proportion of the pension fund. For the Netherlands, Bikker, Broeders, and De Dreu (2010) found that about 60% of such changes in asset proportions are not removed by re-balancing. Rauh (2009) showed that investment returns have a positive

[3] Addoum, Van Binsbergen, and Brandt (2010), Amir and Benartzi (1999), An, Huang, and Zhang (2013), Anantharaman and Lee (2014), Atanasova and Gatev (2013), Bodie et al. (1985, 1987), Comprix and Muller (2006), Coronado, Liang, and Orszag (2006), Friedman (1983), Gallo and Lockwood (1995), Guan and Lui (2014), Mohan and Zhang (2014), Petersen (1996) and Rauh (2009).

[4] Guan and Lui (2014), LCP (2014), Li (2010), and McCarthy and Miles (2013).

relationship with pension fund equity allocation, implying less than full re-balancing.

High levels of leverage tend to increase the risk of default by the sponsor, and Davis and De Haan (2012) found that Dutch DB pension funds with a more highly levered sponsor have a lower equity allocation. Various studies have found that DB pension funds with a large sponsor also tend to have higher equity allocations (US – Amir and Benartzi 1999; Netherlands – Bikker et al. 2012; Netherlands – Davis and De Haan 2012; Switzerland – Gerber and Weber 2007; Kenya – Ngugi and Njuguna 2018; US – Rauh 2009). Another factor that has been found to influence asset allocations is the volatility of the sponsor's cash flows. Amir and Benartzi (1999) found that for US schemes the more volatile are the sponsor's cash flows, the lower is the equity allocation of its pension fund.

Finally, the structure of a scheme's liabilities may affect a pension fund's asset allocation. Previous studies for six countries (US, Canada, Netherlands, Finland, Switzerland and Belgium) of the effect of maturity (measured in various ways) on pension fund asset allocation support the view that, as a scheme becomes more mature, its equity allocation decreases.[5]

Some DB schemes are immature with mostly young active members, while others are mature with few or no active members. Immature schemes have liabilities that will not become due for many years, and a strong positive cash flow due to large contributions and small pension payments. Mature schemes are in the opposite position, with most of their liabilities due for payment in the near future, and a negative cash flow due to small contributions and large pension payments. Immature schemes are expected to favour equity investment, as they hope to benefit from the equity risk premium, and have the time to recover from a deficit by raising contribution rates and changing the benefits and retirement age. As they have little scope for raising contribution rates or changing the benefits and retirement age, mature schemes are expected to favour low-risk investments such as bonds. Bonds hedge the interest rate risk of the pension liabilities, are easy to liquidate to pay the pensions, and have low risk.

As well as cross-section differences in the liability structure of schemes, it has also been shifting over time. Over recent decades, the liability structure of DB schemes has been changing as many schemes have closed to new members or future accruals, to be replaced by defined contribution schemes. For example, in the UK, the proportion of DB schemes closed to future accruals in 2020 was 46% (Pension Protection Fund 2020). As a result, the average time lag before accrued benefits are paid has become shorter. However, increased longevity means that additional payments are required for pensioners at the end of their lives, which tends to lengthen the average time lag before payments are made. So the net effect of scheme closure and increased longevity on the time lag before accrued benefits are paid is unclear. The measure of scheme maturity needs to allow for such effects.

II. Measuring maturity

There is no agreed way of measuring scheme maturity, and a large number of alternative definitions have been used in previous empirical studies. These include the ratio of the number of active members to pensioners (US, Canada – López-Villavicencio and Rigot 2013), the ratio of active members to total participants (Belgium – Defau and De Moor 2018; US – Lucas and Zeldes 2009; Netherlands, US, Canada – Boon, Brière, and Rigot 2018; US – Friedman 1983; US – Rauh 2009), the average age of all members and pensioners (Switzerland – Gerber and Weber 2007), the average age of active members (Netherlands – Bikker et al. 2012; Chandler 2017; Switzerland – Gerber and Weber 2007), the average age of the sponsor's employees (Finland – Alestalo and Puttonen 2006), the average age of pensioners (Canada – Chandler 2017), the proportion of liabilities represented by pensioners (Canada – Chandler 2017), and the log

[5] US (Amir and Benartzi 1999; Friedman 1983; Lucas and Zeldes 2009; López-Villavicencio and Rigot 2013; Rauh 2009), US, Canada and Netherlands (Boon, Brière, and Rigot 2018), Canada (López-Villavicencio and Rigot 2013), Netherlands (Bikker et al. 2012), Finland (Alestalo and Puttonen 2006), Switzerland (Gerber and Weber 2007) and Belgium (Defau and De Moor 2018).

(Pension benefit obligation/Accrued benefit obligation) divided by the log(1+ Salary growth rate) (US – Amir and Benartzi 1999).

All these measures of maturity, apart from the last, simply group participants according to their age or membership status, which assumes that those of the same age or with the same membership status have the same effect on maturity. This ignores substantial differences in the magnitude of the benefits accrued by participants of the same age or membership status. Since scheme maturity influences a pension fund's asset allocation via its effect on when the scheme's liabilities fall due for payment, what is needed is a summary measure of the timing of future pension payments, irrespective of the age or membership status of participants. Macaulay duration provides such a measure (Macaulay 1938; Van Zijl 1990). Duration is expressed in years as it measures the weighted average number of years until pension payments are made, where the present values of these cash flows vary with the discount rate.

$$\text{MacaulayDuration} = \frac{1}{L_i}\sum_{t=1}^{n} t\frac{C_t}{(1+i)^t}$$

where C_t is the total of the DB pension payments expected to be made in time period t, i is the discount rate used to calculate the present value of the DB pension liabilities, L_i is the DB pension liability when the discount rate is i, and n is the total number of time periods

Macaulay's duration depends on several assumptions. First, a single interest rate is applied to discount all the cash flows, i.e. the yield curve is flat. Second, there are only parallel shifts in the yield curve. Finally, the cash flows are independent of changes in the yield curve. To avoid making these assumptions McCaulay (2013) suggested using effective duration to measure the duration of pension liabilities. The value of effective duration is usually reasonably similar to the Macaulay duration, with a smaller effective duration indicating a more mature pension scheme, i.e. pension payments are weighted more towards the present, than to some distant horizon. The information in UK annual reports does not permit the calculation of Macaulay's duration (or modified duration), only effective duration. So we measure the maturity of pension schemes in years using effective duration, which is defined as:

$$\text{PensionEffectiveDuration} = \frac{\mathrm{L}_{\mathrm{i-x}} - \mathrm{L}_{\mathrm{i+x}}}{2\mathrm{L}_{\mathrm{i}}\mathrm{x}}$$

where$x$ is the change in the discount rate, and x and L_{i+x} are the DB pension liabilities when the discount rate is $i \pm x$.

III. Empirical model

To investigate the determinants of the asset allocation of pension funds we estimate the model:

$$\begin{aligned} Equity_{it} = {} & \alpha + \beta_1 ED_{it} + \beta_2 FR_{it} + \beta_3 FR_{it}^2 \\ & + \beta_4 LEV_{it} + \beta_5 SDCF_{it} + \beta_6 Size_{it} \\ & + \beta_7 Close_{it} + \beta_8 EHB_t + \beta_9 Overseas_{it} \\ & + \beta_{10} T_t + \varepsilon_{it} \end{aligned}$$

The dependent variable ($Equity_{it}$) is the percentage of the pension fund's equity assets, as a proportion of the total pension assets of firm i at the end of financial year t. ED_{it} is the effective duration of firm i's pension liabilities (years) at the end of financial year t. We expect a positive relation between the effective duration of pension liabilities and the equity allocation. In other words, more immature (or younger) schemes are expected to have higher equity allocations.

Bader (1991) argues that pension schemes with substantial over or underfunding should invest mainly in fixed-income securities, whereas fully funded schemes should allocate more to equities. This implies an upside-down *U*-shaped relationship between the funding ratio and equity allocation. Using UK data Li (2010) found empirical support for this view, which involves both risk sharing and risk management. To allow for a non-linear relationship between the funding ratio and equity allocation we include the funding ratio squared (FR_{it}^2), as well as the funding ratio (FR_{it}). FR_{it} is the total market value of pension assets divided by the DB pension liabilities (%) for firm i at the end of financial year t. Whether the funding ratio has a positive, negative on non-monotonic effect on the equity allocation is an empirical question.

Higher levels of leverage increase the risk of default, and Amir, Guan, and Oswald (2010) argue that companies close to violating debt covenants are particularly at risk. To capture the effect of debt, we include the financial leverage ratio (LEV_{it}) in our model. LEV_{it} is measured as long-term debt divided by the sum of long-term debt and the market value of the sponsor's equity (%) for firm i at the end of year t. A higher level of leverage increases the sponsor's default risk, and we expect this to result in a lower allocation of pension assets to equities.

Sponsors usually make pension fund contributions using their net cash inflows from operations. If these cash flows fluctuate this increases the risk that the sponsor will have difficulty in making their pension contributions; and this risk is increased if the size of the required contributions also fluctuates. To reduce this risk sponsors with fluctuating net cash inflows from operations may tend to invest their pension fund in low-risk assets. $SDCF_{it}$ is the volatility of cash flows from operating activities, measured as the standard deviation of operating cash flows over the current and previous four years, deflated by the book value of common equity for firm i at the end of financial year t. We expect this variable to have a negative effect on the equity allocation.

Larger companies tend to have lower risk and better access to investment expertise, and so are willing to hold more risky assets in their pension fund (De Dreu and Bikker, 2012). To control for this effect, we include company size ($Size_{it}$), which we measure as the natural logarithm of the DB pension sponsor's market capitalization (£ million) for company i at the end of year t. We also use an alternative measure of $Size_{it}$, which is the natural logarithm of total DB pension assets (£ million) of company i at the end of year t (Gorter and Bikker, J.A. 2013). We expect size to have a positive effect on the equity allocation.

Over the past two decades many UK companies have closed their DB pension schemes to future accruals (hard closed), and these schemes are now in 'run-off'. Since these schemes have no contributions, they will probably invest in low-risk assets (Butt 2011). We use the (1–0) dummy variable $Close_{it}$ to capture the effect of hard closure on the pension fund's asset allocation. $Close_{it}$ equals one when the sponsor's principal DB scheme is hard closed for firm i at the end of financial year t, and zero otherwise. We expect a negative effect of this dummy variable on equity allocations.

When equity markets have a higher average total return than bond markets, this will not only increase the proportion of pension assets in equities but also encourage DB schemes to invest more in equities. Therefore, we include a (1–0) dummy variable EHB_{it}, which is one when the total return on the equity index is higher than the total return on the bond index in year t, and zero otherwise. We expect the relation between this dummy variable and equity allocations to be positive.

Some companies in the FTSE 100 are multinational businesses with DB pension schemes in other countries. These companies are concentrated in industries such as basic materials and oil and gas with major operations in developing countries, and this may mean they have younger members. Because overseas schemes are subject to different regulations, we include another (1–0) dummy variable ($Overseas_{it}$) to capture this effect. It is equal to one if company i has more than 20% of its pension assets in overseas schemes at the end of fiscal year t, and zero otherwise. The sign on this variable is difficult to predict.

In the 1950s UK pension funds began a trend towards increasing their investment in equities (the cult of the equity), which culminated in the 1990s with very high average equity allocations (Sutcliffe 2005). As Figure 2 shows, this century there has been a steady downward trend in the average equity allocation. So we include a time trend (T), with the expectation that it will have a negative coefficient.

Since all the firms in our data are FTSE 100 companies, the tax arbitrage motive probably applies to all, or most, of them; implying a general motive to invest the pension fund in 100% bonds. All these firms are also subject to the Pension Protection Fund[6] which aims to price its insurance fairly, and this implies 100% of the pension fund in equities. The presence of risk sharing between the sponsor and members, and its likely effect on the pension fund's asset

[6]The Pension Protection Fund began operating in 2004, and so does not apply in 2003.

Table 1. Descriptive statistics for FTSE 100 companies from 2003 to 2019.

Variable	FTSE 100 Sample		
	Mean	Median	STD
Equity	35.23	34.16	18.40
ED	18.00	17.89	3.13
FR	91.88	92.65	17.96
FR^2	8757.21	8572.89	3258.79
LEV	16.38	13.47	13.76
SDCF	0.12	0.06	1.33
Size (SMC)	9.49	9.08	1.75
Size (PA)	7.19	7.29	1.89
Close	0.22	0	0.42
EHB	0.64	1	0.48
Overseas	0.31	0	0.46
T	11.04	11	3.61

Equity is the percentage of the pension fund's equity assets, as a proportion of the total pension assets. *ED* is the effective duration of firm's pension liabilities (years). *FR* is the total market value of pension assets divided by the DB pension liabilities (%), and FR^2 is the funding ratio squared to allow for the non-linear relation between the funding ratio and equity allocation. *LEV* represents the leverage which is measured as long-term debt divided by the sum of long-term debt and the market value of the sponsor's equity (%). *SDCF* is the volatility of cash flows from operating activities, measured as the standard deviation of operating cash flows over the current and previous four years, deflated by the book value of common equity. *Size(SMC)* is the natural logarithm of the sponsor's market capitalization (£ million), and *Size(PA)* is the natural logarithm of pension scheme assets (£ million). *Close* equals one when the sponsor's principal DB scheme is hard closed, and zero otherwise. *EHB* is one when the total return on the equity index is higher than the total return on the bond index, and zero otherwise. *Overseas* is equal to one if a company has more than 20% of its pension assets in overseas schemes, and zero otherwise. *T* is a time trend (1, 2, 3, 4, ...) starting in 2007 to pick up the time effect of the credit crunch, with prior years assigned a value of zero.

allocation are hard to determine; and could lead to more or less investment in equities. These three factors are not included in our empirical model as there is minimal, or no, within sample variation in the first two factors, and no data on the third factor.

IV. Data

Our sample consists of annual data on 125 of the past and present FTSE 100 constituents that have, or had, DB pension schemes over the 2003–2019 period. The information to compute the effective duration was collected manually from the sensitivity analysis section of each company's annual reports. The dates of the closure of DB schemes to future accruals, and the proportions of pension assets in overseas schemes were also obtained from the annual reports. The funding ratios, percentage of pension asset allocations, sponsors' market capitalization and other financial data for the sample companies were downloaded from Bloomberg. Market capitalizations denoted in foreign currency were converted to pound sterling using official exchange rates from World Bank Open Data.[7] The annual returns for the equity and bond indices were downloaded from Datastream.[8] After removing observations with missing values, the sample contains 1,304 company-year observations.

Descriptive statistics for our data are presented in Table 1. During the sample period companies allocated an average of 35.23% of their total pension assets to equities. The average effective duration (*ED*) for the sample is 18 years, which is close to the median. The average funding ratio (*FR*) is 91.88%, which means the sample is moderately underfunded. We use the natural logarithm of each DB pension sponsor's market capitalization to represent the *Size (SMC)*; but we also consider the natural logarithm of DB pension assets, *Size (PA)*, as an alternative measure of size. Finally, for our three dummy variables, 22% of the sample pension schemes are closed to future accruals. Over the sample period 64% of the time the equity index generated higher total returns than the bond index, and 31% of the sponsors had overseas DB schemes which accounted for over 20% of their total pension assets.

From Figure 1, we can see a clear downward trend in the average maturity of pension liabilities per year for our sample companies, dropping from 21.2 years in 2003 to 17.8 years in 2019. This is

[7]Official exchange rate is the local currency units relative to the US dollar calculated and based on monthly averages supplied by the World Bank: databank.worldbank.org/reports.aspx?source = 2&series = PA.NUS.FCRF&country =

[8]We use the FTSE All-World Index as the equity index, and the J.P. Morgan Global Aggregate Bond Index as the bond index.

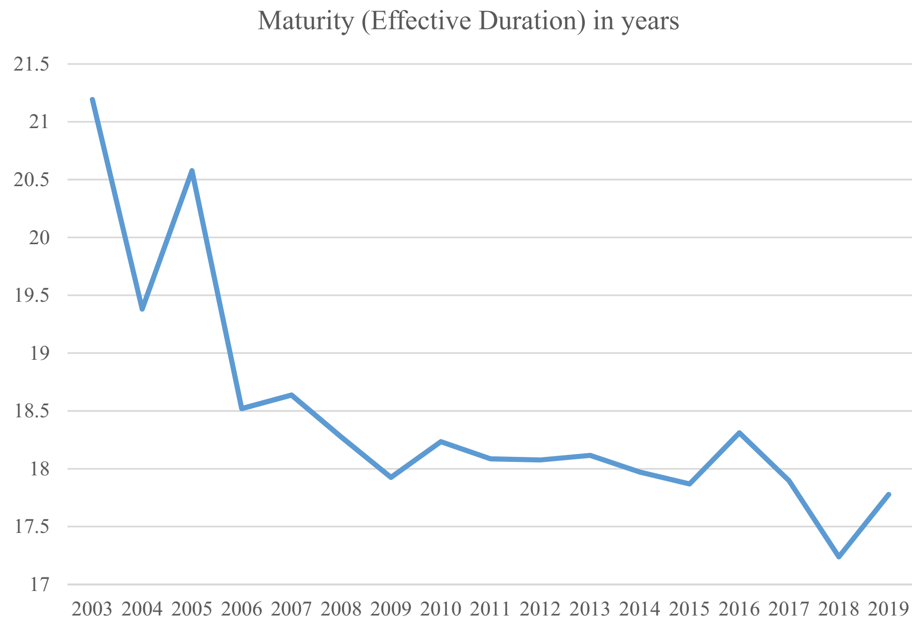

Figure 1. Trend in the average maturity (Effective duration) of UK pension funds – 2003-2019.

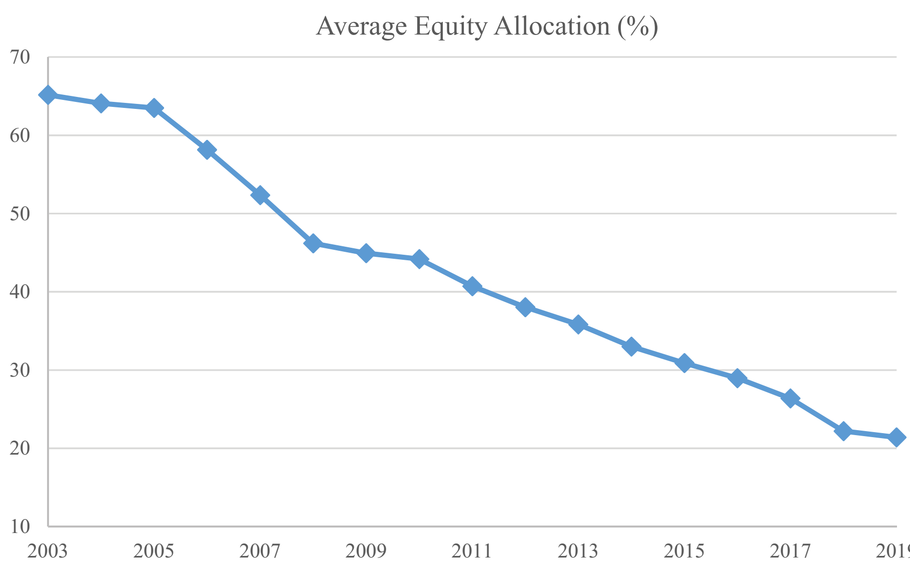

Figure 2. The average equity allocation of FTSE 100 pension funds – 2003-2019.

probably due to the continuing closure of DB schemes to new members or future accruals. In 2006 43% of UK DB schemes were open to new members, but by 2020 this had dropped to 11% (Pension Protection Fund 2020). Figure 2 shows that there is a clear and relatively smooth downward trend in the average equity allocation in our sample, decreasing from 65.17% in 2003 to 21.40% in 2019. Table 2 has the correlations between the variables in our model. There are only two correlations above 0.5, so multicollinearity does not appear to be a problem.

V. Empirical results

We use linear regression with heteroscedastic panel corrected standard errors (PCSE), where we cluster the standard errors at the level of the sponsor

Table 2. Correlation matrix for the variables of the companies studied – 2003-2019.

	Equity	ED	FR	FR^2	LEV	SDCF	Size (SMC)	Size (PA)	Close	EHB	Overseas	T
Equity	1											
ED	0.173	1										
FR	−0.285	0.154	1									
FR^2	−0.338	0.163	0.954	1								
LEV	0.067	−0.012	−0.086	−0.099	1							
SDCF	−0.006	0.016	0.018	0.023	0.006	1						
Size (SMC)	−0.135	−0.167	0.128	0.109	−0.294	0.056	1					
Size (PA)	−0.157	−0.199	0.319	0.243	0.014	0.027	0.570	1				
Close	−0.252	−0.015	0.174	0.170	−0.166	0.022	−0.077	−0.060	1			
EHB	0.077	0.003	0.024	0.010	−0.010	−0.033	0.015	0.020	−0.055	1		
Overseas	0.112	−0.294	−0.312	−0.290	0.107	−0.077	0.257	0.007	−0.218	0.018	1	
T	−0.521	−0.068	0.167	0.199	−0.094	−0.016	0.031	0.006	0.377	−0.165	−0.053	1

Equity is the percentage of the pension fund's equity assets, as a proportion of the total pension assets. *ED* is the effective duration of firm's pension liabilities (years). *FR* is the total market value of pension assets divided by the DB pension liabilities (%), and *FR^2* is the funding ratio squared to allow for the non-linear relation between the funding ratio and equity allocation. *LEV* represents the leverage which is measured as long-term debt divided by the sum of long-term debt and the market value of the sponsor's equity (%). *SDCF* is the volatility of cash flows from operating activities, measured as the standard deviation of operating cash flows over the current and previous four years, deflated by the book value of common equity. *Size(SMC)* is the natural logarithm of the sponsor's market capitalization (£ million), and *Size(PA)* is the natural logarithm of pension scheme assets. *Close* equals one when the sponsor's principal DB scheme is hard closed, and zero otherwise. *EHB* is one when the total return on the equity index is higher than the total return on the bond index, and zero otherwise. *Overseas* is equal to one if a company has more than 20% of its pension assets in overseas schemes, and zero otherwise. *T* is a time trend (1, 2, 3, 4, . . .) starting in 2007 to pick up the time effect of the credit crunch, with prior years assigned a value of zero.

company, since the sample is an unbalanced panel and contains possible heteroscedasticity and serial correlation in the errors. The initial number of observations is 1,304, but after removing observations with missing values and outliers with extremely large or small values, the number of observations decreases to 1,268. The Jarque-Bera test (2.143, χ^2 = 0.3426) shows that the regression residuals are normally distributed, and so the significance tests on the coefficients are reliable.

Since the coefficient on *ED* is positive and highly significant, the results in model (1) of Table 3 support our hypothesis that FTSE 100 companies with less mature pension schemes allocate more assets to equities. The coefficient means the equity allocation is increased by 1.232% when the effective duration (*ED*) of DB pension liabilities is increased by one year. The positive coefficient on the funding ratio (*FR*) of pension schemes shows that every 1% increase in the funding ratio leads to a 0.431% increase in the equity allocation. This supports the risk management hypothesis. The negative coefficient of −0.004 on *FR^2* indicates that, for funding ratios of less than 54%, increases in *FR* have a net positive effect on the equity allocation, but at a decreasing rate. However, for funding ratios above 54%, the equity allocation decreases, giving an inverted *U*-shaped relationship. As only 2.84% of the funding ratios of our sample of 1,304 observations are below 54%, the empirical reality for the UK is risk shifting.

As expected, pension funds with more highly levered sponsors (*LEV*) have lower equity allocations, with a 1% higher financial leverage leading to equity allocations that are 0.089% lower. The negative coefficient on *Size (SMC)* (−1.178) indicates that the schemes of larger companies have lower equity allocations. This conflicts with our expectation and may be because larger schemes have responded more strongly to the general trend for de-risking. Companies with pension schemes closed to future accruals (*Close*) have equity allocations 3.413% lower than otherwise, which accords with our expectations. Those companies with more than 20% of their pension assets in foreign schemes (*Overseas*) have equity allocations that are 4.900% higher. The highly significant time trend (*T*) shows there is a strong de-risking trend. Finally, the coefficients on *SDCF* and *EHB* are insignificant, indicating that changes in the volatility of operational cash flows do not cause UK listed companies to hold less equities in their pension funds; and higher annualized total returns for the equity index have no effect on the equity allocation.

Model (2) of Table 3 measures size using total pension assets *Size (PA)*, and leads to the same main conclusions as model (1). The differences are that *LEV* is no longer significant, *Overseas* has

Table 3. The equity allocation of DB pension funds.

Variable	Expected Sign	(1)	(2)
ED	+	1.232***	1.211***
		(9.55)	(8.89)
FR	?	0.431***	0.452***
		(4.94)	(4.57)
FR^2	?	−0.004***	−0.004***
		(−7.31)	(−6.76)
LEV	-	−0.089***	−0.035
		(−3.29)	(−1.36)
SDCF	-	0.020	−0.053
		(0.05)	(−0.14)
Size	+	−1.178***	−0.746***
		(−4.98)	(−2.75)
Close	-	−3.413***	−3.131***
		(−3.16)	(−2.84)
EHB	+	0.238	0.348
		(0.29)	(0.42)
Overseas	?	4.900***	3.435***
		(5.88)	(4.09)
T	-	−2.097***	−2.076***
		(−17.67)	(−17.33)
Constant	+	38.713***	31.838***
		(7.89)	(6.54)
Observations		1268	1287
Number of companies		125	125
Adj. R^2		0.4155	0.3972

This table shows the regression results of heteroscedastic panel corrected standard errors (clustering the standard errors at the level of a sponsor firm) for a sample of FTSE 100 companies with DB pension schemes. The dependent variable is *Equity*, it represents the percentage of the pension fund's equity assets, as a proportion of the total pension assets. *ED* is the effective duration of firm's pension liabilities (years). *FR* is the total market value of pension assets divided by the DB pension liabilities (%), and FR^2 is the funding ratio squared to allow for the non-linear relation between the funding ratio and equity allocation. *LEV* represents the leverage which is measured as long-term debt divided by the sum of long-term debt and the market value of the sponsor's equity (%). *SDCF* is the volatility of cash flows from operating activities, measured as the standard deviation of operating cash flows over the current and previous four years, deflated by the book value of common equity. *Size(SMC)* is the natural logarithm of the sponsor's market capitalization (£ million), and *Size(PA)* is the natural logarithm of pension scheme assets (£ million). *Close* equals one when the sponsor's principal DB scheme is hard closed, and zero otherwise. *EHB* is one when the total return on the equity index is higher than the total return on the bond index, and zero otherwise. *Overseas* is equal to one if a company has more than 20% of its pension assets in overseas schemes, and zero otherwise. *T* is a time trend (1, 2, 3, 4, . . .) starting in 2007 to pick up the time effect of the credit crunch, with prior years assigned a value of zero. Column (1) provides coefficients and z-statistics (in parentheses) when *Size* is denoted by the natural logarithm of the sponsor's market capitalization. Column (2) provides coefficients and *z*-statistics (in parentheses) when *Size* is denoted by the natural logarithm of total pension assets. ***, ** and * indicate the significance levels 1%, 5% and 10%, respectively.

a smaller coefficient, and *Size* has a larger coefficient.

To further measure the importance of each explanatory variable on the equity allocation, we use sensitivity analysis to quantify the effect of a one standard deviation change in the value of each significant non-dummy explanatory variable on the predicted average equity allocation, with all other explanatory variables set to their average values. These sensitivities depend on both the variability of each variable and its regression coefficient. Since the two *Size* variables are natural logs, their effect on the dependent variable is non-linear. So we first use the original values of *Size (SMC)* and *Size (PA)* to compute their means and standard deviations, and then employ the natural logs of the increased and decreased *Size* values in the empirical equation. The effect of changes in the funding ratio is also non-linear as *FR* involves a squared term. The sensitivity results for models 1 and 2 in Table 3 are in Table 4.

Table 4 shows that the sensitivity of the equity allocation to one standard deviation changes in *ED*, *FR*, *Size* and *T* are broadly similar for models (1) and (2). The dependent variable is most sensitive to variations in *T* (24%), closely followed by variations in *FR* (−21% for an increase, and 13% for a decrease of one standard deviation). Variations in *ED* have half the effect (12%) of *T* and *FR* on the equity allocation. Variations in *LEV* have a much smaller effect (4%), and *Size* has an even smaller effect (below 1%). Changes in the dummy variables *Close* and *Overseas* change the equity allocation by between 3% and 5%.

As a robustness check, we apply fixed effects and random effects panel regressions for both the *Size (SMC)* and *Size (PA)* models, with a Hausman test to select between fixed and

Table 4. Sensitivity analysis of significant explanatory variables.

Significant Explanatory Variable (One Std. Dev. Increase or Decrease)*	Model 1 - % Change in *Equity*	Model 2 - % Change in *Equity*
ED	12.10%	12.06%
FR	−21.19% & 13.09%	−20.29% & 12.07%
LEV	−3.84%	– –
Size	−0.65% & 0.92%	−0.42% & 1.33%
T	23.76%	23.85%

This table is calculated on the basis of the descriptive statistics from Table 1, and the regression coefficients from Table 3. All the variables have been explained in Table 3. The predicted values of *Equity* using the average values of the explanatory variables are 31.86% for model 1, and 31.42% for model 2.

* The effects of a decrease of one standard deviation are the same as those for a decrease, except for the funding ratio and the size variable, where we report the effect of both an increase and a decrease in their standard deviation.

Table 5. Robustness test for the equity allocation of DB pension funds.

Variable	(1)	(2)	(3)	(4)
ED	0.417**	0.576***	0.434***	0.592***
	(0.181)	(0.165)	(0.181)	(0.166)
FR	0.038	0.083	0.012	0094
	(0.092)	(0.084)	(0.094)	(0.086)
FR^2	−0.001**	−0.001***	−0.001*	−0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
LEV	−0.073	−0.094**	−0.024	−0.021
	(0.046)	(0.041)	(0.039)	(0.037)
SDCF	−0.066	−0.049	−0.013	−0.023
	(0.182)	(0.182)	(0.186)	(0.186)
Size	0.265	−0.558	1.655	−0.436
	(0.661)	(0.500)	(1.021)	(0.533)
Close	−2.547***	−2.762***	−2.893***	−2.987***
	(0.967)	(0.934)	(0.984)	(0.957)
EHB	0.510	0.511	0.571	0.588
	(0.496)	(0.495)	(0.502)	(0.503)
Overseas	2.863	2.679	2.310	2.072
	(2.192)	(1.733)	(2.153)	(1.701)
T	−2.452***	−2.371***	−2.497***	−2.327***
	(0.092)	(0.087)	(0.109)	(0.089)
Constant	57.134***	60.915***	47.650***	54.855***
	(9.328)	(7.583)	(8.240)	(6.265)
Observations	1268	1268	1287	1287
Number of companies	125	125	125	125
Robust standard errors	Yes	Yes	Yes	Yes
Fixed effects in company	Yes	No	Yes	No
Random effects	No	Yes	No	Yes
R^2 overall	0.3607	0.3891	0.2882	0.3685
Hausman test	0.0064		0.0000	

Notes: This table shows the regression results of the fixed and random effects with robust standard errors. All the variables have been explained in (Table 3). Columns (1) and (2) provide coefficients and robust standard errors (in parentheses) when *Size* is denoted by the natural logarithm of the sponsor's market capitalization. Columns (3) and (4) provide coefficients and robust standard errors (in parentheses) when *Size* is denoted by the natural logarithm of total pension assets. ***, ** and * indicate the significance levels 1%, 5% and 10%, respectively.

random effects. We also apply robust standard errors to address heteroscedasticity and autocorrelation in the errors. The panel data results of these regressions are presented in Table 5.

Columns (1) and (2) in Table 5 show the fixed and random effects models with robust standard errors when size is denoted by the natural logarithm of sponsor's market capitalization, i.e. *Size (SMC)*. The Hausman test statistic of 0.0064 means the fixed effects model (1) is superior to the random effects model (2). Column (1) confirms that for the fixed effects model *ED* has a positive effect on *Equity; and FR^2*, *Close* and *T* have a negative effect on *Equity*. Columns (3) and (4) has the results for the fixed and random effects models with robust standard errors, where size is now denoted by the natural logarithm of total pension assets, i.e. *Size (PD)*. The Hausman test statistic of 0.0000 favours the fixed effects model in column (3), rather than the random effects model in column (4); and the results in column (3) confirm those in column (1) of Table 5.

Overall, the results of these four regressions (models 1 and 2 in Table 3, and 1 and 3 in Table 5) support a positive effect of *ED* on *Equity*; and negative effects for FR^2, *Close* and *T*. There is also evidence from models (1) and (2) in Table 3 that *FR* and *Overseas* have a positive effect on *Equity*, and *LEV* and *Size* have a negative effect. Apart from *Size*, the signs of the eight significant variables are in accord with our prior expectations.

VI. Conclusions

We use a sample of 125 UK-listed companies who were constituents of the FTSE 100 index over the 2003–2019 period to study the factors affecting their pension fund asset allocation. This is a very important decision for pension schemes and their sponsors that has a major effect on their funding ratios and contribution rates. We use ten explanatory variables, including the first use of effective duration to measure maturity, as well as being the first to include scheme closure, the long-term downward trend, the presence of overseas liabilities and excess equity returns in the analysis.

Our panel regressions indicate a positive relation between the effective duration of pension liabilities, and the proportion of the pension fund invested in equities. In other words, UK companies with less mature pension schemes tend to increase the investment of their DB pension fund in equities. There is also evidence for a small non-linear negative effect of the funding ratio on the equity allocation, consistent with risk shifting; and strong evidence of a de-risking time trend. We also find that firms with a hard closed pension scheme also have lower equity allocations.

There is weaker evidence that the equity allocation is higher for firms with more than 20% of their pension assets in overseas schemes, and that the funding ratio has a positive effect of the equity allocation. When combined with the negative effect of the squared funding ratio, the result is that the funding ratio has an inverted *U*-shaped effect on the equity allocation, as proposed by Bader (1991) and Li (2010). Some evidence is also available that firms with a higher leverage have a lower equity proportion. Contrary to expectations, sponsor or scheme size has a negative effect on the equity proportion, which suggests that larger schemes have responded more strongly to the general de-risking trend. The volatility of cash flows from operations and the return on the equity index exceeding that on bond index do not have a significant effect on the equity allocation. Our sensitivity analysis finds that variations in scheme maturity and the funding ratio, along with the time trend, have the largest effect on the equity allocation. The leverage of the sponsor, size of the sponsor/scheme, hard closure of the scheme, and a sponsor with more than 20% of its pension assets in overseas schemes have smaller effects on the equity allocation.

Our results indicate that the DB pension schemes of large UK firms have adjusted their equity allocation in a way that is consistent with our prior expectations; and provide some justification for the wide range of scheme specific asset allocations that occur in practice. They may also assist trustees and scheme sponsors in setting an asset allocation that is appropriate for their particular circumstances. The upward time trend in maturity (see Figure 1), and the downward time trend in the equity allocation (see Figure 2), will lead to even less investment in low-risk assets in the future. The continuing closure of DB schemes will also cause a further decrease in their average equity allocation.

Our analysis of 125 FTSE 100 companies using nine scheme-specific variables and one economic variable has explained about 40% of the variation in asset allocation. It could be extended to the constituents of the FTSE 350, and by the inclusion of additional control variables to explain more of the variation in the dependent variable. For example, acquisitions, mergers, and buy-ins could be examined. Finally, since pension scheme regulations differ between countries, an analysis of DB pension scheme asset allocation in developing countries would be interesting.

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References

Addoum, J. M., J. H. Van Binsbergen, and M. W. Brandt. 2010. *Asset Allocation and Managerial Assumptions in Corporate Pension Plans, Working Paper*. North Carolina: Duke University.

Alestalo, N., and V. Puttonen. 2006. "Asset Allocation in Finnish Pension Funds." *Journal of Pension Economics & Finance* 5 (1, March): 27–44. doi:10.1017/S1474747205002295.

Amir, E., and S. Benartzi. 1999. "Accounting Recognition and the Determinants of Pension Asset Allocation." *Journal of Accounting, Auditing and Finance* 14 (3): 321–343. doi:10.1177/0148558X9901400309.

Amir, E., Y. Guan, and D. Oswald. 2010. "The Effect of Pension Accounting on Corporate Pension Asset Allocation." *Review of Accounting Studies* 15 (2): 345–366. doi:10.1007/s11142-009-9102-y.

An, H., Z. Huang, and T. Zhang. 2013. "What Determines Corporate Pension Fund Risk-Taking Strategy?" *Journal of Banking and Finance* 37 (2, February): 597–613. doi:10.1016/j.jbankfin.2012.09.018.

Anantharaman, D., and Y. G. Lee. 2014. "Managerial Risk Taking Incentives and Corporate Pension Policy." *Journal of Financial Economics* 111 (2, February): 328–351. doi:10.1016/j.jfineco.2013.10.009.

Atanasova, C., and E. Gatev. 2013. "Pension Plan Risk-Taking: Does It Matter if the Sponsor Is Publicly-Traded?" *Journal of Pension Economics & Finance* 12 (2, April): 218–249. doi:10.1017/S1474747212000339.

Bader, L. N. 1991. *The Financial Executive's Guide to Pension Plans*. New York: Salomon Brothers, .

Bartram, S. M. 2016. "Corporate Post-Retirement Benefit Plans and Leverage." *Review of Finance* 20 (2, March): 575–629. doi:10.1093/rof/rfv021.

Bartram, S. M. 2017. "Corporate Post-Retirement Benefit Plans and Real Investment." *Management Science* 63 (2, February): 355–383. doi:10.1287/mnsc.2015.2307.

Bartram, S. M. 2018. "In Good Times and in Bad: Defined Benefit Pensions and Corporate Financial Policy." *Journal of Corporate Finance* 48 (February): 331–351. doi:10.1016/j.jcorpfin.2017.10.015.

Bikker, J. A., D. W. G. A. Broeders, and J. De Dreu. 2010. "Stock Market Performance and Pension Fund Investment Policy: Rebalancing, Free Float or Market Timing?" *International Journal of Central Banking* 6 (2, June): 53–79.

Bikker, J. A., D. W. G. A. Broeders, D. A. Hollanders, and E. H. M. Ponds. 2012. "Pension Funds' Asset Allocation and Participant Age: A Test of the Life-Cycle Model, *Journal of Risk and Insurance*, Vol. 79, No. 3, September, Pp. 595-618. Reprinted." In *Pension Fund Economics and Finance*, edited by J. A. Bikker, 141–162. Vol. 2018. Abingdon: Routledge.

Black, F. 1980. "The Tax Consequences of Long Run Pension Policy." *Financial Analysts Journal* 36 (4, July-August): 21–28. doi:10.2469/faj.v36.n4.21.

Bodie, Z., J. O. Light, R. Morck, and R. A. Taggart. 1985. "Corporate Pension Policy: An Empirical Investigation." *Financial Analysts Journal* 41 (5, September-October): 10–16. doi:10.2469/faj.v41.n5.10.

Bodie, Z., J. O. Light, R. Morck, and R. A. Taggart. 1987. "Funding and Asset Allocation in Corporate Pension Plans: An Empirical Investigation." In *Issues in Pension Economics*, edited by Z. Bodie, J. B. Shoven, and D. A. Wise, 15–47, Chicago: University of Chicago Press.

Boon, L. N., M. Brière, and S. Rigot. 2018. "Regulation and Pension Fund Risk-taking." *Journal of International Money and Finance* 84 (June): 23–41. doi:10.1016/j.jimonfin.2018.01.005.

Bunn, P., and K. Trivedi (2005) "Corporate Expenditures and Pension Contributions: Evidence from UK Company Accounts." Bank of England Working paper no. 276.

Butt, A. 2011. "Management of Closed Defined Benefit Superannuation Schemes - an Investigation Using Simulations." *Australian Actuarial Journal* 17 (1): 27–86.

Campbell, J. L., D. S. Dhaliwal, and W. C. Schwartz. 2012. "Financial Constraints and the Cost of Capital: Evidence from the Funding of Corporate Pension Plans." *Review of Financial Studies* 25 (3): 868–912. doi:10.1093/rfs/hhr119.

Cardinale, M. 2007. "Corporate Pension Funding and Credit Spreads." *Financial Analysts Journal* 63 (5, September-October): 82–101. doi:10.2469/faj.v63.n5.4842.

Carroll, T. J., and G. Niehaus. 1998. "Pension Plan Funding and Corporate Debt Ratings." *Journal of Risk and Insurance* 65 (3, September): 427–441. doi:10.2307/253658.

Castro-Gonzalez, K. C. 2012. "Information Content of Changes in Pension Plan Funding Status and Long Term Debt." *International Journal of Business and Finance Research* 6 (1): 1–14.

Chandler, D. 2017. *Discount Rate Sensitivities in Pension Plans*. March: Society of Actuaries.

Chang, X., J. K. Kang, and W. Zhang (2012) "Corporate Pension Funding Status and the Market for Corporate Control: The Disciplinary Role of Pension Deficits in Mergers and Acquisitions, Working Paper." Nanyang Technological University, November.

Chaudhry, N., H. H. A. Yong, and C. Veld. 2017. "How Does the Funding Status of Defined Benefit Pension Plans Affect Investment Decisions?" *Journal of Business Finance and Accounting* 44 (1 & 2, January-February): 196–235. doi:10.1111/jbfa.12219.

Chen, J., T. Yao, T. Yu, and T. Zhang. 2014. "Learning and Incentive: A Study on Analyst Response to Pension

Underfunding." *Journal of Banking and Finance* 45 (August): 26–42. doi:10.1016/j.jbankfin.2014.04.001.

Chen, Y. 2015. "Funding Status of Defined Benefit Pension Plans and Idiosyncratic Return Volatility." *Journal of Financial Research* 38 (1): 35–57. doi:10.1111/jfir.12049.

Cocco, J. F., and P. F. Volpin. 2013. "Corporate Pension Plans as Takeover Deterrents." *Journal of Financial and Quantitative Analysis* 48 (4, August): 1119–1144. doi:10.1017/S0022109013000355.

Comprix, J., and K. A. Muller (2006) "Pension Funding Rules and Sponsor Firms' Risk Taking with Defined Benefit Pension Plan Assets." Working paper, Pennsylvania University.

Coronado, J., N. Liang, and M. Orszag (2006) "Moral Hazard from Government Pension Insurance: Evidence from US and UK Firm Finances." Working Paper, Federal Reserve Board, 39 pages.

Dambra, M. (2014) "The Effect of Internal Capital Shocks on Manager Behaviour: Evidence from Changes in ERISA Pension Accounting Rules." Working paper, 51 pages.

Davis, E. P., and L. De Haan. 2012. "Pension Fund Finance and Sponsoring Companies." *Journal of Pension Economics & Finance* 11 (3): 1–25.

De Dreu, J., and J. A. Bikker. 2012. "Investor Sophistication and Risk Taking." *Journal of Banking and Finance* 36 (7): 2145–2156. doi:10.1016/j.jbankfin.2012.03.023.

Defau, L., and L. De Moor. 2018. "The Impact of Plan and Sponsor Characteristics on Pension Funds' Asset Allocation and Currency Diversification." *Journal of Asset Management* 19 (1, January): 27–37. doi:10.1057/s41260-017-0058-3.

Feldstein, M., and R. Mørck. 1983. "Pension Funding Decisions, Interest Rate Assumptions, and Share Prices." In *Financial Aspects of the United States Pension System*, edited by Z. Bodie and J. Shoven, 177–210, Chicago: Chicago University Press.

Feldstein, M., and S. Seligman. 1981. "Pension Funding, Share Prices and National Savings." *Journal of Finance* 36 (4, September): 801–824. doi:10.1111/j.1540-6261.1981.tb04885.x.

Frank, M. M. 2002. "The Impact of Taxes on Corporate Defined Plan Asset Allocation." *Journal of Accounting Research* 40 (4, September): 1163–1190. doi:10.1111/1475-679X.00085.

Franzoni, F. 2009. "Under-investment Vs. Over-investment: Evidence from Price Reactions to Pension Contributions." *Journal of Financial Economics* 92 (3, June): 491–518. doi:10.1016/j.jfineco.2008.06.004.

Franzoni, F., and J. M. Marin. 2006a. "Pension Plan Funding and Stock Market Efficiency." *Journal of Finance* 61 (2, April): 921–956. doi:10.1111/j.1540-6261.2006.00859.x.

Franzoni, F., and J. M. Marin. 2006b. "Portable Alphas from Pension Mispricing." *Journal of Portfolio Management* 32 (4, Summer): 44–53. doi:10.3905/jpm.2006.644193.

Friedman, B. M. 1983. "Pension Funding, Pension Asset Allocation and Corporate Finance: Evidence from Individual Company Data." In *Financial Aspects of the United States Pension System*, edited by Z. Bodie and J. B. Shoven, 107–152, Chicago: University of Chicago Press.

Gallagher, R., and D. McKillop. 2010a. "Unfunded Pension Liabilities and Sponsoring Firm Credit Risk: An International Analysis of Corporate Bond Spreads." *European Journal of Finance* 16 (3, April): 183–200. doi:10.1080/13518470903211665.

Gallagher, R., and D. McKillop. 2010b. "Unfunded Pension Liabilities and the Corporate CDS Market." *Journal of Fixed Income* 19 (3): 30–46. doi:10.3905/JFI.2010.19.3.030.

Gallo, J. G., and L. J. Lockwood. 1995. "Determinants of Pension Funding and Asset Allocation Decisions." *Journal of Financial Services Research* 9 (2): 143–158. doi:10.1007/BF01068075.

Gerber, D. S., and R. Weber. 2007. "Demography and Investment Behaviour of Pension Funds: Evidence for Switzerland." *Journal of Pension Economics & Finance* 6 (3): 313–337. doi:10.1017/S1474747207003058.

Gorter, J., and J. A. Bikker, J.A. 2013. "Investment Risk Taking by Institutional Investors." *Applied Economics* 45 (33): 4629–4640. doi:10.1080/00036846.2013.795282.

Guan, Y., and D. Lui. 2014. *Risk Shifting in Pension Investment, Working Paper*. Hong Kong: Hong Kong Baptist University. 48. pages.

Jin, L., R. C. Merton, and Z. Bodie. 2006. "Do a Firm's Equity Returns Reflect the Risk of Its Pension Plan." *Journal of Financial Economics* 81 (1, July): 1–26. doi:10.1016/j.jfineco.2005.06.005.

Kubick, T. R., G. B. Lockhart, and J. R. Robinson (2014) "Internal Capital and Investment: Evidence from 2012 from 2012 Pension Relief, Working Paper." University of Kansas, 42 pages.

LCP. 2014. *LCP Accounting for Pensions 2014*. Lane, Clark and Peacock August 66. pages. London, UK.

Li, Y. 2010. "Corporate Risk Management and Pension Asset Allocation." In *Pension Fund Risk Management: Financial and Actuarial Modelling*, edited by M. Micocci, G. N. Gregoriou, and G. B. Masala, 365–387. London: Chapman and Hall.

Liu, W., and I. Tonks. 2010. "Pension Fund Deficits and Stock Market Efficiency: Evidence from the United Kingdom." In *Pension Fund Risk Management: Financial and Actuarial Modelling*, edited by M. Micocci, G. N. Gregoriou, and G. B. Masala, 659–688. London: Chapman and Hall.

Liu, W., and I. Tonks. 2013. "Pension Funding Constraints and Corporate Expenditures." *Oxford Bulletin of Economics and Statistics* 75 (2, April): 235–258. doi:10.1111/j.1468-0084.2012.00693.x.

López-Villavicencio, A., and S. Rigot (2013) "The Determinants of Pension Funds' Allocation to Private Equity, Working Paper." University of Angers, 30 pages.

Lucas, D. L., and S. P. Zeldes. 2009. "How Should Public Plans Invest?" *American Economic Review* 99 (2): 527–532. doi:10.1257/aer.99.2.527.

Macaulay, F. R. 1938. *Some Theoretical Problems Suggested by the Movements of Interest Rates, Bond Yields and Stock*

Prices in the United States since 1856. New York: National Bureau of Economic Research.

Maher, J. J. 1987. "Pension Obligations and the Bond Credit Market: An Empirical Analysis of Accounting Numbers." *Accounting Review* 62 (4, October): 785–798.

Maher, J. J. 1996. "Perceptions of Post-Retirement Benefit Obligations by Bond Rating Analysts." *Review of Quantitative Finance and Accounting* 6 (1): 79–94. doi:10.1007/BF00290798.

Martin, L. J., and G. V. Henderson. 1983. "On Bond Ratings and Pension Obligations: A Note." *Journal of Financial and Quantitative Analysis* 18 (l4, December): 463–470. doi:10.2307/2330941.

McCarthy, D., and D. Miles. 2013. "Optimal Portfolio Allocation for Corporate Pension Funds." *European Financial Management* 19 (3, June): 599–629. doi:10.1111/j.1468-036X.2010.00594.x.

McCaulay, M. 2013. "Duration and Convexity for Pension Liabilities." *Society of Actuaries Pension Section News* 81 (September): 18–21.

McKillop, D., and M. Pogue. 2009. "The Influence of Pension Plan Risk on Equity Risk and Credit Ratings: A Study of FTSE100 Companies." *Journal of Pension Economics & Finance* vol. 8 (no. 4): 405–428. doi:10.1017/S1474747208003879.

Meijdam, W. I. (2012) "Defined Benefit Pension Plans and Takeover Likelihood, Master Thesis." Tilburg University, 57 pages.

Mohan, N., and T. Zhang. 2014. "An Analysis of Risk-Taking Behaviour for Public Defined Benefit Pension Plans." *Journal of Banking and Finance* 40 (March): 403–419. doi:10.1016/j.jbankfin.2013.12.011.

Nakajima, K., and T. Sasaki. 2010. "Unfunded Pension Liabilities and Stock Returns." *Pacific-Basin Finance Journal* 18 (1, January): 47–63. doi:10.1016/j.pacfin.2009.06.001.

Ngugi, W., and A. Njuguna. 2018. "Nexus between Pension Fund Size, Design and Investment Strategy: A Review of Occupational Retirement Benefits Schemes in Kenya." *International Journal of Financial Research* 9 (3): 108–116. doi:10.5430/ijfr.v9n3p108.

Pension Protection Fund. 2020. "The Purple Book 2020: DB Pensions Universe Risk Profile." In *Pension Protection Fund*. 1-81. Croydon, UK.

Petersen, M. A. 1996. "Allocating Assets and Discounting Cash Flows: Pension Plan Finance." In *Pensions, Savings and Capital Markets*, P. A. Fernandez, J. A. Turner, and R. P. Hinz edited by, 1–26. US Department of Labour; Pension and Welfare Administration, Office of Research and Economic Analysis.

Phan, H. V., and S. P. Hegde. 2013. "Pension Contributions and Firm Performance: Evidence from Frozen Defined Benefit Plans." *Financial Management* 42 (2): 373–411. doi:10.1111/j.1755-053X.2012.01218.x.

Ralfe, J., C. Speed, and J. Palin. 2004. "Pensions and Capital Structure: Why Hold Equities in the Pension Fund?" *North American Actuarial Journal* 8 (3, July): 103–113. doi:10.1080/10920277.2004.10596154.

Rauh, J. D. 2006. "Investment and Financing Constraints: Evidence from the Funding of Corporate Pension Plans." *Journal of Finance* 61 (1, February): 33–71. doi:10.1111/j.1540-6261.2006.00829.x.

Rauh, J. D. 2009. "Risk Shifting versus Risk Management: Investment Policy in Corporate Pension Plans." *Review of Financial Studies* 22 (7, July): 2687–2733. doi:10.1093/rfs/hhn068.

Sharpe, W. F. 1976. "Corporate Pension Funding Policy." *Journal of Financial Economics* 3 (3, June): 183–193. doi:10.1016/0304-405X(76)90002-7.

Shivdasani, A., and I. Stefanesu. 2010. "How Do Pensions Affect Corporate Capital Structure Decisions?" *Review of Financial Studies* 23 (3, March): 1287–1323. doi:10.1093/rfs/hhp094.

Sudarsanam, S., and N. Appadu (2015) "Impact of Target Company Pension Liabilities on Takeover Premium, Bidder's Choice of Payment Currency and Shareholder Returns, Working Paper." Cass Business School, 41 pages.

Sutcliffe, C. M. S. 2005. "The Cult of the Equity for Pension Funds: Should It Get the Boot?" *Journal of Pension Economics & Finance* 4 (1): 57–85. doi:10.1017/S1474747204001726. March 2005.

Sutcliffe, C. M. S. 2016. *Finance and Occupational Pensions*. London: Palgrave Macmillan.

Tepper, I. 1981. "Taxation and Corporate Pension Policy." *Journal of Finance* 36 (1): 1–13. doi:10.1111/j.1540-6261.1981.tb03530.x.

Thomas, J. K. 1988. "Corporate Taxes and Defined Benefit Pension Plans." *Journal of Accounting and Economics* 10 (3, July): 199–237. doi:10.1016/0165-4101(88)90003-1.

Van Zijl, T. 1990. "Macaulay and Closed Form Duration Formulas." *The British Accounting Review* 22 (no. 4, December): 343–349. doi:10.1016/0890-8389(90)90093-W.

Wang, J., C. Wu, and T. Zhang. 2013. *An Empirical Analysis of the Effect of Corporate Pension Risk on the Cost of Debt*. University of Dayton: Working paper.

Wyatt, W. 2005. "Cashing In: Do Aggressive Funding Policies Lead to Higher Credit Ratings?" Virginia: *Watson Wyatt Insider*. October.

Yuan, Y., and D. Lui. 2016. "The Effect of Regulations on Pension Risk Shifting: Evidence from the US and Europe." *Journal of Business Finance and Accounting* 43 (5 & 6, May-June): 765–799. doi:10.1111/jbfa.12199.