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Pension Fund Asset Allocation In Low Interest Rate Environment

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Abstract

We analyze changes in portfolios of pension funds since the start of current low interest rate environment. We find that they have on average decreased the allocation to equity and increased the allocation to fixed income, which is inconsistent with the literature on strategic asset allocation. Next, more generally, we empirically investigate the relationship between variables that predict asset returns and portfolio allocation in levels as well as changes. We find that dividend-price ratio shows the strongest relationship among other variables. However, we find a negative relationship as opposed to a positive one predicted by the literature. Overall, the results suggest that pension funds are unable to incorporate predictive information in their strategic asset allocation, but they take active decisions by under or over-weighting their portfolio relative to the stated strategic portfolio to benefit from time-varying investment opportunities.

Keywords: Pension funds, Asset allocation, Portfolio choice

JEL codes: G11, G12, G23

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1 Introduction

The financial crisis of 2008 has led to a substantial and lasting change in investment opportunities. Both long-term and short-term interest rates have now been at historic lows in many countries for more than five years, presenting new challenges for pension funds. One result has been a substantial increase in the present value of liabilities for Defined Benefit (DB) pension funds. At the same time, fixed-income has become a less attractive asset class due to lower expected returns, which has implications for Defined Contribution (DC) as well as DB funds. We examine the response of pension funds to this prolonged low interest rate environment by analyzing the changes in the portfolio of pensions funds since 2008. However, since other variables have also changed, we examine more generally the actual response of pension funds to variables that predict asset returns, and compare this to what the direction of the response should have been according to existing models in the strategic asset allocation literature that acknowledge predictive variables and the investment constraints of pension funds.

It is well established in the financial literature that macro-economic variables predict asset returns (Fama and French, 1989; Ang and Bekaert, 2007). It is also well established that changes in investment opportunities have implications for long-term investors. Long-term investors can therefore benefit by incorporating this information into their asset allocation (Campbell, Chan and Viceira, 2003; Hoevenaars et al., 2008). The goal of this chapter is to determine whether large institutional investors like pension funds incorporate macro-economic predictive variables for asset allocation. If they do, is this consistent with economic theory? Campbell, Chan and Viceira (2003) find that short-term interest rates forecast excess stock returns negatively. An investor should therefore view a decline in interest rates as an improvement in investment opportunities and invest more in stocks. Additionally, expected stock returns increase when the dividend-price ratio increases. Also stocks are negatively correlated with the dividend-price ratio, which implies that poor stock returns are associated with a high dividend-price ratio, in turn implying higher future stock returns. Thus, good current stock returns are associated with poor expected future stock returns. Yield spread predicts excess bond returns positively, thus an increase in yield spread implies that the investor should increase exposure to bonds to time the market. We test these predictions empirically.

We find that pension funds have on average reduced their allocation to equity and increased their allocation to bonds in the low-interest rate environment. This is inconsistent with the strategic asset allocation literature. However, this behavior is consistent with hedging the asset-liability duration mismatch risk. Next, we find that pension funds are unable to time the market in a way consistent with the return predictability literature. The dividend-price ratio shows the strongest relationship, but the sign is opposite to the expectation. However, when we examine the active changes by pension funds, they are consistent with economic theory. This suggests that when predictive variables move the portfolio away from the previously chosen optimal allocation, pension funds trade actively to rebalance it.

Our results contribute to the literature that examines empirically whether investors take into account economic conditions and vary their allocation over time in accordance with the literature on predictable expected returns. An extensive literature claims that investors can use predictive variables to improve their portfolio performance. Chalmers, Kaul and Phillips (2013) find that individual investors react to changing macroeconomic conditions and reallocate their portfolios in response to forecasting variables. They study the aggregate asset allocation decisions of US mutual fund investors and consider mutual fund flows and the level of predictive variables; Jank (2012) considers changes in the level of predictive variables as an indicator of macro-economic news. However, the two studies reach different conclusions. Chalmers, Kaul and Phillips (2013) find that investors increase risk as the economy is expect to improve, whereas Jank (2012) finds that mutual fund investors sell stocks when predictive variables signal high expected returns. However, our focus of study is on institutional investors. Jiang, Yao and Yu (2007) find that mutual funds have positive market timing ability based on portfolio holdings. They find that active mutual funds use predictive economic variables, in particular dividend yield, to adjust the market exposure of the portfolio. They find that the average market timing measures are positive at short horizons.[1] By considering the strategic asset allocation of the fund instead of the actual asset allocation, we avoid the bias that returns on the portfolio can move the portfolio.

[1] Avramov, Barras and Kosowski (2013) analyze the performance of hedge funds over changing economic conditions.

Large institutional investors like pension funds which have liabilities usually perform asset-liability studies for asset allocation purposes.[2]. These asset-liability studies typically generate possible future economic scenarios. They are then used to understand what impact major decision variables, for example, portfolio choice, contribution management and indexation decisions, will have on the pension fund's solvency. Portfolio decisions can thereafter be made based on the results coming out of the studies. However, empirical evidence on how institutional investors actually incorporate macro-economic news in their portfolio is limited, and our results contribute to this literature.

The paper closest to us is that of Addoum, Van Binsbergen and Brandt (2010) who find that pension fund mangers increase the riskiness of the portfolio when approaching the underfunding status from below to increase the chances of avoiding mandatory additional contributions. They study the market timing ability of pension funds, but consider only US defined benefit (DB) corporate plans, and only one predictive variable (dividend-price ratio). We extend the analysis on both these dimensions. They find that pension funds are unable to time the market in a way that is consistent with return predictability literature. They conclude that pension funds react strongly to regulatory requirements. The regulatory requirements for pension funds can override the sponsor's optimal investment strategy, and the pension funds may therefore be unable to time the market due to these regulatory constraints. Blome et al. (2007) analyze the impact of different regulations on the investments of pension funds. They find that the sensitivity of liabilities to interest rate changes can be the key driver of asset allocation decisions. They also conclude that strict funding requirements followed by pension funds may lead them to invest more conservatively, thereby increasing the total funding costs. This short-term regulation based on the funding ratio can induce real sub-optimal decisions, and pension funds will be unable to time the market. Plantin, Sapra and Shin (2008) find that damage done by marking-to-market is substantial when the claims are long-lived as in the case of pension funds.

[2] For examples of Asset-Liability management (ALM) studies for pension funds see for example Bauer, Hoevenaars and Steenkamp (2006) and van Binsbergen and Brandt (2015) The future scenarios of key economic variables are generated for example by a vector auto-regression (VAR) model.

2 Portfolio implications from the strategic asset allocation literature

[Insert Table 1 here]

What should have been the response of pension funds to the prolonged low interest rate environment according to models of strategic asset allocation? We show in this section that results from the literature imply that pension funds should have increased allocations to equity and reduced allocations to bonds. The theoretical framework for answering this question is provided by the extensive literature on strategic asset allocation.[3] Past empirical research has identified various economic variables as predictors for expected returns. These variables are: short-term interest rates (Campbell, 1987; Ang and Bekaert, 2007); the dividend-price ratio (Campbell and Shiller, 1988; Fama and French, 1988); the yield spread between long-term and short-term interest rates (Shiller et al., 1983; Fama and French, 1989; Cochrane and Piazzesi, 2005), and the credit spread between BAA and AAA corporate bond yields (Hoevenaars et al., 2008). These macroeconomic predictive variables including the short-term interest rate are used to derive optimal portfolios for long-term investors like pension funds. Campbell, Chan and Viceira (2003) provide an approximate solution for the optimal portfolio choice in cash, stocks and bonds for an investor who faces a time-varying investment opportunity set in terms of a vector auto-regression (VAR) in returns and state variables. They show that the optimal portfolio rule ($\boldsymbol{\alpha_t}$) is a linear function of VAR state variables

[Insert Table 2 here]

$$\boldsymbol{\alpha}_t = \boldsymbol{A}_0 + \boldsymbol{A}_1 \boldsymbol{z}_t \tag{1}$$

where $\boldsymbol{z}_t$ is the $m \times 1$ state vector which is first order autoregressive. $\boldsymbol{A}_0$ and $\boldsymbol{A}_1$ are constant coefficient matrices estimated on the history of variables which are $(n-1) \times 1$ and $(n-1) \times m$ respectively. Here n is the number of assets and m is the total number of assets and other state variables. This model provides insights on how long-term investors should behave when asset returns are assumed to be predictable. The coefficient $\boldsymbol{A}_1$ implies the sensitivity of optimal portfolio choice to changes in state variables. Table 1 presents the summary statistics

[3] A seminal contribution in this area is the Campbell and Viceira (2002) textbook.

of the macro-economic variables. Panel A shows the statistics of the variables used for the regressions with sample period 1990-2011. The Domestic T-bill is the short term Treasury Bills for United States, France or Canada depending on the pension fund. Panel B shows the statistics of the variables used to estimate the Campbell, Chan and Viceira (2003) model with sample period 1952 Q2-2014 Q4. The VAR parameter estimates are detailed in Table 2, which are in line with other studies on strategic asset allocation (Campbell, Chan and Viceira, 2003; Hoevenaars et al., 2008; Diris, Palm and Schotman, 2014). Panel A of Table 3 shows the matrix $\boldsymbol{A}_1$ estimated from quarterly data for four levels of risk aversion ($\gamma = 2, 5, 10, 20$). This matrix is normalized using the standard deviation of the state variables. It shows that portfolio allocation to stocks is negatively related to short-term interest rates, positively related to dividend-price ratio and credit spread and negatively related to yield spread. The signs are opposite for excess bond returns. Therefore the allocation to stocks should increase when the short-term interest rate declines. These signs are summarized in Panel B of Table 3. We test these signs in the empirical section. The magnitude of the coefficients increases as the risk-aversion parameter decreases. The data used to estimate the VAR and the matrix $\boldsymbol{A}_1$ is similar to other studies on strategic asset allocation and the details are given in the Appendix 6.1.

[Insert Table 3 here]

Figure 3 in the appendix shows the optimal allocation to stocks and bonds according to Campbell, Chan and Viceira (2003). As expected, the allocations are quite volatile, but they clearly imply that pension funds should have increased the allocation to equity and decreased the allocation to bonds since the start of the low interest environment.[4] The optimal portfolio allocation for a long-term investor described in (1) is different from the optimal allocation of a short-term investor and can be formulated as a combination of a myopic and a hedging portfolio. Myopic is simply the mean-variance optimal portfolio. When investment opportunities are time varying, a risk-averse investor will hedge against the adverse changes in

[4] Indeed the changes over time do not appear to be very practical given the volatility, however they are indicative of the direction of portfolio movement, see Campbell, Chan and Viceira (2003) for a discussion. A more elaborate model with constraints to prevent extreme movements could generate more practical results, however such a model is will require a numerical optimization procedure, as no analytical model exists.

the investment opportunities set, thus giving rise to a hedging portfolio. When the investment opportunities are constant, the hedging portfolio is zero.

[Insert Figure 1 here]

Moreover, we also analyze the portfolio implications of the study by Ang and Bekaert (2002*a*) of asset allocation that takes into account return predictability as well as regimes in interest rates. Ang and Bekaert (2007) find that when short-term rates are low the subsequent equity returns tend to be high. They show that the short rate is a robust predictor in five countries and more significant than the dividend yield. This observation is exploited by the switching market-timing model for asset allocation regime developed in Ang and Bekaert (2002*a*). The model takes into account time variation in expected returns through a regime change and variations in interest rates. Two interest rate regimes are specified in the model: a normal regime with relatively low mean returns on short-term interest rates, low standard deviation and high autocorrelation (therefore more persistent); and a volatile regime with relatively high mean returns and standard deviation and lower autocorrelations. The second regime is therefore volatile, with higher interest rates, and less persistent. The researchers find that the equity beta with respect to interest rate is negative which implies that low interest rates are typically associated with high expected excess equity returns. This means that allocation to equity should be high when interest rates are low. Figure 4 in the appendix shows the allocation according to this model. The results again imply that pension funds should have increased the allocation to equity and decreased the allocation to bonds.

[Insert Figure 2 here]

Figure 1 provides the level of both short-term three-month treasury bill as well as the long term ten-year treasury constant maturity rate over the 1989-2014. The figure shows that the short-term interest rate has been almost zero from 2008 onwards and the long-term interest rate has been at the lowest level since the start of the sample period. Figure 2 plots the average strategic allocation in the three asset classes and alternatives from the CEM database.[5] The

[5] Our data is obtained from CEM Benchmarking Inc., a pension fund cost benchmarking company located in Toronto, Canada that collects data from pension funds annually via a survey, primarily for cost benchmarking purposes.

alternative asset class includes allocations to Real Estate, Private Equity, Hedge Funds and Commodities.[6] This figure can be compared with the models of implied optimal allocations by Campbell, Chan and Viceira (2003) and Ang and Bekaert (2002*b*), which are shown in the appendix. The figures plot the allocations only after 2002, to focus on the allocation before and during the low-interest rate environment. The Campbell, Chan and Viceira (2003) model shows that the optimal allocation in bonds should be declining, whereas the optimal allocation to equity should be increasing. However, in the data we find the *opposite*. Average allocations to equity have been decreasing since the start of the low-interest rate regime and allocations to bonds have been increasing.

[Insert Table 4 here]

2.1 Optimal portfolio choice with liabilities

Pension funds have long-term liabilities. Assets that can hedge their long-term liabilities are therefore valuable for them. Moreover, many regulations for pension funds are based on their funding ratios. Therefore pension funds look particularly at the asset-liability mismatch risk of their portfolio and decide upon an acceptable duration mismatch between assets and liabilities, so that any changes in interest rates have a tolerable impact on their funding ratio. One might be concerned about the fact that the linear portfolio rule (1) of Campbell, Chan and Viceira (2003) is for an investor without liabilities, and results may therefore not be completely relevant for pension funds, which do have liabilities. Hoevenaars et al. (2008) consider differences between the optimal portfolio of an asset-only and an asset-liability investor. The Hoevenaars et al. (2008) model allows us to determine how the changes in the state variables affect optimal asset allocation for an investor with liabilities. Using their model and insights from Campbell, Chan and Viceira (2003), we find that the optimal portfolio rule is a linear function of the state variables of the VAR(1) model, where the coefficients of the linear rule can be calculated from the VAR coefficients. 6.2 shows that the τ horizon optimal portfolio choice with liabilities is

$$\alpha_{t,L}^{(\tau)} = \tilde{A}_0 + \tilde{A}_1 z_t \tag{2}$$

[6] For more details on the database, we refer to Andonov (2014).

Moreover, for the asset-only investor, the optimal portfolio choice is

$$\boldsymbol{\alpha}_{t,AO}^{(\tau)} = \tilde{\boldsymbol{A}}_2 + \tilde{\boldsymbol{A}}_1 \boldsymbol{z}_t \tag{3}$$

where $\tilde{\boldsymbol{A}}_0, \tilde{\boldsymbol{A}}_1$ and $\tilde{\boldsymbol{A}}_2$ are constant functions of estimated parameters of VAR(1) model and the risk-aversion parameter. The coefficient $\tilde{\boldsymbol{A}}_1$ measures the sensitivity of optimal portfolio allocation to changes in the state variables. Additionally, the sensitivity $\tilde{\boldsymbol{A}}_1$ does not change between the asset-liability and asset only investor.

The difference between the asset-liability and asset-only portfolio stems from the so-called hedging portfolio. The optimal portfolio rule can be decomposed into two components, a speculative portfolio and the hedging portfolio. The asset-only investor's hedging portfolio minimizes the risk of the asset mix, whereas the hedging portfolio of asset-liability investor takes into account the time-invariant covariance of assets and liabilities. The hedging portfolio in this setting does not change over time and is constant. The correlations and volatilities are assumed constant in the model and do not change with time. Overall, bonds are the best hedge against interest rate risk and therefore have a large weighting in the liability hedging portfolio, even in a constrained portfolio.[7]

The inter-temporal hedging considerations of liabilities affect the optimal portfolio choice through $\tilde{\boldsymbol{A}}_0$ and $\tilde{\boldsymbol{A}}_2$ only as these are the constants that contain correlations with liabilities. The $\tilde{\boldsymbol{A}}_1$ function is not dependent on the correlation between asset and liabilities. This sensitivity is related to liabilities through the coefficients of the VAR process. There is therefore no reason for the pension fund to change its allocation apart from the observed changes in the state variables. Table 4 presents the coefficient matrix $\tilde{\boldsymbol{A}}_1$ for stocks and bonds and for the four main state variables. The results are shown for two values of risk aversion parameter $\gamma = 5, 20$ and two horizons $5, 20$. The results are consistent with the results from the earlier analysis and imply that the pension fund should have increased its allocation to stocks since the start of the low interest rate environment. The only change stems from the coefficient of credit spread, whose sign is different for short and long horizons.

The linear portfolio rules (1) of Campbell, Chan and Viceira (2003) and Hoevenaars et al.

[7] See for example Table 5, 6 in Hoevenaars et al. (2008).

(2008) are for an unconstrained investor, i.e. one who does not have any borrowing, short-selling or regulatory constraints. Imposing any of these constraints makes the portfolio choice much more complex: no tractable theoretical result can be derived, and only numerical solutions can be found. Pension funds do indeed have all of these constraints. It is therefore interesting to test whether pension funds can still utilize the benefits of timing the market in the presence of these constraints. One additional reason for change in the portfolio can be change in the risk aversion parameter. If the pension fund becomes more risk averse, then it will invest more in less-risky assets. Less-risky assets for long-term investors are long-term bonds. T-bills are risky at long horizons as they have a substantial roll-over risk. Hoevenaars et al. (2008) also show that bonds are the best hedge against real interest rate risk and therefore have a large weighting in the liability-hedge portfolio.

3 How do low interest rates affect asset allocation?

The prolonged low interest rate environment poses a new challenge for the portfolio allocation of pension funds. Not only have the investment opportunities been affected, but also the market value of liabilities has increased due to low long-term interest rates, thus reducing the funding ratio of pension funds. Figure 1 shows that long-term as well as short-term interest rates have been exceptionally low since 2008. First, the empirical work in this section assesses how pension funds have responded to this special macro-economic situation. Secondly, we look at the cross-sectional characteristics of pension funds and examine whether different pension funds have responded differently. To explore pre and post 2008 equity allocation, we construct a new variable $\Delta\bar{w}_i$ which is the difference between the average allocation to equity in 2009, 2010, and 2011 and in 2005, 2006, and 2007 for pension fund i. We look at an average difference over three years to minimize any short-term changes and focus on long-term changes in the portfolio. The differences are calculated on the policy or strategic asset allocation, as this signals the explicit policy direction of the pension fund.

[Insert Table 5 here]

A statistically significantly positive $\Delta\bar{w}_i$ would indicate that pension funds have increased their allocation to equity in the low-interest rate environment. In the same way, we compute average change variables for fixed income and alternative asset classes. Table 5 provides summary statistics for these variables. Panel A assesses whether there is any significant change in allocation, and Panel B details the difference within various cross-sectional groups. The change in equity is negative at –6.97 percentage point and statistically significant. On the other hand, there is a significant increase in both bonds (+2.36) and alternatives (+4.43). This implies that pension funds, on average, have explicitly decided to reduce their exposure to equities and increase their exposure to bonds as well as alternatives since the onset of low interest rates. Next, we analyze the effect of all the cross-sectional variables together by using the following multivariate regression specification:

[Insert Table 6 here]

$$\Delta\bar{w}_i^j = c_0 + c_1\mathrm{US}_i + c_2\mathrm{Public}_i + c_3\mathrm{DB}_i + c_4 \log \mathrm{Fund\ Size}_i + c_5\mathrm{Retired}_i + \epsilon_i \tag{4}$$

the super-script j refers to equity, bonds and alternative asset classes. Table 6 presents the results of this regression. The standard errors are corrected for heterogeneity and lack of normality by using the Huber-White sandwich estimators.

There are two different motives at work here, a market-timing and a liability-hedging motive. The market-timing motive stems from the predictability literature. Since the short-term interest rate is low, expected returns on equity are high and therefore pension funds should increase their allocation to equity. On the other hand, since long-term interest rates are low pension funds should increase the allocation to bonds to reduce the duration gap between assets and liabilities in anticipation of a further decline in long-term interest rates. Duration of pension liabilities is a concept that measures the sensitivity of the liability to interest rates. The longer the duration of the liability of the pension fund, the greater is the impact of change in interest rates on the funding ratio. A further decline in interest rates at which liabilities are discounted will lower the funding ratio if liabilities have a longer duration than assets. However, this duration immunization at the moment of low long-term interest rates comes at a significant cost. The reason is that buying long-term bonds at historically low interest rates will lock in low yields.

If the pension fund has fully immunized its portfolio, then any change in interest rates will have a similar impact on asset and liabilities and the change in the funding ratio will be minimal. However, full immunization can be very costly due to hedging and transaction costs. The sensitivity of equity in response to changes in interest rate is not useful for liability hedging purposes, so its duration can be assumed to be zero. Thus to gain duration and match assets to liabilities, assets are likely to be shifted to the bond asset class.

The effect of interest rates is strongest for pension funds that have "hard" liabilities, which is the case for defined benefit (DB) pension funds. The overall effect of low interest rates on the funding ratio of the pension fund depends on the duration gap between asset and liabilities (Antolin, Schich and Yermo, 2011). The effect can also vary depending on the financial reporting standards used by the pension fund. For example, discount rate, liability valuation method and asset valuation method (mark-to-market or mark-to-book) will also affect the strength of the impact on the fund's balance sheet. Pension funds may seek to hedge their interest rate risk by increasing the duration of their portfolio, for example by increasing the allocation to bonds in their portfolio. However, strong demand for hedging activities could further reduce the bond yield if all the institutional investors were to herd in a similar way. This would further worsen the financial situation of the pension funds.

The results of linear regression include five cross-sectional variables, two continuous variables - log of fund's assets and percentage of retired members - and three dummy variables to indicate a US fund, a public fund and a defined benefit (DB) fund. We find that US pension funds have strongly reduced their exposure to equity and increased exposure to the fixed-income asset class. One of the most important differences between US and non-US funds lies in the severe underfunding of US funds. This means that US funds are even more constrained than any other pension funds. Additionally, the available assets required for liability hedging are rather limited. Public funds in the US are severely underfunded even according to the relaxed accounting standards (Munnell, Aubry and Quinby, 2011).

Public funds have, on the other hand, significantly increased their exposure to equity and reduced their exposure to bonds. The difference between Public and Corporate funds stems from the regulations they have to follow. In the US, for example, the public and corporate pension funds follow different financial accounting principles. The state and local public pension funds follow the Governmental Accounting Standards Board (GASB) balance sheet accounting. On the other hand, the corporate pension plans follow Financial Accounting Standards Board (FASB) for their financial accounting. One important difference is that corporate pension funds use a corporate bond yield curve as discounting rate whereas public pension funds use expected rate of return. Different rules for discounting liabilities have implications for the interest rate sensitivity of the funding ratio of the fund. More importantly, public funds have no motive for liability hedging since they use the expected rate of return as a liability discount rate which remains fixed. Therefore they can focus fully on market timing by increasing their exposure to equity when expected returns on equity are high. On the other hand, corporate pension funds do have a strong incentive to hedge their liabilities. Although mark-to-market is considered better for transparency, we can see that this can put an additional constraint on pension funds, hindering their ability to time the market. Plantin, Sapra and Shin (2008) find that damage done by marking-to-market is substantial when the claims have a long life, as in the case of pension funds.

According to life-cycle literature, pension funds should reduce the risk of their portfolio if they have a higher proportion of retired members. On the other hand, the effect of low long-term interest rates is exacerbated for pension funds with a longer duration of liabilities. This can be approximated by the percentage of retired members of the pension fund. If there are less retired members in the pension fund, then the duration of liabilities is larger than a pension fund that has more retired members, other things being equal. Therefore the effect of low long-term interest rates is relatively strong. We find a positive sign for the percentage of retired members, consistent with life cycle theory, but it is only marginally statistically significant. Furthermore, the significant and positive coefficients on the size variable show that larger pension funds increased their allocation to alternatives more. On the other hand, larger pension funds reduced their allocation to equity to about the same degree.[8]

3.1 Robustness check

One might worry about the fact that pension funds changed their allocation substantially due to a crisis environment in the years following 2008. The methodology used for Tables 5 and 6 is designed in a fashion similar to several event studies in the finance literature, to compare the change in allocation before and during a low-interest rate environment. The main benefit of comparing portfolio allocation in $2009-2011$ to $2005-2007$ is that the fund characteristics and regulatory environment have not changed substantially and thus we can control for them. One additional benefit is that we do not need a pension fund to be in the database for a long time period, therefore we have more observations. To address the concern that the change in allocation can be due to the crisis environment, we compare the change in allocation in $2009-2011$ to another crisis period which does not exhibit significantly low interest rates.

[Insert Table 7 here]

We compare the allocation in $2009-2011$ with the crisis period $2000-2002$. We choose this crisis period as it is the most recent crisis before 2008, and the annual S&P returns were negative for all three years. These two periods are also comparable in terms of business cycle contractions as specified by NBER.[9] The latest business cycle contraction was from December 2007 to June 2009 and the one immediately proceeding this was during the period of our choice in March 2001 to November 2001. The results are presented in Tables 7 and 8 in the appendix.

[Insert Table 8 here]

Consistent with earlier results presented in Table 5, allocation to Equity and Alternatives has significantly increased and allocation to bonds significantly decreased. Changes for public and non-public funds have similar magnitudes and the same sign. Although the signs are

[8] Rajan (2006) claims that periods of low interest rates induced by monetary policy provide investors with incentives to search-for-yield and invest more in risky assets. In unreported results, we added expected rate of return (EROR) of the pension fund to (4) and restricted the sample to the funds that did not change the EROR, to address the concerns about endogeneity. We found that pension funds which have a higher expected rate of return (EROR) assumption have invested significantly more in equities since the onset of the low interest rate environment.

[9] http://www.nber.org/cycles.html

consistent with Table 5, the results for defined benefit (DB) funds have become weaker statistically. However, we now only have 36 observations for non-DB funds, and this may have contributed to the lack of statistical significance. Similarly, the regression results presented in Table 8 are comparable to results presented in Table 6, where the signs, magnitude and statistical significance are comparable. Additionally, we find that the coefficient of the retired percentage is strongly negative in case of equity and vice-versa for bonds. This is to be expected, as a pension fund would decrease the allocation to risky assets when it has more retired people, in line with life-cycle theory. This analysis suggests that a crisis environment alone cannot explain the magnitude and sign of the coefficients that we observe in the tables. Since other macro-economic variables and expected returns on asset classes have also changed, we examine their effect more generally for the entire time-series in the next section.

4 Pension fund asset allocation and predictive variables

The return predictability literature indicates that the level of variables such as short-term interest rate, dividend-price ratio, credit spread and yield spread predicts asset returns. In this section, we examine whether pension funds respond to the level of predictive variables in their asset allocation decisions. Inspired by the linear portfolio rule (1) of Campbell, Chan and Viceira (2003), we specify the portfolio weight of the pension fund as a linear function of predictive variables. However, we introduce a lag on the independent variables because the pension funds' response would be delayed. We use the following regression model:

$$w^j_{i,t} = \alpha + \beta_1 Y_{t-1} + \beta_2 (d-p)_{t-1} + \beta_3 CS_{t-1} + \beta_4 Spr_{t-1} + \theta_i + \epsilon_{i,t} \quad (5)$$

The dependent variable is the strategic asset allocation for fund i in asset class j, where j can be equities, bonds, or alternative assets. The independent variables are the predictive variables: Y_t is the short-term interest rate, $(d-p)_t$ is the log dividend-price ratio, CS_t is the credit spread, and lastly Spr_t is the yield spread between long-term and short-term yield. The summary statistics of the macro-economic variables are provided in Panel A of Table 1. This model is estimated with fixed-effects θ_i. Therefore, the regression coefficients are driven by the variation over time within each pension fund. In addition, we use a model in which we include the five control variables used in section 3, which results in the following regression model:

$$w^j_{i,t} = \alpha + \beta_1 Y_{t-1} + \beta_2 (d-p)_{t-1} + \beta_3 CS_{t-1} + \beta_4 Spr_{t-1} + \beta_5 \log \text{Fund Size}_i + \beta_6 \text{Retired} + \beta_7 \text{DB} + \beta_8 \text{US} + \beta_9 \text{Public} + \epsilon_{i,t} \quad (6)$$

the super-script j refers to equities, bonds and alternative assets. Table 9 presents the regression results of strategic asset allocation in Equity, Bonds and Alternatives on one period lag of the variables of interest - domestic T-bills, log D–P ratio, credit spread and yield spread. The first three columns present the plan fixed effects specifications using equation (5) and the last three columns present the pooled specification in which we add five plan characteristics using (6). For all the regressions, the standard errors are clustered by fund as well as by year. The signs of the coefficients can be compared with the signs of the coefficients in Table 3 which are expected if the pension funds are able to time the market. In terms of statistical significance, the results are strongest for dividend-price ratio. Since a high dividend-price ratio forecasts high excess stock returns, we expect a positive relationship between strategic allocation to equity and level of dividend-price ratio. Surprisingly, we find that the opposite is true in our empirical tests. The coefficient is statistically significantly negative.

We also find a statistically significant relationship between the other three predictive variables and strategic asset allocation. However, the signs are again inconsistent for T-bills and Yield spread. In the pooled specifications, after controlling for various fund characteristics we find that the relationships between the predictive variable and strategic allocation still holds. Thus, the results are robust to controlling for cross-sectional fund characteristics.[10]

The results show that the level of equity allocation is positively correlated with lagged short-term interest rates, negatively correlated with lagged dividend-price ratio, and positively related to lagged yield spread. For equity allocation, all of the coefficients are statistically significant. Pension funds make decisions that appear to be in contrast with the model

[10] In unreported results, we repeat our analysis of Table 9 with actual asset allocation. The results are statistically weaker compared to Table 9, possibly because of portfolio movements due to realized returns. However, sign are consistent and the statistical significance of the dividend-price ratio is still found to be high.

predictions, as they increase the exposure to equity precisely when the predictive variables signal low expected returns. The results show that the level of equity allocation is positively correlated with credit spread, which has the correct sign; however, the signification weakens when we add the control variables. The economic significance is also strong, for example a one percentage point increase in short term interest rate implies a 0.95 percentage point increase in strategic equity allocation. Similar magnitudes are found for yield spread and slightly magnitudes higher for credit spread. The highest magnitude of the coefficient is found for the dividend-price ratio; however, the standard deviation is also small for this variable. For example, a 0.30 (one standard deviation) increase in dividend price ratio implies a 3.15(0.3×-10.5) percentage point decrease in strategic asset allocation to equity.

Similarly, the results for the dividend-price ratio are statistically strongest for strategic bond and alternatives allocation. However, again the signs are inconsistent with theory. The signs remain the same and still statistically significant when we consider the pooled regression with additional control variables. The signs of the control variables are in accordance with expectations. The pension funds invest more conservatively when the percentage of retired members in the pension fund increases, in line with life-cycle theory. US funds and DB funds take more risk than the average fund in the sample. Lastly, larger pension funds are investing more in alternative asset classes as expected; however, there seems to be asset substitution from equities to alternatives by these pension funds.

The results discussed above suggest that pension funds are not able to invest taking into account macro-economic information that predicts future asset returns. One of the possible reasons could be that pension funds are constrained from fully benefiting from the changing economic conditions. Although they are aware of the possible benefits of shifting their portfolio weights, they are unable to invest like an unconstrained investor. For example, (Shin, 2010, Chapter 5) provides a theoretical model with mark-market accounting for pension funds in which demand for bonds by a liability hedging fund increases as the price of the bonds increases. This behavior is clearly not desirable from a market timing perspective.

4.1 Active changes and asset allocation

[Insert Table 9 here]

Pension funds are allowed to deviate from their strategic asset allocation in the short term in order to benefit from the changing investment scenario.[11] This involves under or over weighting a particular asset class relative to the strategic benchmark, based on the market or economic considerations. Moreover, any change in the macro-economic scenario is reflected in changes in the predictive variables. Jank (2012) also carries out an analysis with changes in the variables. For this reason, we examine the relationship between the active changes (i.e. the explicit active investment decisions of the pension fund) and the lagged changes in predictive variables. The active change, denoted by $\text{Act}_{i,t+1}$, is the change in the weight of the risky asset due to active investment decisions by the fund managers. Following Calvet, Campbell and Sodini (2009), we calculate $\text{Act}_{i,j,t}$, the active change for fund i at time t, in asset class j, where j is either equity, bonds or alternatives. It is calculated in the following way

$$\text{Act}_{i,j,t+1} = w_{i,j,t+1} - w_{i,j,t} \times \left(\frac{1 + r_{i,j,t}}{1 + r_{i,p,t}} \right) \tag{7}$$

where w and r denote weights and returns respectively. Thus, the return of asset class j for fund i at time t is denoted by $r_{i,j,t}$ and $r_{i,p,t}$ similarly denotes the return for the whole portfolio of the fund. We use the following regression model:

$$\text{Act}_{i,j,t} = \alpha + \beta_1 \Delta Y_{t-1} + \beta_2 \Delta(d-p)_{t-1} + \beta_3 \Delta CS_{t-1} + \beta_4 \Delta Spr_{t-1} + \theta_i + \epsilon_{i,t} \tag{8}$$

As before, log dividend-price ratio is denoted by $(d - p)$, credit spread by CS, Y is the nominal T-Bill rate. The coefficients of interest are $\beta_1, \beta_2, \beta_3$, and β_4. Finally, θ_i denotes the fund fixed effects. The results of regression (8) are presented in Table 10.

[Insert Table 10 here]

We find that the relationship between active changes in asset allocation and predictive variables is consistent with theoretical predictions. The coefficients for changes in T-bill rates and changes in yield spread are negative and statistically significant. Therefore when the value of T-bills increases, then pension funds actively reduce the allocation to equities, consistent

[11] For a brief description of the strategic portfolio and the tolerance around it for active decisions by the largest pension fund in the US, California Public Employees' Retirement System (CalPERS) see `https://www.calpers.ca.gov/docs/forms-publications/cerbt-strategy-1.pdf`

with theoretical prediction. Similarly, when the yield spread widens, the pension funds reduce their exposure to equity. The coefficient for dividend-price ratio is positive. When the change in the D-P ratio is positive, the pension funds increase their exposure to equity.

There are two possible explanations. First, when the changes in predictive variables change the actual portfolio of the pension funds, they actively trade in order to negate this mechanical movement, consistent with the market-timing motive. The changes in predictive variables can move the pension fund portfolio because the returns on various asset classes are *correlated* with predictive variables, as is clear from cross-correlations of residuals in Table 2. When the realized returns move the portfolio away from the optimal allocation, pension funds actively trade in order to rebalance back to the previous optimal. Secondly, pension funds can take into account the predictive variables in actively under or over-weighting the portfolio relative to the strategic portfolio. This implies that pension funds exploit the predictive variables in the short-term via active bets.

5 Concluding remarks

This chapter addresses two related questions regarding the portfolio allocation of pension funds. First, how have pension funds responded to the fundamental changes in the economy since the start of the low interest rate environment? Secondly and more generally, are pension funds able to time the market in a way that is consistent with finance literature on return predictability? It is important to determine whether the pension funds are able to exploit the changes in investment opportunities as long-term investors. Pension funds are also constrained investors, raising the question of whether this affects their ability to time the market and invest in a way that is consistent with economic theory.

We find that pension funds have responded strongly to this fundamental change in the economy, and there are interesting cross-sectional differences in their response. Overall, pension funds have reduced their allocation to the equity asset class and increase their allocation to fixed income and alternative asset classes. From a market timing perspective, this is inconsistent with the finance literature on return predictability, which would suggest an increase in equity allocation and reduction in fixed income exposure. More generally, we next analyze the response of pension funds to other variables that have been found to predict asset returns. We find that pension funds are largely unable to time the market and miss out on benefiting from changes in the investment opportunity set. One of the possible reasons is that various constraints are binding on the pension funds and prevent them from investing as an efficient investor.

Next, analyzing the active changes of pension funds net of changes due to realized returns we find that pension funds actively rebalance the allocation to neutralize the changes in actual portfolio reflecting changes in predictive variables. Although pension funds are long-term investors, future work could analyze a shorter horizon response of the pension funds to changes in predictive variables. However, we are unable to do so due to the data only being available annually. These results raise interesting questions about the constraints pension funds face when investing. It would be a question for future research to test which specific short-term constraints on pension funds, for example regulations or short term liability hedging motives, contribute the most to under-performance of the pension funds and restrict them from exploiting the benefits from changes in the investment opportunities set.

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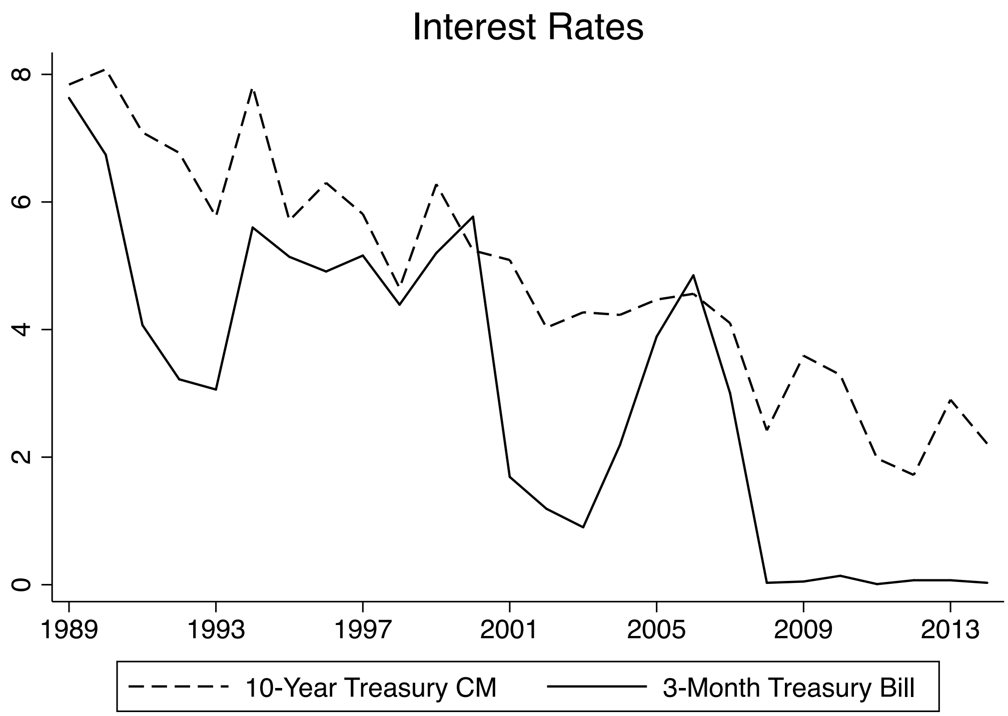

Figure 1: The level of interest rates. This figure provides the level of both short term three-Month Treasury Bill as well as long term ten-Year Treasury Constant Maturity Rate rates over the period 1989-2014. The Figure depicts that the short term interest rate has been almost zero from 2008 onwards as well as the long term interest rate has been at the lowest level since the start of the sample period.

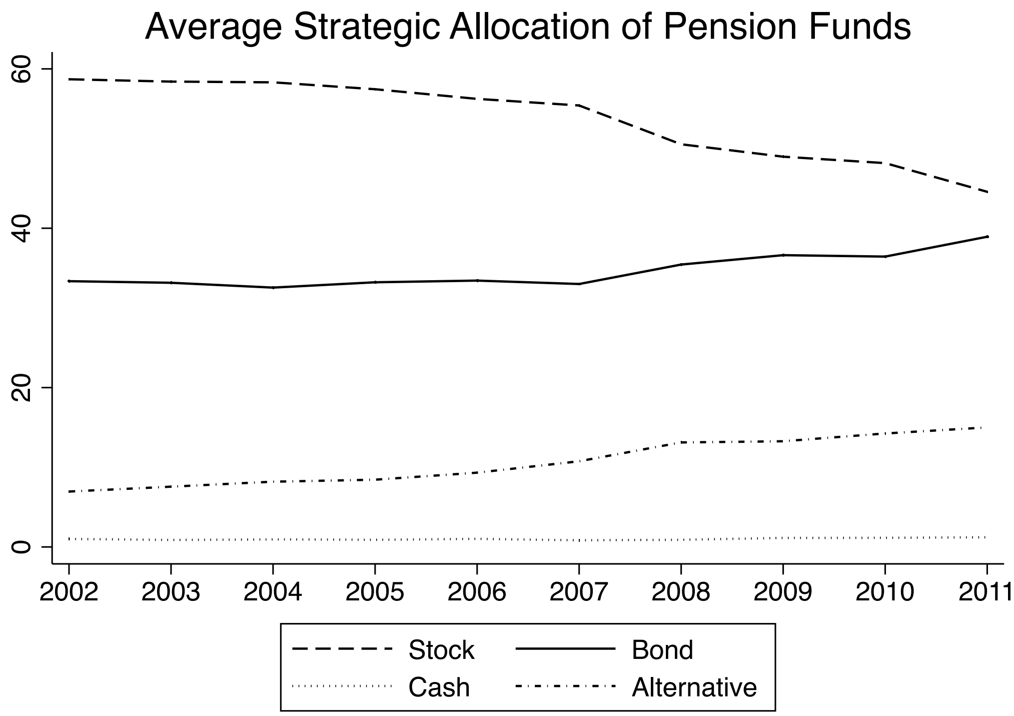

Figure 2: The average allocation of the pension funds is the mean of all funds in a given year as reported in the CEM database. The alternative asset class includes allocations to Real Estate, Private Equity, Hedge Funds and Commodities.

Table 1: Summary Statistics

	Mean	Std. dev.	5th percentile	Median	95th Percentile	N
A1. Regressions						
Domestic T-bill	3.41	2.14	0.07	3.40	7.11	4613
Log DP Ratio	-3.99	0.30	-4.47	-4.04	-3.43	4613
Credit Spread	1.05	0.63	0.54	0.95	3.37	4613
Yield Spread	1.66	1.26	-0.28	1.71	3.52	4613

A2. Correlations	(1)	(2)	(3)	(4)
Domestic T-bill (1)	1			
Log DP Ratio (2)	-0.04	1		
Credit Spread (3)	-0.46	0.46	1	
Yield Spread (4)	-0.71	0.30	0.18	1

	Mean	Std. dev.
B. Model Calibration		
Real T-bills	0.92	1.61
Excess Equities	7.25	16.89
Excess Bonds	1.76	5.46
Nominal Yield	4.42	1.45
DP ratio	-3.56	0.38
Yield Spread	1.12	0.45
Credit Spread	1.75	0.39

Notes: This table gives the summary statistics of the macro-economic variables. Panel A shows the statistics of the variables used for the regressions with sample period 1990-2011. The Domestic T-bill is the short term Treasury Bills for United States, France or Canada depending on the pension fund. Panel B shows the statistics of the variables used to estimate the Campbell, Chan and Viceira (2003) model with sample period 1952 Q2-2014 Q4. The variables are in logs and the mean excess log returns are adjusted by one-half of the variance. The sample statistics are annualized except for dividend-price ratio.

Table 2: VAR parameter estimation results (1952.Q2-2014.Q4)

	rtb_t	xr_t	xb_t	y_t	$(d-p)_t$	spr_t	cs_t	R^2/p
rtb_{t+1}	0.153	-0.002	0.043	0.392	-0.003	0.740	-0.861	0.192
	(1.946)	(-0.332)	(1.981)	(4.288)	(-2.256)	(3.367)	(-2.534)	(0.000)
xr_{t+1}	0.262	0.084	0.222	-2.420	0.056	-1.058	3.189	0.077
	(0.295)	(1.124)	(0.954)	(-2.593)	(3.095)	(-0.387)	(0.791)	(0.002)
xb_{t+1}	-0.122	-0.058	-0.039	0.391	-0.008	3.464	-0.710	0.096
	(-0.538)	(-3.091)	(-0.344)	(1.088)	(-1.607)	(3.131)	(-0.619)	(0.000)
y_{t+1}	0.008	0.003	0.000	0.962	-0.000	0.179	-0.180	0.911
	(0.372)	(1.955)	(0.020)	(26.199)	(-0.064)	(1.649)	(-1.517)	(0.000)
$(d-p)_{t+1}$	-0.614	-0.076	-0.135	1.570	0.947	0.525	-4.997	0.952
	(-0.685)	(-0.970)	(-0.551)	(1.604)	(49.005)	(0.187)	(-1.082)	(0.000)
spr_{t+1}	-0.003	0.001	0.003	0.010	0.000	0.672	0.237	0.575
	(-0.217)	(0.452)	(0.407)	(0.474)	(1.600)	(10.627)	(3.113)	(0.000)
cs_{t+1}	-0.011	-0.003	-0.001	0.023	-0.000	0.017	0.888	0.842
	(-1.657)	(-3.374)	(-0.230)	(2.199)	(-2.327)	(0.720)	(15.332)	(0.000)

Cross-correlations of residuals

	rtb	xr	xb	y	$(d-p)$	spr	cs
rtb	0.725	0.101	0.327	-0.313	-0.132	0.088	0.358
xr	-	8.121	0.024	-0.101	-0.963	0.079	-0.205
xb	-	-	2.597	-0.694	-0.043	-0.070	0.723
y	-	-	-	0.216	0.126	-0.660	-0.446
$(d-p)$	-	-	-	-	8.317	-0.094	0.193
spr	-	-	-	-	-	0.147	-0.117
cs	-	-	-	-	-	-	0.078

Notes: This table presents the results of VAR estimation with sample 1952 Q2- 2014 Q4. *rtb* denotes the ex post real treasury bill rate, *xr* denotes the excess stock return, *xb* denotes the excess bond return, y denotes the nominal treasury yield, $(d-p)$ denotes the dividend price ratio, *spr* denotes the yield spread and *cs* denotes the credit spread. The last column reports the R2 statistic for each equation in the system and the p-value of the F-test of the joint significance in parenthesis. Panel B reports the covariances of the innovations in the VAR, with the diagonal elements being the standard deviations per quarter.

Table 3: Sensitivity of the optimal portfolio allocation to changes in the state variables

	Real rate	Ex stock	Ex bonds	Nom yield	Div-price ratio	Yield spread	Credit spread
Panel A:							
$\gamma = 2$							
Ex stock	11.78	0.38	3.02	-160.31	13.65	-263.21	614.28
Ex bonds	-55.37	-2.48	-5.34	367.09	-27.15	6271.15	-1409.46
$\gamma = 5$							
Ex stock	4.38	0.14	1.16	-86.64	6.93	-165.65	208.08
Ex bonds	-21.17	-0.95	-1.99	247.81	-17.09	2839.00	-427.91
$\gamma = 10$							
Ex stock	2.10	0.07	0.57	-52.63	4.02	-110.75	85.13
Ex bonds	-10.25	-0.46	-0.94	165.28	-10.88	1549.83	-132.74
$\gamma = 20$							
Ex stock	1.01	0.03	0.28	-30.43	2.24	-67.99	33.75
Ex bonds	-4.99	-0.22	-0.44	101.18	-6.43	832.32	-26.17
Panel B:							
Ex stock				−	+	−	+
Ex bonds				+	−	+	−

Notes: Panel A of the Table presents the rescaled coefficient matrix $\boldsymbol{A}_1$ from the equation $\boldsymbol{\alpha}_t = \boldsymbol{A}_0 + \boldsymbol{A}_1 \boldsymbol{z}_t$. $\boldsymbol{\alpha}_t$ is the optimal portfolio rule. The constant coefficient matrices $\boldsymbol{A}_0$ and $\boldsymbol{A}_1$ are estimated on the history of state vector $\boldsymbol{z}_t$ with sample period 1952 Q2 to 2014 Q4. The results are presented for four levels of relative risk aversion parameter (γ) 2, 5, 10 and 20. The coefficient matrix $\boldsymbol{A}_1$ is rescaled using the standard deviations of the state variables from Table 1. The panel B summarizes the expected signs based on the model.

Table 4: Sensitivity of portfolio choice to state variables, with liabilities and longer horizons

Panel I	Nominal yield	Dividend yield	Yield Spread	Credit spread
$\gamma = 5$				
5 year horizon				
Stocks	-1526.1	3281.2	-1250.7	1454.8
Bonds	3092.7	-3801.6	3850.4	1806.5
20 year horizon				
Stocks	-3566.8	8015.0	-2806.4	-178.1
Bonds	10135.6	-9332.4	9891.9	5010.2
$\gamma = 20$				
5 year horizon				
Stocks	-456.3	926.2	-399.5	342.9
Bonds	912.6	-1179.4	1108.8	434.5
20 year horizon				
Stocks	-1330.6	2581.9	-1105.1	-203.1
Bonds	3552.8	-3566.2	3425.4	1656.3
Panel II				
Stocks	-	+	-	?
Bonds	+	-	+	?

Notes: The Panel I of this table presents the coefficient matrix A_1 from the equation $\alpha_t^{(\tau)} = A_0 + A_1 z_t$. $\alpha_t^{(\tau)}$ is the optimal portfolio rule of Hoevenaars et al. (2008), for a pension fund with liabilities and horizon τ. The constant coefficient matrices are calculated using the coefficients in their results. The results are presented for two levels of relative risk aversion parameter (γ) 5 and 20 and two horizons 5, 20 years. Panel II summarizes the expected signs.

Table 5: Summary statistics: Average change in strategic asset allocation before and during low-interest rate environment

	Equity	Bonds	Alternatives	Obs
Panel A:				
Difference	-6.97	2.36	4.43	313
t-value	(-14.05)	(5.07)	(10.99)	
Panel B:				
US	-8.92	3.47	5.11	188
Non US	-4.04	0.69	3.40	125
Difference	-4.88	2.78	1.72	
t-value	(-5.00)	(2.96)	(2.10)	
Public	-4.93	-1.82	6.38	110
Non-public	-8.00	4.66	3.25	200
Difference	3.07	-6.47	3.12	
t-value	(2.98)	(-7.11)	(3.78)	
DB	-7.51	3.00	4.36	260
Non-DB	-4.31	-0.78	4.77	53
Difference	-3.21	3.77	-0.42	
t-value	(-2.45)	(3.08)	(-0.39)	
Large	-7.22	0.97	5.91	156
Small	-6.72	3.73	2.95	157
Difference	-0.50	-2.76	2.96	
t-value	(-0.50)	(-3.01)	(3.75)	
Old	-8.70	4.70	3.97	134
Young	-6.63	1.17	5.23	135
Difference	-2.07	3.53	1.26	
t-value	(-2.01)	(3.70)	(1.40)	

Notes: This Table provides the results of t-tests of equality of mean of average change variable within various cross-sectional groups. The panel A test if the average change variable has a mean of zero., whereas panel B test if the means are different within different groups. Large group refers to the largest 50 percent pension funds and old refers to top 50 percent pension funds with the highest retired to active participants.

Table 6: Average change in strategic asset allocation before and during low-interest rate environment

	(1)	(2)	(3)
	Difference equity	Difference bond	Difference alternatives
US dummy	-4.55***	2.05**	1.66*
	(-4.29)	(2.18)	(1.85)
Public dummy	3.88***	-5.64***	1.91*
	(3.63)	(-6.46)	(1.93)
Defined Benefit	-0.07	0.40	-1.32
	(-0.04)	(0.23)	(-0.66)
Log Fund Size	-0.94**	-0.14	1.00***
	(-2.43)	(-0.47)	(3.13)
Retired	-2.50	3.81*	-1.30
	(-1.07)	(1.73)	(-0.66)
Constant	3.23	2.56	-3.81
	(0.91)	(0.83)	(-1.13)
Observations	266	266	266
R-squared	0.13	0.15	0.10

Notes: This table reports the OLS regression results of average change variable in each asset class on cross-sectional fund characteristics. The Difference equity variable is the difference between the average strategic or policy allocation to equity in 2009, 2010, and 2011 and in 2005, 2006, and 2007. The Difference bonds and Difference alternatives are similarly constructed. The observations include the pension funds for which at least one observation in each period is available. Robust t-stats are in parentheses, statistical significance is denoted by $***$ $p < 0.01$, $**$ $p < 0.05$ & $*$ $p < 0.1$.

Table 7: Robustness check – a comparison with another crisis period: We construct $\Delta \bar{w}_i$ which is the difference between the average allocation to equity in 2009, 2010, and 2011 and in 2000, 2001, and 2002 for pension fund i. 2000, 2001 and 2002 were chosen because the S&P return had been negative for all three years

	Equity	Bonds	Alternatives	Obs
Panel A				
Difference	-9.49	1.86	7.66	233
t-value	(-12.10)	(2.53)	(12.82)	
Panel B				
US	-11.55	2.53	8.95	140
Non US	-6.37	0.86	5.71	93
Difference	-5.18	1.67	3.24	
t-value	(-3.30)	(1.11)	(2.70)	
Public	-6.29	-3.14	9.64	93
Non-public	-11.61	5.18	6.34	140
Difference	5.32	-8.33	3.30	
t-value	(3.40)	(-5.94)	(2.75)	
DB	-9.56	2.30	7.37	197
Non-DB	-9.07	-0.53	9.20	36
Difference	-0.50	2.83	-1.82	
t-value	(-0.23)	(1.39)	(-1.10)	
Large	-10.53	0.69	9.90	116
Small	-8.45	3.02	5.43	117
Difference	-2.09	-2.33	4.47	
t-value	(-1.33)	(-1.59)	(3.85)	
Old	-11.91	5.27	6.55	101
Young	-7.36	-1.30	8.86	102
Difference	-4.55	6.57	-2.31	
t-value	(-2.70)	(4.36)	(-1.78)	

Notes: This table provides the results of t-tests of equality of mean of average change variable within various cross-sectional groups. The panel A test if the average change variable has a mean of zero., whereas panel B test if the means are different within different groups. Large group refers to the largest 50 percent pension funds and old refers to top 50 percent pension funds with the highest retired to active participants.

Table 8: Robustness regressions – a comparison with another crisis period: We construct $\Delta\bar{w}_i$ which is the difference between the average allocation to equity in 2009, 2010, and 2011 and in 2000, 2001, and 2002 for pension fund i. 2000, 2001 and 2002 were chosen because the S&P return had been negative for all three years.

	(1)	(2)	(3)
	Difference equity	Difference bonds	Difference alternatives
US dummy	-5.58***	2.81*	2.29*
	(-3.19)	(1.70)	(1.73)
Public dummy	6.69***	-7.90***	1.69
	(3.99)	(-5.59)	(1.17)
Defined Benefit	0.77	1.74	-2.10
	(0.20)	(0.52)	(-0.72)
Log Fund Size	-1.33**	0.06	1.28***
	(-2.44)	(0.11)	(2.95)
Retired	-9.20**	9.96**	-1.54
	(-2.28)	(2.30)	(-0.54)
Constant	6.36	-3.60	-2.67
	(1.01)	(-0.67)	(-0.56)
Observations	203	203	203
R-squared	0.15	0.19	0.11

Notes: This table reports the OLS regression results of average change variable in each asset class on cross-sectional fund characteristics. The Difference equity variable is the difference between the average strategic or policy allocation to equity in 2009, 2010, and 2011 and in 2000, 2001, and 2002. The Difference bonds and Difference alternatives are similarly constructed. The observations include the pension funds for which at-least one observation in each period is available. Robust t-stats are in parentheses, statistical significance is denoted by $***$ $p < 0.01$, $**$ $p < 0.05$ & $*$ $p < 0.1$.

Table 9: Levels of predictive variables and pension fund strategic asset allocation

	(1)	(2)	(3)	(4)	(5)	(6)
	Strategic equity	Strategic bonds	Strategic alternatives	Strategic equity	Strategic bonds	Strategic alternatives
T-bills ($t-1$)	0.95**	0.29	-1.66***	1.22**	0.14	-1.72***
	(2.07)	(1.10)	(-4.83)	(2.42)	(0.50)	(-5.02)
Log D-P ratio ($t-1$)	-10.56***	4.41***	5.57***	-10.83***	3.86***	6.28***
	(-8.42)	(4.70)	(4.57)	(-7.34)	(3.87)	(4.82)
Credit spread ($t-1$)	1.49**	-0.78***	-0.88	1.33*	-0.28	-1.11**
	(2.16)	(-2.62)	(-1.43)	(1.81)	(-0.81)	(-2.28)
Yield spread ($t-1$)	0.86**	0.37	-1.71***	1.01**	0.12	-1.56***
	(2.15)	(1.25)	(-4.66)	(2.19)	(0.38)	(-4.07)
Retired				-6.99***	7.37***	-1.80
				(-3.13)	(3.46)	(-1.23)
Log Fund Size				-1.58***	-0.22	1.77***
				(-4.55)	(-0.92)	(6.96)
US dummy				5.48***	-7.17***	2.42***
				(5.73)	(-9.81)	(3.23)
Public dummy				-0.66	0.95	-0.40
				(-0.49)	(0.71)	(-0.61)
DB dummy				2.34***	-1.75**	0.22
				(2.99)	(-2.22)	(0.35)
Constant				15.20**	53.82***	28.63***
				(2.00)	(9.73)	(4.53)
Observations	4,497	4,497	4,497	4,016	4,016	4,016
R-squared	0.12	0.04	0.13	0.15	0.15	0.22
Number of plans	528	528	528			

Notes: This table presents the result of fixed-effects regressions (1-3) and pooled regressions with cross-sectional controls (4-6) of strategic asset allocation to equity, bonds and alternatives on lagged variables that predict asset returns. The sample period is 1990-2011. Robust t-stats in parentheses are double clustered at year and plan level for both fixed effects and pooled specifications, statistical significance is denoted by $***$ $p < 0.01$, $**$ $p < 0.05$ & $*$ $p < 0.1$.

Table 10: Active changes in asset allocation and changes in predictive variables

	(1)	(2)	(3)
	Active equity	Active bonds	Active alternatives
ΔT-bills $(t-1)$	-1.59***	1.50***	0.13
	(-2.84)	(3.40)	(1.16)
ΔLog D-P ratio $(t-1)$	11.72***	-10.44***	-1.68**
	(3.87)	(-3.88)	(-2.03)
ΔCredit spread $(t-1)$	-1.16	1.55**	-0.27
	(-1.46)	(2.13)	(-1.38)
ΔYield spread $(t-1)$	-1.63***	1.38***	0.26**
	(-2.81)	(2.88)	(2.05)
Observations	2,564	2,563	2,564
R-squared	0.25	0.22	0.07
Number of planid	340	340	340

Notes: This table presents the result of fixed-effects regressions of active change in asset allocation in equity, bonds, and alternatives on lagged changes in variables that predict asset returns. Active change measures the active investment decisions of the pension fund managers. The sample period is 1990-2011. Robust t-stats in parentheses are double clustered at year and plan level, statistical significance is denoted by $***$ $p < 0.01$, $**$ $p < 0.05$ & $*$ $p < 0.1$.

6 Appendix

6.1 Data sources

To calibrate the VAR model of Campbell, Chan and Viceira (2003), we use post-war quarterly data for the US stock market as in their paper. However, our data extends from the second quarter of 1952 to the fourth quarter of 2014, and therefore includes the special macro-economic conditions of low interest rates since 2007-08. We obtain most of our data from the Board of Governors of the Federal Reserve System (FRED) and Wharton Research Data Services (WRDS). The three assets are short-term ex post real interest rates, excess stock returns and excess bond returns. The short-term ex post real interest rates are constructed as log lagged yield on three-Month Treasury Bill (obtained from FRED website) minus the log Inflation (obtained from WRDS). The excess stock returns are constructed as the difference between the log Value-Weighted Return-including dividends on NYSE/AMEX/NASDAQ (obtained from WRDS) and the log three-Month Treasury Bill (obtained from FRED). Lastly, the excess bond return is constructed as the difference between log five Year Bond Returns (obtained from WRDS) and log three-Month Treasury Bill (again obtained from FRED). As the data on Yield on 5-year bond from WRDS is only available after quarter one of 1961, we prepend that with data from Campbell, Chan and Viceira (2003) for 1952 Quarter two to 1960 Quarter four.

The return predictive variables that we use are short-term nominal interest rate, the dividend-price ratio, the yield spread and lastly we add credit spread as an additional state variable as in Hoevenaars et al. (2008). The short-term nominal interest rate is log yield on three-Month Treasury Bill (obtained from FRED). To construct the dividend-price ratio, we follow Campbell, Chan and Viceira (2003). First, a dividend payouts series is constructed using the Value-Weighted Return including dividends and price index series Value-Weighted Return excluding dividends (both obtained from WRDS). The dividend series is then the sum of dividends payments over the past year implied from the monthly data. The dividend-price ratio is then simply the log of dividend minus the price index. The log yield spread is constructed as the difference between the log yield on a five-year bond and the log yield on the three-month Treasury bill (both obtained from the FRED). Lastly, the credit spread is constructed as the difference between log Moody's Seasoned Baa Corporate Bond Yield (DAAA) and log yield on ten Year Treasury Constant Maturity Rate (both obtained from FRED).

For the regression analysis we make use of annual macro data from 1990 to 2011. The data is also international. For this reason and for reasons of comparison with other studies, the data used for regression analysis is slightly different than the data for the VAR model calibration. We use quarterly data to model the VAR because we have more data points to estimate our model, so there is less model uncertainty about the parameter and this is also consistent and comparable with other studies like Campbell, Chan and Viceira (2003); Hoevenaars et al. (2008, 2014).

The domestic nominal yield is the Interest Rates, Government Securities, Treasury Bills series for Canada, United States and France (as an approximation for the Euro area). All these series are obtained from FRED database; the original source is International Monetary Fund (IMF) International Financial Statistics. The dividend-price ratio is constructed from the "Irrational Exuberance" data obtained from Robert Shiller's website. The log dividend-price ratio is the log of average dividend in the preceding twelve months divided by the S&P composite price. The yield spread is constructed as the difference between the Moody's Seasoned Aaa Corporate Bond Yield and Moody's Seasoned Baa Corporate Bond Yield (both obtained from FRED). The long-term interest rate is constructed using the Long-Term Government Bond Yields: 10-year: Main (Including Benchmark) series for Canada, United States and France. All these series are obtained from FRED; the original source is Organisation for Economic Co-operation and Development (OECD) Main Economic Indicators. The yield spread is then the difference between the domestic long-term and domestic short-term interest rates.

6.2 Optimal asset allocation with liabilities

Let the VAR model be given by

$$z_{t+1} = \Phi_0 + \Phi_1 z_t + v_{t+1} \tag{9}$$

where

$$z_t = \begin{pmatrix} r_{tb,t} \\ s_t \\ x_t \end{pmatrix}$$

The excess returns on asset i are denoted by $x_{i,t} = r_{i,t} - r_{tb,t}$ which are calculated in excess of return on t-bills $r_{tb,t}$ and the state variables are given by s_t. Assuming that we have CRRA preferences on the future funding ratio of the pension fund with risk-aversion parameter (γ) and with τ period return with fixed horizon specific portfolio weights, given that pension funds rebalance to the initial weight at the end of the period and at some future point in time ($t + \tau$), if the investor chooses to invest α_t in the risky assets, then the portfolio return is given by the following log-linear approximation using the Taylors series expansion, that is

$$V_t^{(\tau)} = \max_{\alpha_t^{(\tau)}} \mathbb{E}\left[\frac{F_{t+\tau}^{1-\gamma}}{1-\gamma}\right] \tag{10}$$

Hoevenaars et al. (2008) show that in this case the optimal portfolio choice for an asset-liability investor is given by

$$\alpha_{t,L}^{(\tau)} = \frac{1}{\gamma}\left(\left(1-\frac{1}{\gamma}\right)\Sigma_{AA}^{(\tau)} + \frac{1}{\gamma}\Sigma_{AA}\right)^{-1}\left(\mu_{t,A}^{(\tau)} + \frac{1}{2}\sigma_A^2 - (1-\gamma)\sigma_{AL}^{(\tau)}\right) \tag{11}$$

whereas the the same for asset only investor is given by

$$\alpha_{t,AO}^{(\tau)} = \frac{1}{\gamma}\left(\left(1-\frac{1}{\gamma}\right)\Sigma_{AA}^{(\tau)} + \frac{1}{\gamma}\Sigma_{AA}\right)^{-1}\left(\mu_{t,A}^{(\tau)} + \frac{1}{2}\sigma_A^2 + (1-\gamma)\sigma_{Ar}^{(\tau)}\right) \tag{12}$$

From (9), we can calculate

$$\mu_t^{(\tau)} = \mathbb{E}_t(z_{t+1}\dots z_{t+\tau}) = \left[\sum_{j=1}^{\tau}\sum_{i=0}^{j-1}\Phi_1^i\right]\Phi_0 + \left[\sum_{j=1}^{\tau}\Phi_1^j\right]z_t$$

Note that the conditional mean depends on the state variables. Finally, the conditional variance is given by

$$\Sigma^{(\tau)} = \mathrm{Var}_t(z_{t+1}\dots + z_{t+\tau}) = \mathrm{Var}_t\left[\sum_{j=1}^{\tau}\left[\sum_{i=0}^{\tau-j}\Phi_1^i v_{t+j}\right]\right] = \sum_{j=1}^{\tau}\left[\left(\sum_{i=0}^{j-1}\Phi_1^i\right)\Sigma\left(\sum_{i=0}^{j-1}\Phi_1^i\right)'\right]$$

From these matrices, we can select the relevant rows and columns relevant for x_t for portfolio choice and calculate $\Sigma_{AA}^{(\tau)}$, Σ_{AA} and $\mu_{t,A}^{(\tau)}$ using a selection matrix H that selects the x_t relevant row and columns from the whole matrix. Note that this means

$$\boldsymbol{\alpha}_{t,L}^{(\tau)} = \tilde{\boldsymbol{A}}_0 + \tilde{\boldsymbol{A}}_1\boldsymbol{z}_t \tag{13}$$

Moreover, for the asset-only investor the optimal portfolio choice is

$$\boldsymbol{\alpha}_{t,AO}^{(\tau)} = \tilde{\boldsymbol{A}}_2 + \tilde{\boldsymbol{A}}_1\boldsymbol{z}_t \tag{14}$$

where $\tilde{\boldsymbol{A}}_0, \tilde{\boldsymbol{A}}_1$ and $\tilde{\boldsymbol{A}}_2$ are constant functions of estimated parameters of the VAR(1) model and the risk aversion parameter. The coefficient $\tilde{\boldsymbol{A}}_1$ measures the sensitivity of optimal portfolio allocation to changes in the state variables. Additionally, the sensitivity $\tilde{\boldsymbol{A}}_1$ does not change between investment as an asset-liability or asset only investor.

6.3 Figures

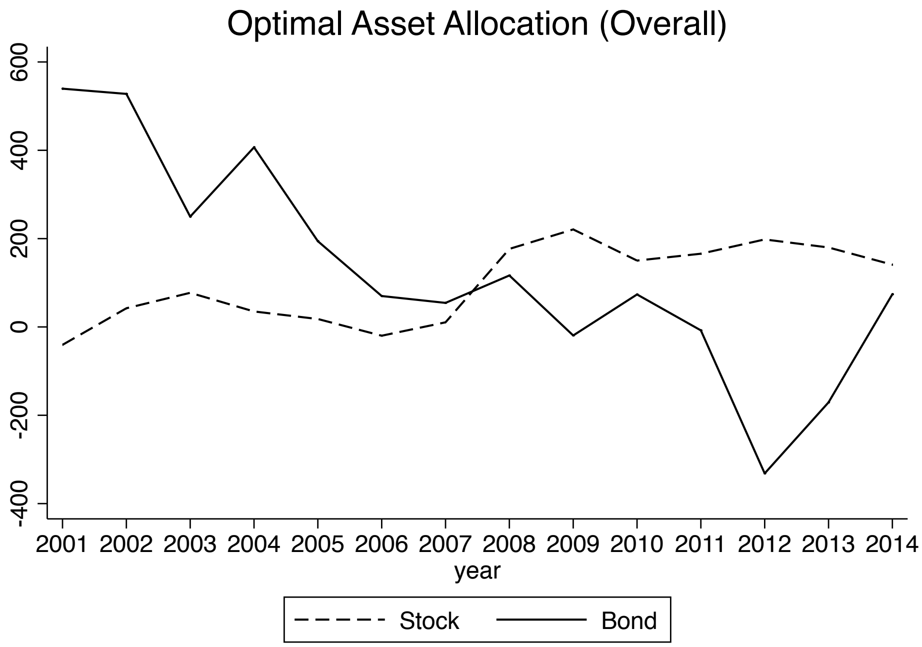

Figure 3: The model implied optimal strategic asset allocation and actual allocation of pension funds before and since the low-interest rate environment. The model implied strategic asset allocation is calculated from Campbell, Chan and Viceira (2003) model. The weight in stock and bond is average of the four quarters in a given year. The time discount factor equals 0.92 annually, the relative risk aversion is equal to 5 and the elasticity of inter-temporal substitution is 1.

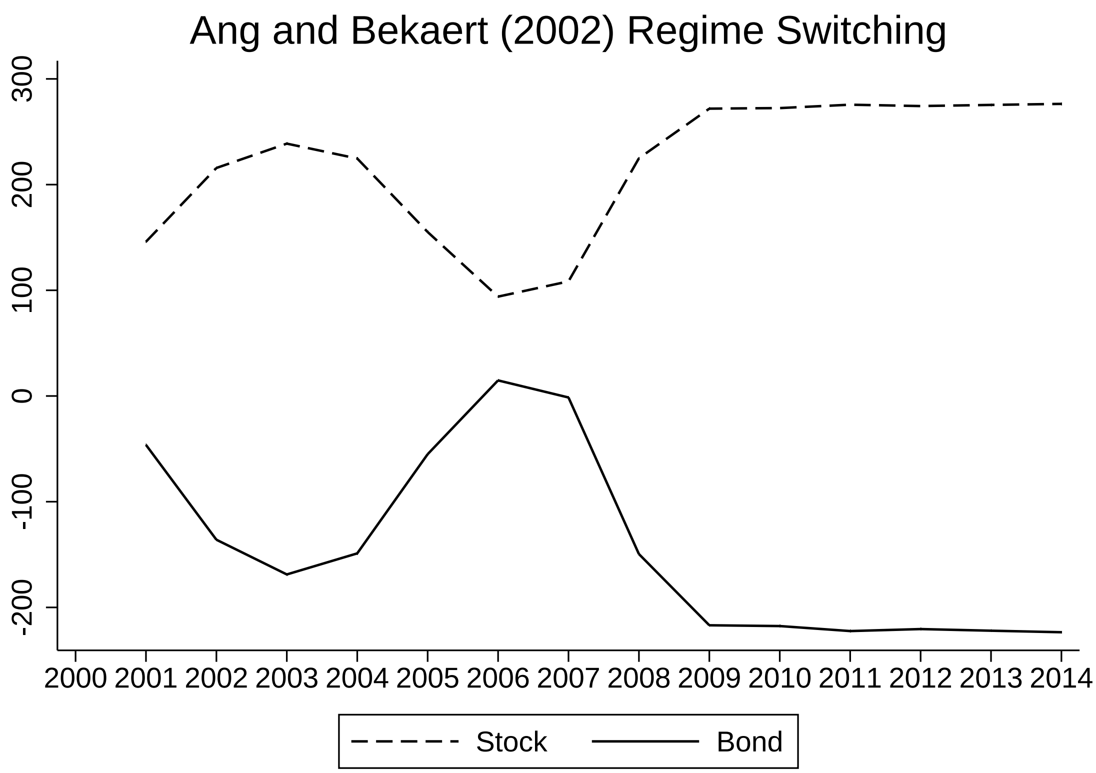

Figure 4: Asset allocation in a regime switching model (Ang and Bekaert, 2002*a*). This figure replicates model I of the Inquire version of their paper which incorporates predictability of returns, extended to the end of 2014. The values in the second panel are averages over year.