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REAL ESTATE IN AN ALM FRAMEWORK

THE CASE OF FAIR VALUE ACCOUNTING

Abstract

This study examines the liability hedging characteristics of both direct and indirect real estate, in the advent of fair value accounting obligations for pension funds. We explicitly model pension obligations as being subject to interest and inflation risk to analyze the ability of real estate investments in hedging the market value of pension liabilities and to quantify its role in an ALM portfolio. We find that the portfolio composition differs depending on the definition of liability return. When liability returns solely follow actuarial changes, the mean variance efficient portfolio allocations towards indirect real estate and fixed income increases compared to the asset only optimization. Once accounting for interest and inflation risk the results indicate that the hedging benefits of direct and indirect real estate are not pervasive enough to materialize in an ALM optimization. The portfolio allocation of direct real estate decreases in favor of fixed income securities. When taking pension liabilities as the starting point and coordinating the management of assets and liabilities in order to maintain a surplus of assets beyond liabilities the role for real estate is slightly more limited.

Keywords: *Real Estate, Asset Liability Management, Liability Hedge Credit*

Introduction

Real estate assets have traditionally been regarded as safe investments with inflation hedging capabilities that offer diversification potential and high absolute returns. Nevertheless there is no consensus as to its role within an investment context. In the selection of portfolios based on means and variances of returns the role for real estate, as a diversifier in a portfolio, appears to be substantial. For real estate allocations the mean-variance literature predicts allocations of at least 20% to be optimal[1]. Conversely, institutional investors like pension funds are not solely aspiring for maximum returns at a selected level of risk in their portfolio choice. Their focus in making asset allocation decisions is on considering risk on a relative basis versus liabilities to optimize their risk adjusted surplus. When taking pension liabilities as the starting point and coordinating the management of assets and liabilities in order to maintain a surplus of assets beyond liabilities the role for real estate seems much more limited.

Chun, Ciochetti and Shilling (2000) offered the first empirical analysis of real estate allocations within an Asset Liability Management (ALM) framework. In their research they recognize real estate assets' correlation and diversification potential with other assets, while simultaneously adjusting for the covariance with the liability stream. The diversification potential on the liability side as a hedge against inflation turns out to be more limited and accounts for the reduced exposure to this asset class as witnessed in institutional portfolios. Even so, this earliest achievement in the asset-liability literature circumvents the imperfections associated with real estate by focusing on real estate securities (REITs) and as such limits the opportunity set of assets to solely indirect real estate. Furthermore, Chun, Ciochetti and Shiling (2000) focus on the reported value of projected benefit obligations and in the advent of fair value accounting obligations for pension funds it becomes of interest how real estate performs in hedging the market value of liabilities.

This paper differentiates itself from previous studies as Chun, Ciochetti and Shilling (2000) and Craft (2001, 2005A, 2005B) by the way in which we define the return on liabilities. With the introduction of fair value accounting standards the dynamics of liabilities are likely to change. To compare the effect of changing accounting practices of the pension liabilities on portfolio allocations we use different liability return definitions. First we proxy the traditional book value of

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[1] For empirical evidence on real estate allocation within mean variance optimizations we like to refer to: Friedman (1971), Fogler (1984), Brinson, Diermeier, Schlarbaum (1986), Firstenberg, Ross and Zisler (1987), Irwin and Landa (1987), Ennis and Burik (1991), Hoesli, Lekander and Witkiewicz (2003) and Lee and Stevenson (2005).

liabilities, which only include actuarial changes, using the changes related to the value of projected pension obligations (PBOs) in accordance with Chun, Ciochetti and Shilling (2000) and Craft (2001, 2005A, 2005B). Next to this traditional definition of liability returns we also model the market value of liabilities, in line with fair value accounting. This paper adds to the existing literature by examining the liability hedge qualities of real estate in light of liabilities being denominated at market value, which we derive from the log yield of a constant maturity bond with a duration of 17 years, the average duration of pension liabilities.

We study US data for the period 1984-2008 to quantify the assets' impact on the pensions fund's future funding surplus and quantify the utility that investors with liabilities can derive from real estate in view of other asset classes. This will enable us to determine whether to classify real estate and other assets as reserve asset, an asset which moves in tandem with liabilities, or return-generating asset, an asset that merits an inclusion in the portfolio because of its attractive risk-reward characteristics (see Black and Jones, 1988). We widen the investment opportunity set by distinguishing between direct and indirect real estate investments. This paper is the first to include the MIT transaction index in a portfolio optimization problem following an ALM specification. The Transaction Based Index (TBI) estimates quarterly market price changes based on the verifiable sales prices of properties sold from the NPI database each quarter, avoiding the smoothing and lagging problems of the NCREIF appraisal based index used in previous studies.

Our results indicate that the portfolio composition differs depending on the definition of the liability return. When liability returns solely follow actuarial changes the mean variance efficient portfolio allocations toward direct real estate and stocks decreases with respect to an asset only portfolio as both asset classes are negatively correlated to actuarial changes. We also document negative correlations with respect to the actuarial definition of liabilities for indirect real estate but the actual allocation increases as it takes over some of the allocation penalty to stocks. Once accounting for interest and inflation risk the hedging benefits of direct and indirect real estate are not pervasive enough to lead to materialize. Within an ALM optimization the allocation to both direct and indirect real estate decreases, vis-à-vis the asset only portfolios. When taking pension liabilities as the starting point and coordinating the management of assets and liabilities in order to maintain a surplus of assets beyond liabilities the role for real estate is slightly more limited.

The remainder of the paper is organized as follows: we present a synthesis of the most relevant theoretical and empirical analyses on real estate allocations and asset-liability management. In the third and fourth section the data set and the methodology of the empirical tests are presented. We initially proceed by quantifying real estate allocations assuming an asset only mean variance optimization. Next, in section six, we analyze the liability hedging potential of various assets classes, compared both to the market value and to the actuarial denomination of liabilities. This will allow us to answer the question whether the change in accounting practices to fair value accounting of pension liabilities will cause a significant change in pension plan allocations. In section seven we compute optimal ALM portfolios and asses the interplay between the different weights attached to liabilities, levels of risk tolerance and funding levels of pension schemes. Finally, the last section summarizes our most important findings.

Literature Review

In the context of real estate allocations Friedman (1971) was one of the first to use the mean-variance methodology to select optimal direct real estate and mixed-asset portfolios. The inclusion of real estate assets in mean-variance optimal portfolios resulted in a widespread belief that actual real estate allocations in investment portfolios fall short. Bajtelsmit and Worzala (1995) put forward that on average American pension funds allocate less than 4% of their assets to equity real estate. In their survey among 96 pension funds the dominant asset classes were domestic stock (42.6%) and bonds (32%) followed by international stocks (7.2%). More recently, Dhar and Goetzmann (2006) surveyed leading investment managers from the U.S. and found the reported allocation among funds who invest in real estate to be relatively small 3%-5%, although a large number of funds announced plans to increase their respective allocations. Hoesli, Lekander and Witkiewicz (2005) explicitly compare the actual and suggested weights of real estate in the institutional portfolio and find that against the classic mean-variance framework, the predicted allocations are inconsistent with reported allocations.

The discrepancy between actual allocations and theoretical predications in this asset only view lead Chun, Ciochetti and Shilling (2000) to examine pension plan investments in an asset-liability framework using U.S. REITs. The relationship between assets and liabilities seems to be at the heart of explaining the limited exposure to real estate. Within the mean-variance framework real estate plays an important role as a diversifying asset class, but when accounting for liability obligations real estate seems to offer reduced diversification benefits as a hedge against actuarial changes and inflation on the liability side of the balance sheet. The latter diversification potential accounts for the reduced exposure to this asset class as apparent among institutional portfolios. Chun, Ciochetti and Shilling (2000) also found cross-sectional differences in REIT allocations. For overfunded plans the optimal allocation is higher than for underfunded funds.

Following this first empirical ALM study on real estate allocations Craft (2001) further examined real estate investments by distinguishing between private and public real estate allocations, while correcting for appraisal smoothing. The asset-liability framework predicts an allocation of 12.5% to private real estate and 4.7% to public real estate. And as the returns increase the private real estate allocation decreases sharply while the allocation to public real estate decreases at a lower progressive pace. Moreover, in accordance with Chun, Ciochetti, and Shilling (2000) overfunded pension plans are much more likely to hold both private and public real estate than underfunded counterparts (Craft, 2005A, 2005B). The particular nature and conditions of a pension fund apparently influence the optimal allocation decision. Similarly, Booth (2002) finds considerably different optimal portfolios depending on the liability structure of the pension funds. For mature U.K. schemes (whose members have already retired) direct real estate allocations prevail around 10%. For immature pension plans (active members) index-lin ked U.K. government bonds and U.S. equities replace real estate allocations.

Finally, another strand of literature by Fugazza, Guidolin and Nicadono (2007) and Hoevenaars, Molenaar, Schotman and Steenkamp (2008) incorporates predictability of asset returns in the optimal portfolio choice. Fugazza, Guidolin and Nicadono (2007) explicitly distinguish the time-varying properties of indirect real estate in light of bonds and stocks. When allowing for linear predictability patterns in indirect real estate returns the optimal allocation should obtain a weight between 12% and 44%, depending on the risk tolerance, parameter uncertainty and investment horizon. On the other hand when optimizing returns in excess of liabilities, Hoevenaars, Molenaar, Schotman and Steenkamp (2008) find that the role for indirect real estate in a liability driven investment portfolio is negligible.

This paper extends the work of Chun Ciochetti and Shilling (2000), Craft (2001) and Booth (2002) by examining the market value liability hedge qualities of real estate in light of other asset classes. We explicitly model liabilities as being subject to interest and inflation rate risk and summarize the assets' impact on the pensions fund's future funding surplus. Furthermore we compare the allocation to that using actuarial liability to distinguish the impact accounting practices have on the portfolio composition. To do so, this study applies a liability framework as developed by Sharpe and Tint (1990), which arises from a traditional mean-variance optimization problem. More specifically, the objective function follows a standard asset only optimization problem, while considering the change in pension liabilities and their covariance with assets. The latter, also referred to as the liability hedge credit, quantifies the utility due to assets correlation with a pension fund liabilities. This methodology further allows for a differential in emphasis attached to liabilities, the level of risk tolerance and the funding level of pension schemes. This enables us to determine how sensitive the results are to these factors, but more importantly it permits pension funds to tailor their portfolios to their particular nature and objectives. And most notably, it allows institutional investors to quantify the liability hedging utility of each asset class both in terms of market value and in terms of actuarial changes.

Methodology

To determine real estates' role as a reserve asset, asset which moves in tandem with liabilities, or a return-generating asset we apply a single-period surplus optimization investment framework of Sharpe and Tint (1990) that explicitly links investment opportunities and pension-plan obligations. The objective of the pension fund is to maximize surplus, defined as:

$$S_{t+1} = A_{t+1} - kL_{t+1} \ , \tag{1}$$

where A_{t+1} represents the value of the fund's assets at t+1, L_{t+1} the value of the relevant liability concept and k the attached importance to it. Choosing k=1 means that full importance is attached to the liabilities, k=0 corresponds to an asset only optimization. Denoting the return on the asset portfolio by $R_{A,\,t+1}$ and the growth rate of the liabilities by $R_{L,\,t+1,}$ the surplus can be written as:

$$S_{t+1} = A_t \left[\left(1 + R_{A,t+1}\right) - k \frac{L_t}{A_t} \left(1 + R_{L,t+1}\right) \right], \tag{2}$$

where L_t/A_t denotes the fund's current inverse funding ratio.

Maximizing the expected utility of S_{t+1} is equivalent to maximizing that of:

$$Z_{t+1} = R_{A,t+1} - k\left(\frac{L_t}{A_t}\right)R_{L,t+1} \tag{3}$$

Accordingly, Sharpe and Tint (1990) formulate the optimization problem of the pension fund as:

$$\max\left[E_t\left(Z_{t+1}\right) - \frac{1}{\lambda}\operatorname{var}_t\left(Z_{t+1}\right)\right], \tag{4}$$

where λ denotes a fund's risk tolerance. If the portfolio weights to be chosen are denoted by *w*, we have $R_{A,t+1} = \sum_i w_i R_{i,t+1}$, where $R_{i,t+1}$ denotes the return on asset *i*.

Following Sharpe and Tint (1990) let us focus on the second term in (4), which can be written as:

$$\begin{aligned} &\operatorname{var}_t\left(R_{A,t+1} - k\frac{L_t}{A_t}R_{L,t+1}\right) \\ &= \operatorname{var}_t\left(R_{A,t+1}\right) + k^2\frac{L_t^2}{A_t^2}\operatorname{var}_t\left(R_{L,t+1}\right) - 2k\frac{L_t}{A_t}\operatorname{cov}_t\left(R_{A,t+1}, R_{L,t+1}\right) \end{aligned} \tag{5}$$

The second term is irrelevant to the outcome of the maximization problem. The difference with the standard asset only optimization problem is concentrated in the last term. It stresses that the assets' covariances with the growth rate of the liabilities are key for the optimal allocation. Sharpe and Tint (1990) define the liability hedge credit for any asset *i* as

$$LHC_i = \frac{2}{\lambda}k\frac{L_t}{A_t}\operatorname{cov}_t\left(R_{i,t+1}, R_{L,t+1}\right), \tag{6}$$

while the LHC of the entire portfolio is simply

$$LHC_a = \sum_i w_i LHC_i\ . \tag{7}$$

The total objective function follows a standard asset only optimization problem, the expected surplus return minus a risk penalty, while considering the change in pension liabilities and their covariance with assets (LHC_a).

$$\max\left[Expectedreturn - Riskpenalty + LiabilityHedgeCredit\right]$$

$$\max\left[R_{A,t+1} - \frac{\mathrm{var}_t(R_{A,t+1})}{\lambda} + LHC_a\right] \tag{8}$$

Other things being equal, an asset whose returns are highly correlated with liabilities provide better liability hedging and receive a greater liability hedging credit. This ultimately results in a higher weight in the ALM portfolio than under the traditional mean variance optimization.

Data description

Our study employs data from the United States, as for this country broad data coverage on both transaction based property indices and property share indices are available. The analysis of the asset returns is based on the 1984 to 2008 (Q2) period, taking quarterly observations. We choose an investment feasibility set in accordance with previous papers of Chun, Ciochetti, Shilling (2002) and Craft (2001, 2005). The inclusion of additional asset classes will trouble the results making inferences concerning the contribution of real estate in an ALM portfolio difficult to ascertain. Furthermore the objective is not to establish the optimal allocation but to asses the interplay between the various definitions of liabilities, the weights attached to liabilities, levels of risk tolerance and funding levels of pension schemes on portfolio allocations.

Data on stock returns were taken from Datastream Advance. Stock returns are approximated by the returns on the MSCI US index. Indirect real estate returns are based on Global Property Research (GPR) General National index. Direct real estate returns are from the MIT series. MIT TBI is based on actual transaction prices of properties in the NCREIF database using advanced econometrics techniques to correct for sample selection bias and noise filtering. In comparison to the appraisal-based NCREIF Property Index, the MIT TBI index does not suffer from appraisal biases and has slightly higher volatility, less autocorrelation, and 1 to 3 years lead in major peaks and troughs (Fisher, Geltner and Pollakowski, 2007). This paper is the first to include the MIT transaction index in an optimization problem in an ALM setting. The fixed income assets consist of a 20-year Treasury bond and Moody's Seasoned Aaa Corporate bond. Both the 10-year constant maturity and Moody's Seasoned Aaa Corporate bond yields, are from the US Federal Reserve Bank website[2]. Moody's Seasoned Aaa Corporate Bond Yield are averages of daily data within a

[2] http://research.stlouisfed.org/

given quarter. The 20-year Treasury bond is based on an index from Lehman Brothers. We further combine the two fixed income securities to establish a duration matched portfolio similar to those of the pension liabilities for the ALM portfolio. The duration of the fixed income assets is calculated as

$$D_{n,t} = \frac{1-(1+Y_{n,t})^{n}}{1-(1+Y_{n,t})^{-1}}$$

where, $Y_{n,t}$ is the log annualized yield of a n-year maturity bond at time t. The average duration is 12.09 years for the 20 year Treasury bond and 5.67 years for the Moody's Seasoned Aaa Corporate bond.

To obtain the fraction weight (w) of each fixed income security in the duration hedged portfolio we solve the following equation:

$$D_{L,t} = w * D_{20,t} + (1-w) * D_{7,t}$$

$$w = \frac{D_{20,t} - D_{7,t}}{D_{L,t} - D_{7,t}}$$

where D_L equals the duration of the pension liability, set equal to the average duration of pension liabilities, 17 years. $D_{20,t}$ is the duration of the first fixed income security per quarter, the 20-year treasury bond and similarly $D_{7,t}$ is the duration of the Corporate bond.

Table 1 presents a summary of the performance of the asset categories that are considered in our study. The mean returns and standard deviations are computed for the 1984-2008 sample period. We document the highest return for indirect real estate, while direct real estate appears to have outperformed stocks and indirect real estate in terms of the risk adjusted performance of the asset class. The Sharpe ratio of direct real estate, calculated as annualized excess return divided by the annualized standard deviation of returns, is 0.52 versus 0.42 for stocks and 0.40 for indirect real estate.

Table 1: Sample Statistics

A crucial step in determining optimal portfolios for pension funds is the definition of the liability. Each definition of the liability conceivably can result in different portfolio allocations. Subsequently this paper differentiates itself from previous studies as Chun, Ciochetti and Shilling

(2000) and Craft (2001A, 2005B) by the way in which we define the return on liabilities. These previous studies measure the returns on liabilities using the value of projected pension benefit obligations (PBOs) of corporate-sponsored defined benefit pension plans. Projected benefit obligations represent actuarial present value of all benefits earned by employees to the annual reporting date, plus projected benefits attributable to future salary increases as determined by each company's benefit formula. To compare the effect of changing accounting practices of the pension liabilities on allocations we model the market value of liabilities and proxy the actuarial changes using the changes related to the value of projected pension obligations (PBOs), the latter in accordance with Chun, Ciochetti and Shilling (2000) and Craft (2001A, 2005B). We obtain the annual PBOs from Compustat. We construct a panel of pension liabilities using firms reporting over the entire available study period (1988-2007)[3]. Our study includes 471 firm plans. The actuarial change is approximated by the equally weighted annual rate of change of this sample. The mean annual rate of change in pension liabilities was 9.88% and the standard deviation 6.22%, close to those reported by Craft (2001).

For the analysis of the market value of liability changes we assume that the returns on liabilities follow the returns of the long-term constant maturity bond, estimated over the 1984 to 2008 period. A common assumption in pension studies as Nijman and Swinkels (2003), Hoevenaars, Molenaar, Schotman and Steenkamp (2008) and Binsbergen and Brandt (2005).

Before the introduction of IFRS, liabilities were valued using actuarial principles and the present value of liabilities was determined by discounting future these future contributions at a fixed rate (r), typically 4% per year.

$$V_t^{actuarial} = \sum_n CF_{t+n} * (1+r)^{-n}$$

Due to international accounting standards liabilities are denominated at market value. Valuation of the market value of liabilities comes down to discounting nominal fixed payments using the market rates $R_t^{(m)}$.

$$V_t^{market} = \sum_n CF_{t+n} * (1+R_t^{(m)})^{-n}$$

If longevity risk is ignored, the cash flows of the portfolio of nominal pension liabilities equal those of a portfolio of bonds. Further assuming a pension fund is in stationary state the

[3] By 1988 firms were required by the Financial Accounting Standards Board (FASB) to report PBO annually.

distribution of the age cohorts and pension rights are constant over time, we can describe its liabilities as a constant maturity bond. The market value of liabilities is solely influenced by changes in interest rates. The liability return is derived as a function of the log yield of the constant maturity bond, assuming duration of 17 years, the average duration of pension liabilities.

$$(1+r_{n,t+1}) = D_{n,t}(1+Y_{n,t}) - (D_{n,t} - \frac{1}{4})(1+Y_{n-1,t+1}) = \frac{1}{4}Y_{n-1,t+1} - (D_{n,t}(Y_{n-1,t+1} - Y_{n,t}))$$

where, $Y_{n,t}$ is the log annualized yield of a n-year maturity bond at time t. We further approximate $Y_{n-1,t+1}$ by $Y_{n,t+1}$, a common assumption also made by Hoevenaars, Molenaar, Schotman and Steenkamp (2008). The mean annual rate of change in the market value of pension liabilities was 14.67% and the standard deviation is significantly higher namely 15.27%.

We further distinguish two series of nominal and real liability returns. In quantifying the utility a pension fund can derive form various asset classes we use nominal liabilities as the starting point, in the advent of indexation we consider the hedging capabilities surrounding real liabilities. Following the Fisher hypothesis we calculate both the nominal $(R_{L,t+1})$ and the real liability return $(RR_{L,t+1})$. We decompose the nominal yield into a real return $(RR_{L,t+1})$ and inflation compensation, where the inflation compensation reflects expected inflation (π_{t+1}) and an inflation risk premium, which for reasons of simplicity we assume constant.

$$Y_t^{nom} = Y_t^{real} + E_t[\pi_{t+1}]$$

We further assume that inflation expectation is derived from a fourth order autoregressive model. The coefficients are estimated using rolling regressions using 10 years of history (40 quarters). Thus we assume that for each year investors form expectations on the basis of the last 10 years of quarterly observations. This way, we will explicitly model the riskiness of liabilities as being subject to interest and inflation risk and determine which asset class is capable of providing the appropriate payout structure to hedge interest rate risk and aid in providing indexation. Finally, we define pension liabilities to also include active liabilities. Active liabilities are salary linked liabilities, the relationship between salary linked liabilities and asset returns will determine the attractiveness of the various asset classes in a young versus mature pension fund portfolio. For the calculation of active liabilities we include wage increases in addition to real liability returns[4]. The data on wage growth was obtained using the U.S. national average wage index[5].

The difference between an actuarial ALM and an ALM at market value lies mostly in differences between actuarial changes (mortality, longevity, projected salary increases) and interest and inflation than in the differences in discount rates. Active liabilities stress the importance of hedging wage developments. Other things being equal, an asset whose returns are highly correlated with developments in mortality, longevity (or wages) provide better liability hedging in an actuarial ALM (active ALM) than an asset class that hedges interest rate and inflation shocks. By allowing for various definitions of liabilities we can establish the role of each asset class within various ALM portfolios.

Asset only Optimization

Mean-variance methodology ensures a portfolio selection that embodies diversification between assets and identifies the efficient set of portfolios that maximize expected return while minimizing the variance of the expected returns. Risk reduction is a function of low or negative correlation coefficients between asset classes. Table 1 panel D presents a correlation matrix between the returns on stocks, long-term Treasury bonds, corporate bonds and direct and indirect real estate. Direct real estate returns appear to be negatively correlated to stocks and corporate bonds and positively correlated with treasury bonds. Real estate stocks in contrast do not appear to be highly correlated with direct real estate investments, but more with common stocks. In the context of portfolio diversification direct real estate offers greater risk diversification benefits. The low covariance of direct real estate with stocks and bonds should greatly reduce portfolio risk.

Table 2: Asset Only Allocations

The efficient set of portfolios that maximize expected return for a given level of risk are constructed under the standard mean-variance analysis. We impose short-selling constraints on all assets and portfolios must be fully invested. Table 2 reports portfolio compositions for seven

[4] The inclusion of solely real liability returns comes with the assumptions of no passive liabilities, mortality or morbidity.

[5] http//www.ssa.gov

portfolios on the efficient frontier, beginning with the minimum variance portfolio (MVP), the tangency portfolio and ending up at the high risk range of the efficient frontier.

In the selection of portfolios based on means and variances of returns the role for direct real estate, as a risk diversifier in a portfolio, is substantial. The low correlation of direct real estate with bonds and stocks in combination with the low standard deviation of returns results in high allocations to this asset class in the low-risk range of the efficient frontier. The mean-variance model, on the basis of transaction based real estate returns, estimates allocations to direct real estate of 24.99%. At the higher risk tolerance levels indirect property investments substitute the direct counterpart. The absence of indirect real estate in the low risk portfolios can be explained by the high standard deviation of the asset class and the high correlation with stocks, while direct real estate offers superior risk-adjusted returns next to risk diversification properties. The efficient real estate allocation is relatively stable around 25%. The results are in line with those of Ziering and Mclntosh (1997), Ziobrowski and Ziobrowski (1997), Kallberg, Lui and Greig (1996), and Mueller and Mueller (2003), who use the NCREIF index while accounting for the added smoothing risk and still find an optimal real estate allocation of 20%-30%. On the basis of a mean-variance asset only optimization direct real estate warrants inclusion in a mixed-asset portfolio because of its attractive risk-reward properties and its low correlation with stocks and bonds.

The Liability Hedge Potential

An asset-liability model (ALM) is a model of the assets and liabilities that facilitates decision-making with respect to asset allocation and the properties of the liabilities. An important distinguishing feature is the interdependence between assets and liabilities. Table 3 presents the correlations between the different liability specifications and asset returns for the asset classes considered in this analysis.

Table 3: Correlation of asset returns with pension liabilities

For both direct and indirect real estate we document negative correlations compared to the actuarial definition of liabilities, nonetheless once we account for interest rate risk and inflation the correlation coefficients increase considerably. Though the magnitude of the correlation is quite small indirect real estate in particular appears to offer hedging benefits against interest rate risk and inflation, especially in comparison to stocks. For both direct and indirect real estate including inflation risk increases the correlation, indicating a positive hedge against inflation. Once we define liabilities as active or salary linked liabilities hedging potential of indirect real estate is lost. In effect direct real estate, bonds and stocks appear to be positively correlated with wage increases. With equities correlating the most with wage changes.

In terms of the liability utility to be derived, the liability hedge credit (LHC) follows directly from the correlations of the asset return with the liability returns, current assets to liability ratio and the risk tolerance.

$$LHC_i = \frac{2}{\lambda} k \frac{L_t}{A_t} \operatorname{cov}_t\left(R_{i,t+1}, R_{L,t+1}\right) \qquad (6)$$

The liability hedge credit is positively related to the covariance between an asset and liabilities and to the inverse of the current funding ratio (L_t/A_t), while inversely related to the risk tolerance (λ). The LHC as specified under actuarial change is negative for direct real estate, ranging from -0.12% in the full surplus optimization scenario for fully funded funds with a typical risk tolerance (λ=5) to -0.02% for underfunded funds (L/A=1.5) under similar constraints (Figure 1). Once we account for interest and inflation risk as under the market value of liability, the hedging utility becomes slightly stronger, 0.03% for a fully funded fund and 0.05% for the underfunded funds. Direct real estate appears to be more attractive from a market valuation perspective as a hedge against interest and inflation than as a hedge against actuarial developments. Overall, the LHC's are more pervasive when denominating liabilities at market value. Once we define liabilities as active liabilities, direct real estate obtains a lower hedge credit, as the correlation with respect to wage developments is close to zero (Figure 2). For indirect real estate the liability hedging credit is even more pronounced due to positive correlation with interest and inflation changes. The correlation between salary linked liabilities and indirect real estate worsens the utility and results in a sharp reduction for this asset class.

Figure 1: Actuarial and Market value Liability Hedge Credit (LHC) per asset class

Figure 2: Active Liability Hedge Credit (LHC) per asset class

Indirect real estate provides more utility than stocks in terms of hedging inflation and interest rate risk. Fixed income instruments also offer a liability benefit for the portfolio of a pension fund, as the correlation between these assets and liabilities is high[6]. Including these asset classes in a pension portfolio can enhance returns up to 1.05% for an underfunded fund with a typical risk tolerance (λ=5). A clear distinction arises between return generating assets like stocks and liability hedging asset classes like bonds, as the latter provide the most utility when the funding status is unfavorable, while return generating assets provide an improved utility when pension funds are overfunded.

Overall, we have seen that the definition of liabilities mildly influences the liability hedging return to be derived of the various asset classes. In the next section we will advance from the hedging characteristics to the implications for an ALM portfolio and determine how the definition of liabilities influences portfolio allocations.

ALM Portfolio Optimization

Within the mean-variance asset only framework real estate plays an important role as a diversifying asset class. Mean-variance efficient portfolios tend to contain a high level of direct real estate and a higher portion of indirect real estate at higher risk levels. The portfolio composition differs depending on the definition of the liability return. When liability returns solely follow actuarial changes the mean variance efficient portfolio allocations toward indirect real estate and fixed income increases compared to the asset only optimization. Indirect real estate dominates stocks in terms of hedging actuarial changes and consequently obtains a higher allocation. The allocation towards direct real estate and stocks decreases in an actuarial ALM setting. Surprisingly, even though direct and indirect have a positive liability hedge credit once denominating liabilities in market value terms, the actual portfolio allocation towards these asset classes decreases with respect to the asset only scenario. As compared to the actuarial ALM optimization the allocations are also slightly lower, especially for indirect real estate. Nonetheless, when including inflation rate risk the allocation of both the real estate asset classes increases slightly in contrast to the nominal ALM optimization. Reflecting real estate's hedging ability with respect to inflation. However, the positive correlation between real pension liabilities and real estate cannot materialize in an ALM portfolio where fixed income securities take the upper hand. The differences among the portfolios are subtle as reflected by the contained liability hedge credits.

[6] Note that liabilities are derived from constant maturity bond, as such the hedging potential might be biased upwards.

Taken as a whole, the efficient frontier does indicate that once accounting for liabilities a pension fund can increase its expected value for a given variability and that is especially pronounced once we include interest and inflation risk, leaving the pension fund in a much better position in terms of probability of under funding.

Table 4: Actuarial vs Market Value ALM allocations

Figure 3: Efficient frontiers

The change in accounting practice influences the optimal portfolio allocation and makes real estate less attractive vis-à-vis fixed income securities, nonetheless the actual weight remains to be quite dominant. The optimal portfolio allocations for real estate, both direct and indirect, range from 22% to 25% depending on the definition of liability return. To obtain a similar standard deviation as the minimum variance portfolio in the asset only scenario a fully invested pension fund would need to allocate 23.65% to direct real estate when considering real liabilities versus the 24.99% when focusing on asset returns solely. The equivalent maximum Sharpe ratio portfolio still contains considerable direct real estate exposure, 22.96% versus 23.38%. Again this is mainly attributable to the supremacy of fixed income securities in terms of hedging utility (LHC) regarding interest and inflation movements. At higher risk levels, real estate exposure in terms of direct real estate decreases as real estate stocks dominate direct real estate. Nonetheless, the allocation in an ALM portfolio denominated at market value is slightly less. In line with the results of Chun, Ciochetti and Shilling (2000), if we restrict the opportunity set of real estate to indirect real estate solely, we find a reduced role for indirect real estate in an ALM portfolio. Moreover, in table 6 the allocations come close to those observed in current institutional portfolios (e.g. Dhar and Goetzmann (2006).

The attractiveness of real estate as an asset class is also dependent on the particular disposition of the pension fund. As funding ratios improve or the importance attached to liabilities deteriorate, direct real estate obtains a higher portfolio allocation. Direct real estate materializes in an asset-liability portfolio as a relatively safe asset class of particular utility to fully or over funded pension funds. In line with Chun, Ciochetti, and Shilling (2000) and Craft (2005A, 2005B) overfunded funds are much more likely to hold public real estate than underfunded counterparts. The optimal portfolio allocations for real estate, both direct and indirect, lingers around 25%, which result in an expected return utility of around 9%, depending on the level of risk tolerance and funding ratio of the pension fund. Though the hedging utility of real estate relatively to fixed income securities is limited the return enhancement properties of direct and indirect real estate investments ensure an allocation in an ALM portfolio, real estate can increase returns more sharply than it increases surplus risk. Direct and indirect real estate warrants inclusion in a mixed-asset portfolio because of its attractive risk-reward properties, its diversification potential with stocks and bonds, and to a lesser extent to its interest and inflation hedging abilities.

Table 5: ALM Allocations

Table 6: Asset only versus ALM allocations (Indirect real estate)

Conclusion

Within the mean-variance asset only framework real estate plays an important role as a diversifying asset class. Mean-variance efficient portfolios tend to contain a high level of direct real estate with a clear substitution effect in favor of indirect real estate at higher risk levels. When accounting for liability obligations real estate offers hedging benefits against inflation and interest rates but has a negative correlation with actuarial movements. Consequently, the portfolio composition differs depending on the definition of the liability return. When liability returns solely follow actuarial changes the mean variance efficient portfolio allocations toward indirect real estate and fixed income increases compared to the asset only optimization. Our results show that even though direct and indirect real estate have a positive liability hedge credit once denominating liabilities in market value terms, the actual portfolio allocation towards these asset classes decreases with respect to the asset only scenario. The positive correlation between real pension liabilities and real estate cannot materialize in an ALM portfolio where fixed income securities take the upper hand. The optimal portfolio allocations for real estate lingers around 25%, which result in an expected return of about 9%, depending on the level of risk tolerance and funding ratio of the pension fund.

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Table 1: Sample Statistics

Mean returns and standard deviations are annualized continuously compounded quarterly total returns related to the sample period of 1984-2008. The mean returns are also displayed in excess of the 3-month T-bill. Stock returns are based on MSCI indices, direct real estate returns are from NAREIT series and indirect real estate returns are based on the MIT TBI index. Moody's Seasoned Aaa Corporate Bond (Duration 7 years) and the 3-month T-bill were obtained from the US Federal Reserve Bank website. The 20-year Treasury bond is based on an index from Lehman Brothers. The duration matched portfolio is constructed using the two fixed income classes to match the duration of the market value of real pension liabilities. Panel D exhibits the correlation matrix of the asset classes.

Panel A: Annualized Return	*Return*	*Excess Return*	*σ*	*Sharpe ratio*
Stock (MSCI)	11.27%	6.53%	15.43%	0.42
Real Estate Stock (GPR)	11.56%	6.82%	16.94%	0.40
Direct Real Estate (MIT TBI)	8.59%	3.86%	7.38%	0.52
20-Year Treasury Bond	9.37%	4.63%	12.66%	0.37
Moody's Seasoned Aaa Corporate Bond Yield	8.70%	3.96%	4.65%	0.85

Panel B: Annualized Return Sub periods	*Return*	*σ*	*Return*	*σ*
	Subperiod (1984-1994)		*Subperiod (1995-2007)*	
Stock (MSCI)	12.99%	15.37%	9.90%	15.60%
Real Estate Stock (GPR)	11.48%	20.20%	11.62%	14.03%
Direct Real Estate (MIT TBI)	4.16%	7.44%	12.12%	6.90%
20-Year Treasury Bond	10.40%	13.62%	8.55%	11.95%
Moody's Seasoned Aaa Corporate Bond Yield	10.43%	5.39%	7.32%	3.87%

Panel C: Descriptive Statistics Bonds	*YTM*	*Return*	*Excess return*
20-Year Treasury Bond	6.35%	9.37%	4.63%
Moody's Seasoned Aaa Corporate Bond Yield	7.73%	8.70%	3.96%
Duration matched portfolio		8.56%	3.87%

Panel D: Correlation Asset Returns	*Direct Real Estate (MIT TBI)*	*Stock (MSCI)*	*Real Estate Stock (GPR)*	*20-Year Treasury Bond*
Direct Real Estate (MIT TBI)	1.00			
Stock (MSCI)	-0.13	1.00		
Real Estate Stock (GPR)	0.01	0.55	1.00	
20-Year Treasury Bond	0.01	-0.13	0.08	1.00
Moody's Seasoned Aaa Corporate Bond Yield	-0.03	-0.16	-0.11	0.12

Table 2: Asset Only Allocations

Portfolios were derived using historical return and risk characteristics (1984-2008). The fixed income assets consist of a 20-year Treasury maturity bond (effective duration 10 years) and Moody's Seasoned Aaa Corporate bond (effective duration 7 years). The tangency portfolio represents the optimal Sharpe portfolio that optimizes the mean excess return divided by the standard deviation of returns. Panel B reports portfolio compositions for five portfolios along the efficient frontier.

Mean-Variance Efficient Portfolios (Asset-Only)							
Unsmoothed Real Estate Returns	MVP	Sharpe Optimal	1	2	3	4	5
μ	8.98%	9.07%	9.28%	9.41%	9.51%	9.61%	9.70%
σ	3.43%	3.47%	3.81%	4.16%	4.51%	4.85%	5.20%
Portfolio Weights							
Direct Real Estate (MIT TBI)	24.99%	23.38%	19.71%	17.56%	15.60%	14.13%	12.62%
Stock (MSCI)	9.51%	11.10%	14.73%	16.87%	18.62%	20.24%	21.71%
Real Estate Stock (GPR)	0.68%	2.26%	5.83%	7.97%	9.74%	11.30%	12.78%
Fixed Income	64.82%	63.26%	59.73%	57.60%	56.04%	54.33%	52.88%
Total Real Estate Exposure	25.67%	25.63%	25.54%	25.52%	25.34%	25.43%	25.41%

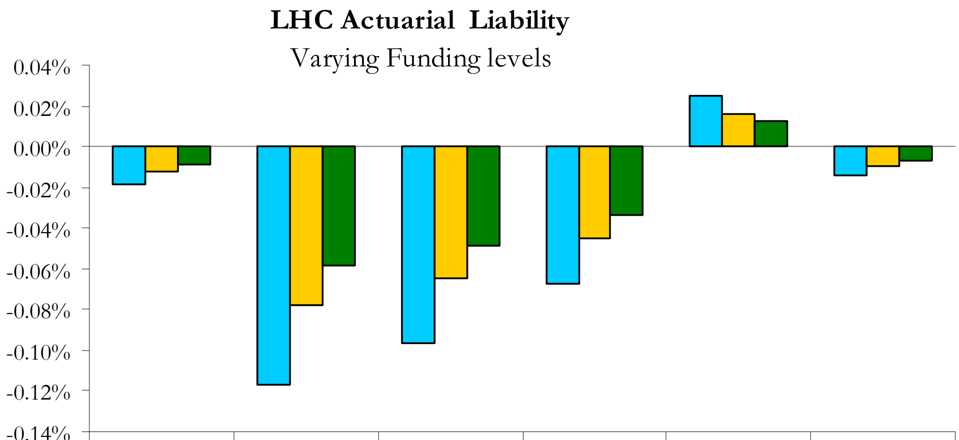
Table 3: Correlation of asset returns with pension liabilities

Table 3 displays the correlation coefficients of the asset returns with liabilities, both actuarial and the market value of liabilities. We proxy the actuarial changes using the changes related to the value of projected pension obligations (PBOs). For the analysis of the market value of liability changes we assume that the return on liabilities follows the return of the long-term constant maturity bond, estimated over the 1984 to 2008 period. The market value of liabilities is solely influenced by changes in interest rates and inflation. The liability return is derived as a function of the log yield of the constant maturity bond, assuming duration of 17 years, the average duration of pension liabilities. Real liabilities are adjusted for inflation and interest rate risk. We decompose the nominal yield into a real yield and inflation compensation, where the inflation compensation reflects expected inflation (π_{t+1}) and an inflation risk premium, which for reasons of simplicity we assume constant. We further assume that inflation expectation follows a fourth order autoregressive function. For the definition of active liabilities we partition from wage, the data on wage growth was obtained using the national average wage index: http//www.ssa.gov.

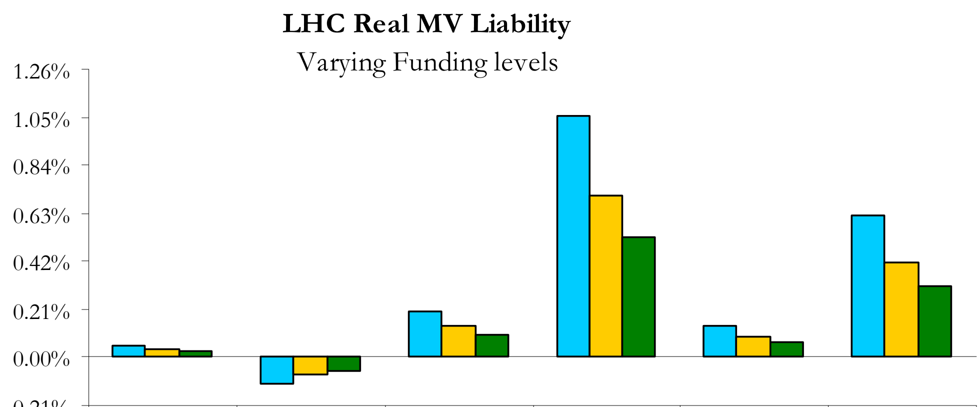
	Direct Real Estate (MIT TBI)	*Stock (MSCI)*	*Real Estate Stock (GPR)*	*20-Year Treasury Bond*	*Moody's Seasoned Aaa Corporate Bond*	*Duration matched portfolio*	*Liability Actuarial*	*Nominal Liability (MV)*	*Real Liability (MV)*
Direct Real Estate (MIT TBI)	1.00								
Stock (MSCI)	-0.13	1.00							
Real Estate Stock (GPR)	0.01	0.55	1.00						
20-Year Treasury Bond	0.01	-0.13	0.08	1.00					
Moody's Seasoned Aaa Corporate Bond	-0.03	-0.16	-0.11	0.12	1.00				
Duration matched portfolio	-0.04	-0.21	0.02	0.92	0.37	1.00			
Liability Actuarial	-0.06	-0.17	-0.13	-0.13	0.21	-0.04	1.00		
Nominal Liability (MV)	0.05	-0.06	0.11	0.85	0.34	0.79	-0.14	1.00	
Real Liability (MV)	0.07	-0.08	0.12	0.85	0.32	0.79	-0.15	0.99	1.00
Active Liability (MV)	0.02	0.12	-0.04	-0.20	0.17	-0.13	0.97	-0.18	-0.20

Figure 1: Actuarial and Market value Liability Hedge Credit (LHC) per asset class

The liability hedge credit (LHC) quantifies the annualized utility that investors with liabilities can derive from different asset classes. LHC is positively related to the covariance of an asset and the liability and to the current assets to current liabilities (L_0/A_0), while inversely related to the risk tolerance (λ). LHC further depends on the weight of importance attached to it (k), full consideration of liabilities (k=1) yields similar results as surplus optimization, while no consideration (k=0) provides the same results as an asset only methodology. The following graphs depict LHC's for the actuarial and the market value of liabilities. We proxy the actuarial changes using the changes related to the value of projected pension obligations (PBOs). For the analysis of the market value of liability changes we assume that the return on liabilities follows the return of the long-term constant maturity bond, estimated over the 1984 to 2008 period. The market value of liabilities is solely influenced by changes in interest rates and inflation. The liability return is derived as a function of the log yield of the constant maturity bond, assuming duration of 17 years, the average duration of pension liabilities. Real Liabilities are adjusted for inflation and interest rate risk.



	Direct Real Estate (MIT TBI)	Stock (MSCI)	Real Estate Stock (GPR)	20-Year Treasury Bond	Moody's Seasoned Aaa Corporate	Duration matched fixed income
L/A=1.5 k=1 λ=5	-0.0183%	-0.1169%	-0.0966%	-0.0674%	0.0246%	-0.0140%
L/A=1 k=1 λ=5	-0.0122%	-0.0780%	-0.0644%	-0.0450%	0.0164%	-0.0093%
L/A=0.75 k=1 λ=5	-0.0091%	-0.0585%	-0.0483%	-0.0337%	0.0123%	-0.0070%

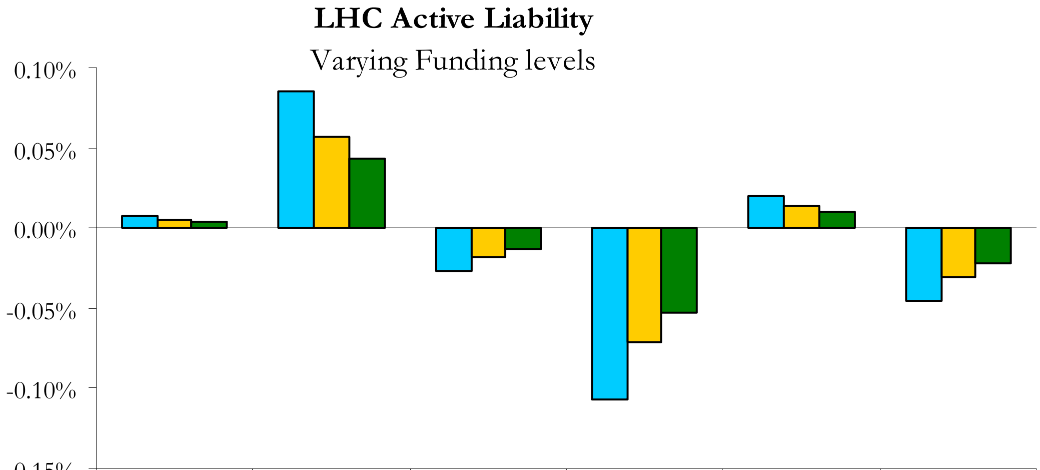


	Direct Real Estate (MIT	Stock (MSCI)	Real Estate Stock (GPR)	20-Year Treasury Bond	Moody's Seasoned Aaa	Duration matched fixed
L/A=1.5 k=1 λ=5	0.0505%	-0.1174%	0.2025%	1.0545%	0.1401%	0.6173%
L/A=1 k=1 λ=5	0.0336%	-0.0783%	0.1350%	0.7030%	0.0934%	0.4115%
L/A=0.75 k=1 λ=5	0.0252%	-0.0587%	0.1013%	0.5272%	0.0701%	0.3087%

L/A=1.5 k=1 λ=5 L/A=1 k=1 λ=5 L/A=0.75 k=1 λ=5

Figure 2: Active Liability Hedge Credit (LHC) per asset class

The liability hedge credit (LHC) quantifies the annualized utility that investors with liabilities can derive from different asset classes. LHC is positively related to the covariance of an asset and the liability and to the current assets to current liabilities (L_0/A_0), while inversely related to the risk tolerance (λ). LHC further depends on the weight of importance attached to it (k), full consideration of liabilities (k=1) yields similar results as surplus optimization, while no consideration (k=0) provides the same results as an asset only methodology. The following graphs depict LHC's for active liabilities. We compute the return of active liabilities by adding wage increases to the real liability returns, the data on wage growth was obtained using the national average wage index: http//www.ssa.gov.



	Direct Real Estate (MIT TBI)	Stock (MSCI)	Real Estate Stock (GPR)	20-Year Treasury Bond	Moody's Seasoned Aaa Corporate	Duration matched fixed income
L/A=1.5 k=1 λ=5	0.0077%	0.0856%	-0.0273%	-0.1066%	0.0204%	-0.0449%
L/A=1 k=1 λ=5	0.0051%	0.0571%	-0.0182%	-0.0711%	0.0136%	-0.0299%
L/A=0.75 k=1 λ=5	0.0039%	0.0428%	-0.0136%	-0.0533%	0.0102%	-0.0225%

L/A=1.5 k=1 λ=5 L/A=1 k=1 λ=5 L/A=0.75 k=1 λ=5

Table 4: Actuarial vs Market Value ALM allocations

Table 4 displays the optimal portfolio allocations for both the asset only as the ALM model. Portfolios were derived using historical return and risk characteristics (1984-2008). Furthermore we use different classifications of the liability return, both actuarial and the market value of liabilities. We proxy the actuarial changes using the changes related to the value of projected pension obligations (PBOs). For the analysis of the market value of liability changes we assume that the return on liabilities follows the return of the long-term constant maturity bond, estimated over the 1984 to 2008 period. The market value of liabilities is solely influenced by changes in interest rates and inflation. The liability return is derived as a function of the log yield of the constant maturity bond, assuming duration of 17 years, the average duration of pension liabilities. Real Liabilities are adjusted for inflation and interest rate risk. We decompose the nominal yield into a real yield and inflation compensation, where the inflation compensation reflects expected inflation (π_{t+1}) and an inflation risk premium, which for reasons of simplicity we assume constant. We further assume that inflation expectation follows a fourth order autoregressive function. For the definition of active liabilities we partition from wage increases, the data on wage growth was obtained using the national average wage index: http//www.ssa.gov. The fixed income portfolio includes a Moody's Seasoned Aaa Corporate Bond, a 20 year Treasury bond and a duration matched portfolio. The duration matched bond portfolio was constructed using the two fixed income asset classes to match the duration of the market value of real pension liabilities.

	Portfolios							Changes in Allocations			
Asset-Only	Minimum Variance	Tangency	1	2	3	4	5	Δ wrt Asset only	Δ wrt Actuarial liabities	Δ wrt Nominal liabities	Δ wrt Real liabities
Er	8.98%	9.07%	9.28%	9.41%	9.51%	9.61%	9.70%				
Stdev	3.43%	3.47%	3.81%	4.16%	4.51%	4.85%	5.20%				
Asset-Only											
Direct Real Estate (MIT TBI)	24.99%	23.38%	19.71%	17.56%	15.60%	14.13%	12.62%				
Stock (MSCI)	9.51%	11.10%	14.73%	16.87%	18.62%	20.24%	21.71%				
Real Estate Stock (GPR)	0.68%	2.26%	5.83%	7.97%	9.74%	11.30%	12.78%				
Fixed Income	64.82%	63.26%	59.73%	57.60%	56.04%	54.33%	52.88%				
ALM (L/A=1 k=1 λ=5)											
Actuarial Liabilitites											
Direct Real Estate (MIT TBI)	24.99%	23.38%	19.32%	16.95%	15.09%	13.38%	11.70%	-			
Stock (MSCI)	9.51%	11.10%	14.62%	16.64%	18.39%	19.95%	21.35%	-			
Real Estate Stock (GPR)	0.68%	2.26%	5.96%	8.22%	10.02%	11.64%	13.18%	+			
Fixed Income	64.82%	63.26%	60.10%	58.18%	56.51%	55.03%	53.77%	+			
MV Nominal Liabilities											
Direct Real Estate (MIT TBI)	23.61%	22.90%	18.62%	16.05%	13.89%	11.91%	10.17%	-	-		
Stock (MSCI)	10.91%	11.09%	13.86%	15.58%	17.10%	18.47%	19.67%	-	-		
Real Estate Stock (GPR)	1.83%	2.30%	5.54%	7.58%	9.21%	10.67%	12.10%	-	-		
Fixed Income	63.65%	63.71%	61.98%	60.79%	59.81%	58.95%	58.07%	+	+		
MV Real Liabilities											
Direct Real Estate (MIT TBI)	23.65%	22.96%	18.83%	16.30%	14.16%	12.35%	10.65%	-	-	+	
Stock (MSCI)	10.89%	11.07%	13.78%	15.58%	17.07%	18.33%	19.52%	-	-	-	
Real Estate Stock (GPR)	1.86%	2.34%	5.62%	7.63%	9.29%	10.85%	12.28%	-	-	+	
Fixed Income	63.59%	63.62%	61.77%	60.48%	59.47%	58.47%	57.56%	+	+	-	
MV Active Liabilities											
Direct Real Estate (MIT TBI)	23.85%	23.21%	19.65%	17.54%	15.66%	13.97%	12.67%	+	+	+	+
Stock (MSCI)	11.35%	11.63%	14.99%	17.23%	19.11%	20.82%	22.47%	+	+	+	+
Real Estate Stock (GPR)	1.88%	2.41%	5.68%	7.76%	9.46%	10.95%	12.31%	-	-	+	+
Fixed Income	62.91%	62.75%	59.67%	57.47%	55.77%	54.26%	52.56%	-	-	-	-

Figure 3: Efficient frontiers

Figure 3 depicts the efficient combinations of portfolios for different classifications of liability returns. We proxy the actuarial changes using the changes related to the value of projected pension obligations (PBOs). For the analysis of the market value of liability changes we assume that the return on liabilities follows the return of the long-term constant maturity bond, estimated over the 1984 to 2008 period. The market value of liabilities is solely influenced by changes in interest rates and inflation. The liability return is derived as a function of the log yield of the constant maturity bond, assuming duration of 17 years, the average duration of pension liabilities. Real Liabilities are adjusted for inflation and interest rate risk. We decompose the nominal yield into a real yield and inflation compensation, where the inflation compensation reflects expected inflation (π_{t+1}) and an inflation risk premium, which for reasons of simplicity we assume constant. We further assume that inflation expectation follows a fourth order autoregressive function.

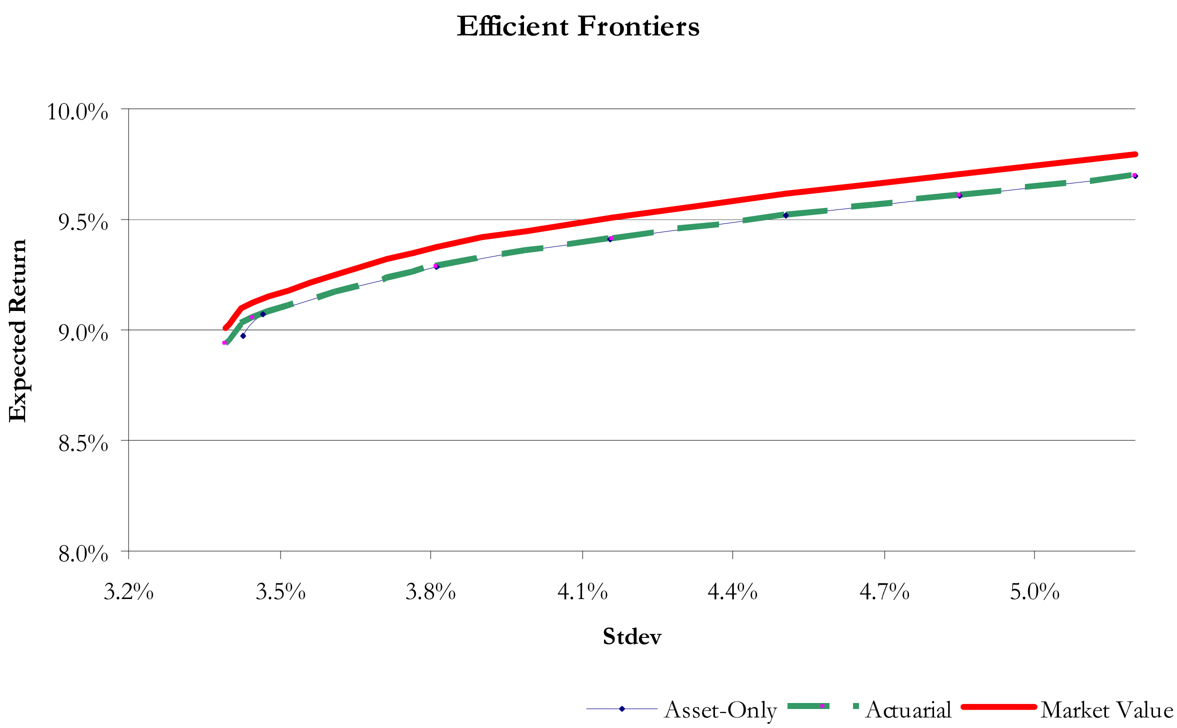


Table 5: Sensitivity analysis ALM Allocations

Portfolios were derived using historical return and risk characteristics (1984-2008). The tangency portfolio represents the optimal Sharpe portfolio that optimizes the mean excess return divided by the standard deviation of returns. Portfolio compositions for five portfolios along the efficient frontier are also given. Portfolio weights are determined by maximizing the objective function given the standard deviation of the asset only portfolios. The ALM portfolio parameters are the inverse funding level, the current liability to current asset level (L_0/A_0), risk tolerance (λ) and the weight of importance attached to liabilities (k), full consideration of liabilities (k=1) yields similar results as surplus optimization, while no consideration (k=0) provides the same results as an asset only methodology. For the analysis of the market value of liability changes we use real liabilities as adjusted for inflation and interest rate risk.

			Portfolio Weights				
Portfolios	Er	Std. Dev.	Direct Real Estate (MIT TBI)	Stock (MSCI)	Real Estate Stock (GPR)	Fixed Income	Total Real Estate
ALM Allocations (Real Liabilities)							
L/A=1.5 k=1 λ=5							
Minimum Variance	9.16%	3.43%	23.59%	10.44%	1.87%	64.09%	25.47%
Tangency	9.21%	3.47%	22.86%	10.92%	2.29%	63.93%	25.14%
1	9.45%	3.81%	18.60%	13.30%	5.43%	62.67%	24.03%
2	9.58%	4.16%	15.94%	14.84%	7.40%	61.82%	23.34%
3	9.70%	4.51%	13.80%	16.17%	8.99%	61.04%	22.79%
4	9.80%	4.85%	11.75%	17.29%	10.44%	60.52%	22.19%
5	9.89%	5.20%	10.11%	18.47%	11.76%	59.66%	21.87%
L/A=1 k=1 λ=5							
Minimum Variance	9.10%	3.43%	23.65%	10.89%	1.86%	63.59%	25.51%
Tangency	9.15%	3.47%	22.96%	11.07%	2.34%	63.62%	25.31%
1	9.38%	3.81%	18.83%	13.78%	5.62%	61.77%	24.44%
2	9.51%	4.16%	16.30%	15.58%	7.63%	60.48%	23.93%
3	9.62%	4.51%	14.16%	17.07%	9.29%	59.47%	23.45%
4	9.71%	4.85%	12.35%	18.33%	10.85%	58.47%	23.20%
5	9.80%	5.20%	10.65%	19.52%	12.28%	57.56%	22.92%
L/A=0.5 k=0.5 λ=5							
Minimum Variance	9.02%	3.43%	24.45%	11.94%	0.51%	63.11%	24.96%
Tangency	9.07%	3.47%	23.17%	11.30%	2.42%	63.11%	25.59%
1	9.28%	3.81%	19.44%	14.51%	5.82%	60.22%	25.26%
2	9.41%	4.16%	17.15%	16.53%	7.95%	58.36%	25.11%
3	9.51%	4.51%	15.06%	18.34%	9.59%	57.01%	24.65%
4	9.59%	4.85%	13.48%	19.87%	11.18%	55.47%	24.67%
5	9.68%	5.20%	11.90%	21.21%	12.70%	54.19%	24.60%
L/A=0.5 k=0.5 λ=10							
Minimum Variance	9.03%	3.43%	23.85%	11.12%	1.90%	63.14%	25.75%
Tangency	9.07%	3.47%	23.26%	11.39%	2.42%	62.92%	25.69%
1	9.28%	3.81%	19.59%	14.61%	5.84%	59.95%	25.44%
2	9.41%	4.16%	17.35%	16.72%	7.95%	57.98%	25.30%
3	9.51%	4.51%	15.53%	18.48%	9.69%	56.30%	25.22%
4	9.60%	4.85%	13.88%	20.02%	11.29%	54.82%	25.17%
5	9.68%	5.20%	12.26%	21.49%	12.73%	53.53%	24.98%

Table 6: Asset only versus ALM allocations (Indirect Real Estate)

Portfolios were derived using historical return and risk characteristics (1984-2008). The opportunity set of available real estate assets is restricted to indirect real estate solely. Stock returns are based on MSCI indices, and indirect real estate returns are based on GPR indices. The fixed income assets consist of a 20-year Treasury bond (effective duration 10 years) and Moody's Seasoned Aaa Corporate Bond (effective duration 7 years) and a duration matched portfolio. The duration matched bond portfolio was constructed using the two fixed income asset classes to match the duration of the market value of real pension liabilities. Furthermore we use different classifications of the liability return, both actuarial and the market value of liabilities. We proxy the actuarial changes using the changes related to the value of projected pension obligations (PBOs). For the analysis of the market value of liability changes we assume that the return on liabilities follows the return of the long-term constant maturity bond, estimated over the 1984 to 2008 period. The market value of liabilities is solely influenced by changes in interest rates and inflation. The liability return is derived as a function of the log yield of the constant maturity bond, assuming duration of 17 years, the average duration of pension liabilities. Real Liabilities are adjusted for inflation and interest rate risk. We decompose the nominal yield into a real yield and inflation compensation, where the inflation compensation reflects expected inflation ($\pi t+1$) and an inflation risk premium, which for reasons of simplicity we assume constant. We further assume that inflation expectation follows a fourth order autoregressive function.

	Portfolios							Changes in Allocations		
Asset-Only	Minimum Variance	Tangency	1	2	3	4	5	Δ wrt Asset only	Δ wrt Actuarial	Δ wrt Nominal
Er	9.08%	9.20%	9.44%	9.58%	9.70%	9.80%	9.90%			
Stdev	4.04%	4.10%	4.51%	4.92%	5.33%	5.74%	6.15%			
Asset-Only										
Stock (MSCI)	9.80%	11.93%	16.19%	18.76%	20.90%	22.84%	24.60%			
Real Estate Stock (GPR)	2.79%	4.75%	8.65%	11.02%	13.02%	14.76%	16.40%			
Fixed Income	87.41%	83.32%	75.17%	70.22%	66.08%	62.40%	58.99%			
ALM (L/A=1 k=1 λ=5)										
Actuarial Liabilities				*Portfolio Weights*						
Stock (MSCI)	11.36%	12.41%	16.11%	18.39%	20.23%	22.04%	23.64%	-		
Real Estate Stock (GPR)	3.72%	4.26%	6.93%	8.65%	10.09%	11.33%	12.47%	-		
Fixed Income	84.92%	83.34%	76.96%	72.96%	69.68%	66.63%	63.89%	+		
MV Nominal Liabilities				*Portfolio Weights*						
Stock (MSCI)	10.67%	11.59%	15.18%	17.39%	19.21%	20.87%	22.28%	-	-	
Real Estate Stock (GPR)	3.39%	4.62%	8.28%	10.42%	12.31%	13.88%	15.52%	-	+	
Fixed Income	85.95%	83.78%	76.53%	72.19%	68.48%	65.25%	62.19%	+	-	
MV Real Liabilities				*Portfolio Weights*						
Stock (MSCI)	10.80%	11.57%	15.09%	17.24%	19.00%	20.59%	22.04%	-	-	-
Real Estate Stock (GPR)	3.47%	4.65%	8.38%	10.61%	12.48%	14.15%	15.77%	-	+	+
Fixed Income	85.73%	83.78%	76.53%	72.15%	68.52%	65.26%	62.19%	+	-	+