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Research informatie

Thema	Asset-allocatie
Titel	Incorporating uncertainty about alternative assets in strategic pension fund asset allocation
Auteur	Wilma de Groot, Laurens Swinkels
Datum	2008
Taal	Engels

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30 November 2007

Pension Research Center

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1 Introduction

Recent developments in regulation require pension funds to perform strategic and tactical asset allocation decisions while taking into account their pension liabilities. Sharpe and Tint (1990) show how portfolio theory can be adapted when liabilities enter the portfolio choice problem. The portfolio weights that result in this framework are highly depending on the expected returns that are used as an input for this model. This is an important reason why the framework has not been very popular amongst practitioners. In this article we describe a robust method for asset allocation that takes into account uncertainty about the expected returns on different asset classes and takes into account pension liabilities. We apply this method to a UK pension fund that contemplates investing in alternative assets such as emerging markets equity, real estate, hedge funds, private equity, and commodities.

2 Framework

Nowadays it is common to use quantitative techniques to support strategic asset allocation decisions made by institutional investors. The use of standard portfolio optimisation models typically lead to unrealistic high allocations to alternative assets. This problem was already described by Michaud (1989) and Best and Grauer (1991). The framework including uncertainty on expected returns that Black and Litterman (1992) introduced, circumvented this problem to a large extent and has therefore often been applied in practice. In this article we apply their technique in an asset-liability-management framework. This way we extend the surplus optimization framework originally described in Sharpe and Tint (1990). They define the surplus as:

$$S_t\left(\tilde{k}\right)=A_t-\tilde{k}\times L_t$$

with A_t the value of the assets and L_t the value of the pension liabilities at time t. The parameter $\tilde{k}$ denotes the importance of the liabilities in the portfolio choice problem. For $\tilde{k}=0$ we are back in an asset-only framework, while with $\tilde{k}=1$ we speak about full surplus optimization. The return on the surplus is then defined as

$$R_t^S\left(k\right)=R_t^A-k\times R_t^L$$

with R_t^A the return on the assets, R_t^L the return on the liabilities, and k again a parameter denoting the importance of the pension liabilities. In this article we assume a pension fund with full surplus optimization, i.e. k =1.[1] This coincides with the use of the *funding ratio return* as introduced by Leibowitz, Kogelman, and Bader (1994).

Pension funds or their advisors often start their strategic asset allocation with a set of expected returns, risks, and correlations, often based on historical data or economic theory. If the strategic asset allocation that comes out of the standard portfolio optimization is much different than expected, it is not uncommon to change the set of expected returns or introduce restrictions on the portfolio weights to arrive at a strategic

[1] The parameter k equals $\tilde{k}$ divided by the funding ratio on time *t-1*.

asset allocation that is "more realistic" and "acceptable" to the pension fund board of trustees.

Our approach allows a more systematic way of thinking about strategic asset allocation in an asset-liability-management context by introducing uncertainty about the expected returns on asset class returns. The core idea is that pension fund boards are uncertain about past average returns being representative for the future when the investment manager shows that an allocation to the alternative asset he offers improves the risk-return profile of the asset portfolio. Including pension liabilities and uncertainty in the expected asset returns as we do in this article can be useful to take this scepticism into account in a systematic way.

The first step in the analysis is assuming that the current strategic asset allocation is optimal and we derive the expected returns that are consistent with this choice. In order to take the liabilities into account we do not model the absolute returns of asset classes, but use the excess return of the asset class with respect to the pension liabilities and use the covariance matrix of these excess returns. This implies that liability matching assets are less risky, because they reduce the risk in the funding ratio.

The second step in the analysis is to introduce the alternative assets that we would like to include in our strategic asset allocation and formulate the expected return on these alternative asset classes, including the level of uncertainty that the pension fund has about this expectation. The optimal strategic asset allocation is then formed by taking a combination of expected returns that are implied by the current allocation (step one) and the new expected returns (step two), in which the level of uncertainty determines the tilt to either side. We apply this methodology to a UK pension fund that considers investing in alternative assets such as emerging markets equity, real estate, hedge funds, private equity, and commodities.

3 Should pension funds include alternative assets?

In this section we analyse the question how much to invest in alternative assets such as emerging markets, real estate, hedge funds, private equity, and commodities for a UK pension fund with inflation-protected liabilities. We assume this pension fund currently has a strategic allocation to UK government bonds of 50%, to global equities of 37%, to emerging markets of 3% and to real estate of 10%.

The data we use for this analysis are obtained from Thomson Financial Datastream on a quarterly basis over the period January 1994 – June 2007. The return on the pension liabilities are proxied by long-term UK inflation-linked bonds for which we take the Barclays UK Govt Inflation Linked >10yrs index. For cash we use the JP Morgan UK 3M Cash, for UK bonds the JP Morgan UK government bond return index, for global equities the total return on the MSCI World index (hedged). For the alternative assets we use the following indices: for emerging markets the IFC/S&P Emerging Markets, for real estate the GPR General Global, for hedge funds the CSFB/Tremont HFR index (hedged), for private equity the Venture Economics index[2] (hedged), and for commodities the GSCI (hedged).

[2] US and Europe all private equity data are directly collected from Venture Economics and combined in a global index (70% US and 30% Europe)

Descriptive statistics on these asset classes are presented in Table 1. We see that cash and nominal bond investments had a lower return than that on the pension liabilities, indicating that real interest rates have decreased over time. Equities show a considerably higher average return of 5.36% over cash, while emerging markets have a more difficult period with an average return equal to cash. Emerging markets are on average more risky, with a volatility of 27.6%. The other alternative assets show excess returns varying between 1.04% for real estate and even 10.58% for private equity. Notice that the realized return of hedge funds and private equity in this period is higher than equities, while the volatility is even lower than equities, which results in high Sharpe ratios for these asset classes. Several academic studies, e.g. Phalippou and Gottschalg (2007) and Driessen, Lin, and Phalippou (2007), indicate that performance and risk estimates of private equity are biased in these indices. Agarwal and Naik (2004) and Amin and Kat (2003) suggest that historical returns and volatilities of hedge funds have several biases, which cause these statistics to be too optimistic.

Table 1: Annualised statistics Jan 1994 - Jun 2007

	Liabilities	Cash	Bonds	Equities	Emerging mkts	Real Estate	Commodities	Hedge Funds	Private Equity
Return	6.59%	5.70%	6.08%	11.06%	5.67%	6.74%	9.29%	12.43%	16.29%
Excess return	0.89%	0.00%	0.37%	5.36%	-0.03%	1.04%	3.59%	6.72%	10.58%
Volatility	6.0%	0.6%	5.5%	15.5%	27.6%	13.7%	19.4%	7.8%	9.9%
Sharpe ratio	0.15	0.00	0.07	0.35	0.00	0.08	0.18	0.86	1.07

The correlations between these asset classes can be found in Table 2. The correlation between bonds and pension liabilities is high with 0.75. The alternative assets show a high correlation with equities, e.g. the correlation between emerging and developed equities is 0.71. The only exception is commodities with low or sometimes even negative correlations. The correlation between bonds and equities is slightly negative, and we also see that equities do not offer strong protection against pension liability risk in the short run with a correlation of 0.27.

Table 2: Correlation matrix Jan 1994 – Jun 2007 (%)

	Liabilities	Cash	Bonds	Equities	Emerging mkts	Real Estate	Commodities	Hedge Funds	Private Equity
Liabilities	100								
Cash	27	100							
Bonds	75	42	100						
Equities	27	6	-8	100					
Emerging mkts	8	-29	-24	71	100				
Real Estate	13	-25	-6	49	66	100			
Commodities	-27	-22	-19	-12	-1	2	100		
Hedge Funds	28	3	11	62	46	25	4	100	
Private Equity	16	25	-8	65	37	14	9	61	100

We calibrate the risk aversion of the pension fund such that the equity premium above the pension liabilities equals 3%. The first line in Table 3 indicates the implied expected returns by the pension fund we consider in this article. As a sensitivity analysis, we also show implied expected returns for different strategic asset allocations in the rows below.

Table 3: Implied expected returns above liabilities for different allocations

	Cash	Bonds	Equities	Emerging mkts	Real Estate	Commodities	Hedge Funds	Private Equity
Asset allocation	0%	50%	37%	3%	10%	0%	0%	0%
Implied return	0.40%	-0.04%	3.00%	4.60%	2.11%	0.68%	1.16%	1.38%
Asset allocation	0%	50%	37%	3%	0%	10%	0%	0%
Implied return	0.54%	0.05%	2.68%	3.89%	1.66%	2.02%	1.23%	1.51%
Asset allocation	0%	50%	37%	3%	0%	0%	10%	0%
Implied return	0.40%	-0.02%	2.90%	4.10%	1.58%	0.67%	1.26%	1.46%
Asset allocation	0%	50%	37%	3%	0%	0%	0%	10%
Implied return	0.41%	-0.03%	2.98%	4.10%	1.56%	0.72%	1.23%	1.64%
Asset allocation	0%	40%	47%	3%	10%	0%	0%	0%
Implied return	0.40%	-0.16%	3.80%	5.70%	2.46%	0.63%	1.39%	1.71%
Asset allocation	0%	60%	37%	3%	0%	0%	0%	0%
Implied return	0.37%	0.03%	2.59%	3.62%	1.44%	0.55%	1.04%	1.26%
Asset allocation	0%	50%	32%	8%	10%	0%	0%	0%
Implied return	0.41%	-0.07%	3.12%	5.35%	2.37%	0.75%	1.22%	1.40%

The implied expected returns on most of the alternative investments are low, because in the table not much weight is allocated to these asset classes. Only for emerging markets the implied expected return is higher than equities, because although volatility is high, the pension fund still invests in this asset class. Note that the implied expected return on emerging markets equity is substantially higher than the realized past return on this asset class we saw in Table 1. The implied expected returns of cash, hedge funds and private equity are low because we do not allocate to these asset classes although volatility is low. The low volatility is also the reason why the implied returns do not change much when we allocate 10%. The reason that the implied expected return for commodities is low are the low correlations with the other asset classes. This is an important reason to invest more in this asset class. Although the average allocation to bonds in Table 3 is 50%, the implied expected excess return is around 0%. This is consistent with the view that expected returns on nominal and inflation-linked bonds are the same, or stated differently, the inflation-risk premium is very small.

In the first stage of our analysis we consider each of the five alternative assets in isolation. In the second stage we investigate the inclusion of all five together. In Table 4 we show for every asset class in the left column the optimal portfolio weight according to the standard portfolio optimization as introduced by Sharpe and Tint (1990) as a function of the expected return on the alternative asset. In the right column we show the optimal portfolio weights that are obtained when including uncertainty around the expected return.

For the non-alternative asset classes we take the uncertainty as a function of the volatility of the asset class (as proposed by He and Litterman 1999). For the alternative asset classes we use a different methodology. In Table 1 we showed that the volatility of several alternative assets is low. When we would take the volatility as a measure for uncertainty in the expected returns, we would implicitly assume that we have more confidence in the expected return of these asset classes than in the expected return of equities. However, as we mentioned before, there are reasons to believe that we should be less confident in the historical observations we use for private equity and hedge funds. For this reason we choose to increase the uncertainty of the alternative assets and use the volatility of emerging markets (the highest) as an indicator for uncertainty for all alternative asset classes that we consider. In practice, the board of trustees of the pension funds can express their own views about uncertainty to find their specific optimal strategic asset allocation.

Table 4 Portfolio weight alternative investments according to standard and robust optimisation depending on the expected excess return (above liabilities) on the alternative asset

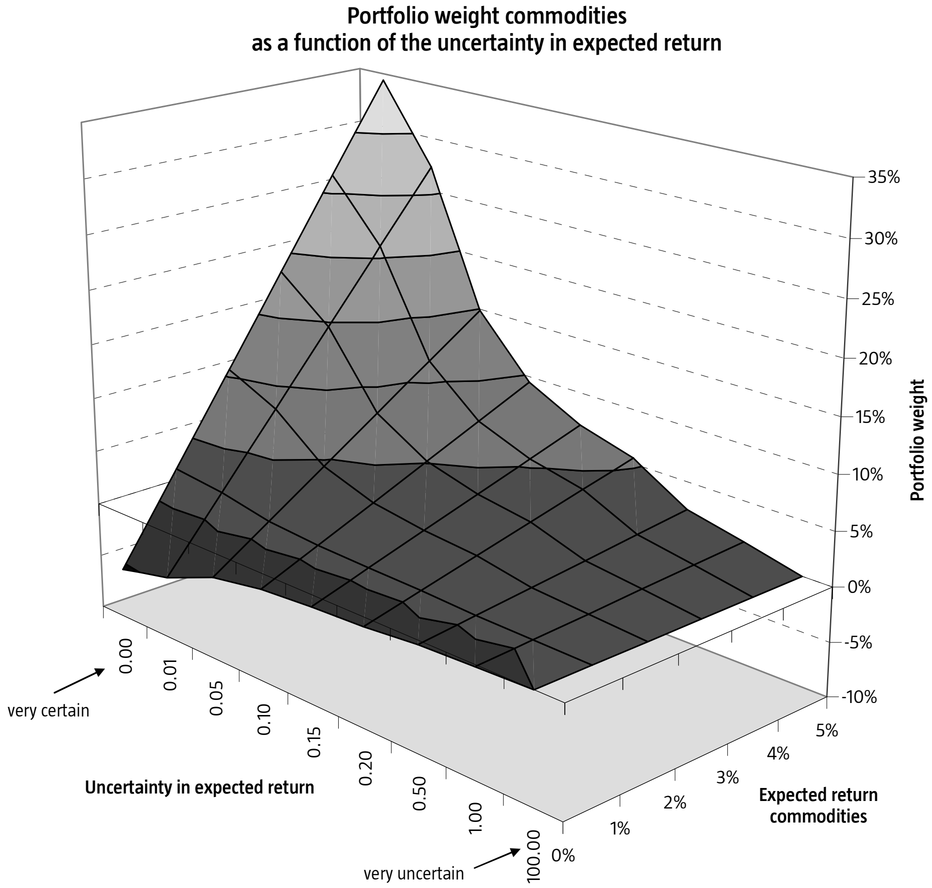
	Portfolio weight									
Expected excess return	Emerging Mkts		Real Estate		Commodities		Hedge Funds		Private Equity	
alternative asset	Standard	Robust	Standard	Robust	Standard	Robust	Standard	Robust	Standard	Robust
0%	-56.3%	-8.2%	-57.3%	2.9%	-6.6%	-1.8%	-121.8%	-4.4%	-102.4%	-5.0%
1%	-43.4%	-5.7%	-25.4%	6.3%	3.1%	0.8%	-16.9%	-0.6%	-28.0%	-1.4%
2%	-30.5%	-3.3%	6.5%	9.6%	12.7%	3.5%	88.0%	3.2%	46.3%	2.3%
3%	-17.6%	-0.9%	38.4%	13.0%	22.4%	6.1%	192.9%	6.9%	120.7%	5.9%
4%	-4.7%	1.6%	70.3%	16.4%	32.0%	8.7%	297.7%	10.7%	195.1%	9.5%
5%	8.2%	4.0%	102.2%	19.8%	41.6%	11.3%	402.6%	14.5%	269.5%	13.2%

In Table 4 we clearly see the drawbacks of the standard portfolio optimization. The expected excess return of the alternative asset is very important for the resulting optimal asset allocation. E.g. if we expect an excess return of 2% instead of 1% for hedge funds, this results in an increase in the optimal portfolio weight of more than 100%, from -16.9%

to 88.0%. This is one of the most important reasons why these standard asset allocation models are hardly used in practice. The robust method we describe in this article results in a more useful portfolio advice with an increase in weight of 3%-4% when the expected return of hedge funds increases with 1%.

In Table 4 we assumed that the uncertainty of our expectations on alternative assets is high. We can deviate from this number if we are more or less certain on our return expectations. In Figure 1 we take commodities as an example and show what this means for the final optimal portfolio weight of commodities.

Figure 1: Portfolio weight commodities according to the robust optimisation depending on different levels of expected excess returns on commodities and the uncertainty around these returns



When we are very uncertain about the expected return of commodities, the final portfolio weight will be equal to the strategic allocation of 0%, irrespective of the expected return level. On the other extreme, when we are very certain about the expected return, the portfolio weight varies between -5% and 35%, depending on the expected return of commodities. We find the robust figures reported in Table 4 when we look at the uncertainty axis at 0.076, which is the historical variance of emerging markets equity returns. This means that the expected return and the uncertainty around it determine the deviations in the strategic allocation in the robust model. In Figure 1 we only varied the level of (un)certainty on the expected return of commodities. If we are simultaneously very certain on the expected return of each asset class, we obtain the standard portfolio optimization weights that are shown in Table 4.

Above, we performed an analysis based on the attractiveness of one alternative asset in isolation in the pension fund asset allocation. While this gives insight to the impact of uncertainty on allocation decisions, trustees of pension funds typically need to decide on the total asset allocation including each of the alternatives available to them. Therefore, as a final step in our analysis, we take a holistic view and determine the optimal strategic asset allocation with all five alternative assets. The results from this analysis can be found in Table 5. Again, as an example, we show the optimal portfolio weights for expected excess returns with levels of uncertainty about these expectations that are the same for each asset class. For usual assumptions of a 2%-3% excess return on alternative assets this results in an allocation to alternatives roughly between 15%-30%. As mentioned before, the allocations to each of these individual alternative assets might be different depending on the specific expectations for one asset class relative to the other, or the uncertainty around this expectation.

Table 5 Portfolio weight alternative investments according to standard and robust optimisation depending on the expected excess return (above liabilities) on the alternative assets

Expected excess return	Portfolio weight					
alternative asset	Emerging Mkts	Real Estate	Commodities	Hedge Funds	Private Equity	Alternatives
0%	-6.8%	5.2%	-0.9%	-3.3%	-4.3%	-10.2%
1%	-5.2%	7.9%	1.3%	0.0%	-1.1%	3.0%
2%	-3.5%	10.7%	3.4%	3.3%	2.2%	16.2%
3%	-1.9%	13.5%	5.6%	6.7%	5.5%	29.3%
4%	-0.3%	16.3%	7.8%	10.0%	8.7%	42.5%
5%	1.4%	19.0%	10.0%	13.3%	12.0%	55.7%

4 Conclusions

In this article we present an asset allocation framework that explicitly accounts for the presence of pension liabilities and takes into account uncertainty about alternative assets. This method has the advantage that it arrives at realistic and acceptable strategic asset allocations relative to the standard portfolio optimization models. Hence, this model can be used to guide boards of trustees of pension funds in a more systematic way when determining the asset allocation. The examples presented in this article indicate that with modest expected return assumptions of alternative asset ranging between 2% and 3% above the pension liabilities, the optimal allocation to alternatives ranges between 15% and 30%.

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