

## Can Stocks Help Mend the Asset and Liability Mismatch?

*By*

*Boualem Djehiche<sup>1</sup> and Jonas Rinne<sup>2</sup>*

### Executive summary

*Stocks are generally used to provide higher returns in the long run. But the dramatic fall in equity prices at the beginning of this century, triggering large underfundings in pension plans, raised the question as to whether stocks can really help mend the asset and liability mismatch.*

*This crisis was probably the reason behind the “traffic light rules” recently implemented in some European countries as part of a risk based solvency regulation in which minimum solvency requirements are set so that they must be maintained even in a defined set of stress scenarios.*

*To avoid a temporary asset and liability mismatch dilemma in the future, the bond-like behaviour of pension liabilities encourages fund trustees to abandon the search for active portfolio management and surrender to large investments in bonds at the cost of long periods of poor performance. In the short-term perspective this regime offers a good market for long dated bonds, but in a medium and long-term perspective it is not necessarily a cost efficient solution for sponsors facing substantial increase in pension costs mainly due to a growing ageing population.*

*To understand some aspects of this topical issue, we examine whether existing major equity indexes can help mend the asset and liability mismatch, given a liability profile of a typical pension fund. We also compare the non-market capitalisation weighted equity indexes recently introduced as Research Affiliates Fundamental Indexes (RAFI) with traditional market capitalisation weighted equity indexes, from an asset and liability management perspective.*

*The analysis of the behaviour of the solvency ratio clearly indicates that interest rate sensitive stocks have a larger potential to improve the link between assets and liabilities, but generally at low returns. Compared with market capitalisation weighted equity indexes, RAFI shows a substantially better potential to mend the asset and liability mismatch, while also improving returns.*

---

<sup>1</sup> Department of Mathematics, KTH, Stockholm and IPM Informed Portfolio Management AB, E-mail: boualem.djehiche@ipm.se and boualem@math.kth.se

<sup>2</sup> IPM Informed Portfolio Management AB, E-mail: jonas.rinne@ipm.se

## 1. Introduction

The pension crisis witnessed at the beginning of this century was characterised by a sharp fall in the value of equities triggering a large underfunding in most pension plans. The underfunding is believed to be caused by the aggressive equity allocation implemented by pension funds during the latest bull market in an attempt to reduce pension costs due to e.g. a growing ageing population, at a cost of weaker linkage between assets and liabilities. As a consequence trustees were forced, even by law in some countries, to drastically reduce their equity holdings and invest more in bonds, as they more closely match liability cash flows. This shift caused an extended period of poor performance for many pension funds. As stocks generally display higher returns than bonds many believe that the only way to improve pension fund returns to a level of long term sustainability is to increase the allocation to equities. Hence, which stocks, if any, can best help mend the asset and liability mismatch?

From an asset and liability management perspective, the bond-like nature of liability cash flows indicates that further investigation into the statistical properties of stocks involved in the asset portfolio, beyond the standard mean-variance analysis, is necessary. In particular, stocks that help mend the asset and liability mismatch should have the right dependence structure with bonds under different regimes in the sense that e.g. the correlation between stock prices and long-dated bond yields should be moderate in inflationary regimes and negative in disinflationary regimes. Moreover, they should act as duration "kickers", in the sense that they should provide longer empirical duration, i.e. negative beta in the regression line of the equities' return, against changes of the appropriate bond yield. This type of interest rate sensitivity of stocks in an asset portfolio would improve the link between assets and liabilities and keep the solvency ratio at a better level especially in a low return environment. Assets with these properties constitute a liability benchmark.

In this note we examine whether some existing major stock indexes feature relevant properties from a liability matching perspective. We also compare non-market capitalisation weighted equity indexes, newly introduced as Research Affiliates Fundamental Indexes (RAFI)<sup>3</sup>, with traditional market capitalisation weighted equity indexes, from the ALM perspective described above, given a liability profile of an existing pension fund.

To keep the exposition simple, we do not consider the much more complicated liability profile of a pool of insurance contracts, as this will end up with valuing all the underlying embedded options, making the study technically much more involved. The same results should apply to insurance companies.

---

<sup>3</sup> Research Affiliates Fundamental Indices (RAFI) is a new family of non-market capitalisation weighted equity indices, where the selection and weighting of companies are based on fundamental measures of size such as sales, cash flow, book value and dividends. Several articles have examined their retrospective returns and found that they beat the leading market cap-weighted indices in all 23 of the world's leading equity markets by well over 2% per annum on average over the past 20 years. Some of these articles also explain the theoretical reasons why fundamental indices should outperform market capitalisation weighted indices. We will not review the construction and properties of RAFI; instead, we refer to Arnott *et al.* (2005), Treynor (2005) and Hsu (2005) and the references therein, for a detailed exposition.

## 2. Statistical properties of the returns from an ALM perspective

In this section we highlight some statistical properties of the RAFI, S&P and MSCI returns which are useful from an ALM perspective. These include the tail behaviour, drawdown and interest rate sensitivity measured in terms of correlation and empirical duration with respect to a pension fund's liability cash flows. As in most cases these cash flows are proprietary and since they behave more like longer and amortising bonds, we consider government bonds as a good proxy to investigate the dependence between the liabilities and stock indexes.

Due to the quality of the available historical data and to ease the comparison between the different markets, the interest rate sensitivity analysis of stock returns is conducted using the US 10 year Treasury Notes for the US and World ex Japan markets, the German 10 year Bunds for the Euro-zone and Swedish 10 year Government Bonds for the Swedish market.

### a) Tail behaviour and draw downs

Concurrence of extreme negative events determines the size of the drawdown. A way to quantify this effect is to find a model that describes the behaviour of the individual return distributions. An efficient way to fit the return distribution to known probability distribution is to use the so-called quantile-quantile (qq)-plot; we compare the returns with different distributions by plotting their quantiles against the quantiles of these distributions. Table 1 below shows a good fit of the monthly returns distributions with the centred symmetric *student t(df)*-distributions with *df* degrees of freedom. When *df* is less or equal 2, the underlying *t*-distribution is fat-tailed with infinite variance. If *df* is infinite, the *t*-distribution becomes Gaussian. The tail dependence coefficient between two streams of returns is another measure that catches the dependence between returns in the tails, beyond the range of the linear correlation. It is a very useful measure to forecast a possible "perfect storm" scenario, where non-priced risks occur at the same time. However, it cannot estimate size of the losses that occur simultaneously. As is the case for the correlation, in a well diversified portfolio, the tail dependence coefficient between the underlying assets should be low.

For the US-market, the monthly returns of RAFI and S&P 500 have about the same probability distribution: a *t(5)*-distribution which is fat-tailed with finite variance. This distribution is not very different from the distribution of the monthly returns 10Y bond. Their tail dependence coefficient is about 80%. This means that if one stream of returns generates a loss in one month, the probability that the other stream of returns generates a loss is about 80%, as also shown in Figure 3, over the 10 largest draw downs that occurred during the period 1962-2005. We also note the systematic and statistically significant larger size of the draw downs of the cap-weighted indexes compared to RAFI, over the five markets as also noticed for example in Treynor (2005). For the Swedish market, the distribution of RAFI's returns has sensibly lighter tails than the corresponding distribution of the returns of MSCI Sweden, while the tail dependence coefficient is about 70%.

Market	Degree of freedom (df)			Tail dependence coef. between RAFI and cap-weighted index
	RAFI	Cap-weighted index	10Y Govt. bond	
USA	5.16	5.61	6.05	81 %
UK	3.67	3.36	15.81	72 %
Japan	9.69	12.71	3.10	79 %
Euro zone	4.03	4.28	9.11	76 %
Sweden	5.06	3.82	8.81	70 %
World ex Japan	4.07	5.69	-	77%

Table 1. Monthly return distributions fitted to student *t(df)*-distributions with *df* degrees of freedom.

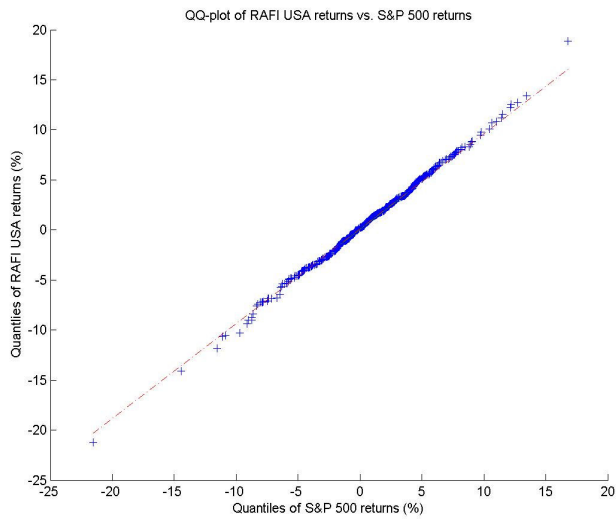


Figure 1. Quantile-quantile plots of RAFI USA versus S&P 500 returns in the period Jan-1962 - Dec-2005.

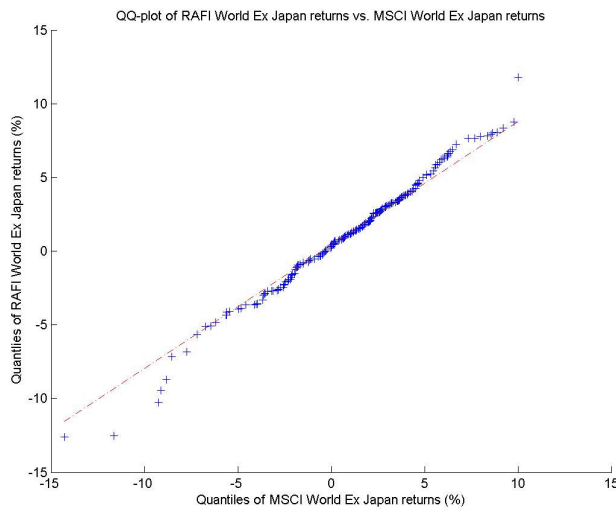


Figure 2. Quantile-quantile plots of RAFI World ex Japan versus MSCI World ex Japan returns in the period Jan-1988 - Jul-2006.

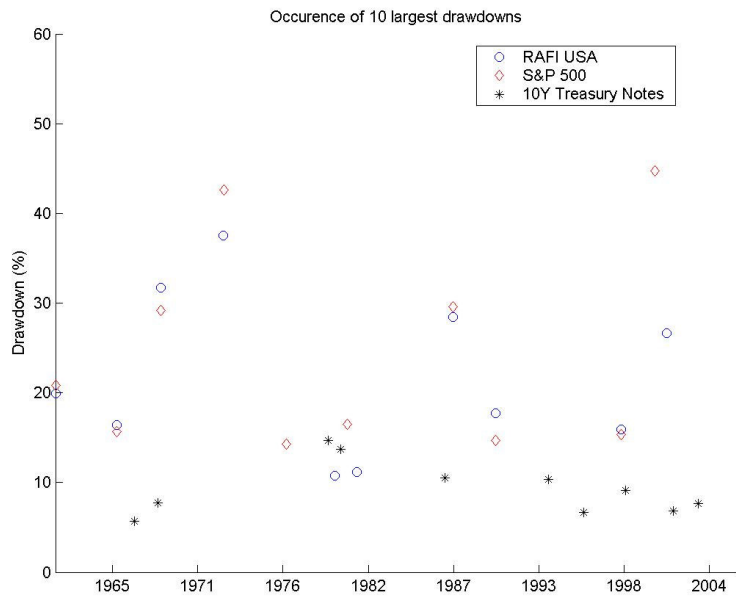


Figure 3. Occurrence of the 10 largest draw downs for RAFI USA, S&P 500 and US 10Y Treasury Notes.

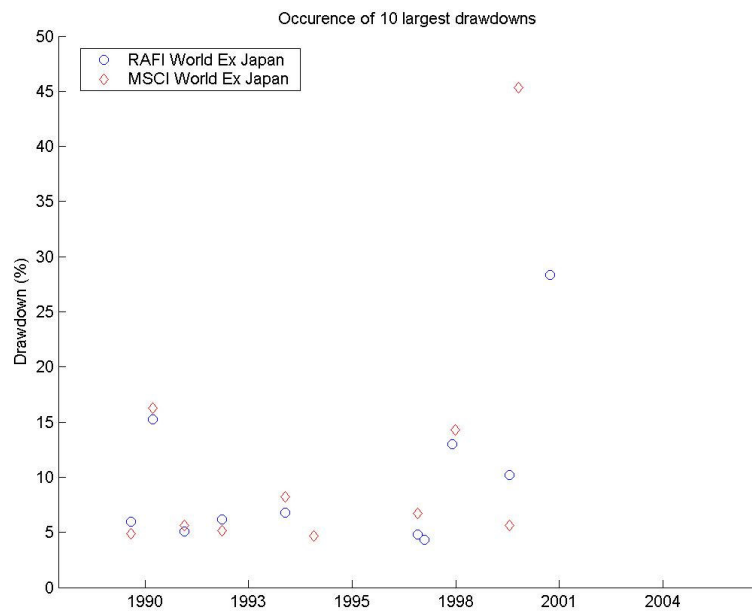


Figure 4. Occurrence of the 10 largest draw downs for RAFI™ World ex Japan and MSCI World ex Japan.

## b) Interest rate sensitivity of equity markets

Interest rate sensitivity of equity indexes is measured in terms of correlation and empirical duration with respect to a pension fund's liability cash flows or a good proxy such as government bonds. The empirical duration is the negative beta in the regression line of the stocks' returns, against the changes of the appropriate bond yield (see Leibowitz (1986) for further details).

The correlations and empirical durations presented in Table 2 below are obtained using yearly returns for the US, Euro Zone, Sweden and World ex Japan. In the case of the US, the analysis covers the period between 1962 and 2005. For the Euro Zone, we consider the period 1988-2005 and for Sweden, we examine the period 1984-2005, whereas for World ex Japan, the period 1988-2005 is analysed. The fact that these indexes have an average empirical duration larger than 2 clearly show that stocks have a large potential to improve the link between assets and liabilities. Unfortunately, the regulators treatment of stocks as having zero duration prevents the pension trustees to fully use the capacity of stocks to mend the asset-liability mismatch. Overall, compared with bonds, stocks are a superior proxy for the real economy.

The figures in Table 2 also show that RAFI as an equity index is a better duration kicker than S&P 500 and MSCI as it provides 0.3 to 2.9 years of additional empirical duration exposure for the asset portfolio. Moreover, its higher correlation with government bonds compared with other indexes helps improve asset-liability matching.

Equity	Market		Correlation with Bonds		Empirical duration vs. Bonds	
	Equity	Bonds	RAFI	Market Cap	RAFI	Market Cap
RAFI US 1000 vs. S&P 500		US 10Y Treasury Notes	0.32	0.23	3.56	2.45
RAFI Euro 150 vs. MSCI Euro		German 10Y Bunds	0.18	0.16	4.26	3.92
RAFI Sweden 100 vs. MSCI Sweden		Swedish 10Y Govt. Bonds	0.22	0.07	4.90	2.02
RAFI World ex Japan vs. MSCI World ex Japan		US 10Y Treasury Notes	0.16	0.05	2.10	0.72
	<b>Average</b>		<b>0.22</b>	<b>0.13</b>	<b>3.71</b>	<b>2.28</b>

Table 2. Correlations and empirical durations of RAFI and market cap-weighted indexes versus government bonds.

We conclude this section with the following exhibit for the US market that summarises the above mentioned aspects of RAFI versus cap-weighted indexes.

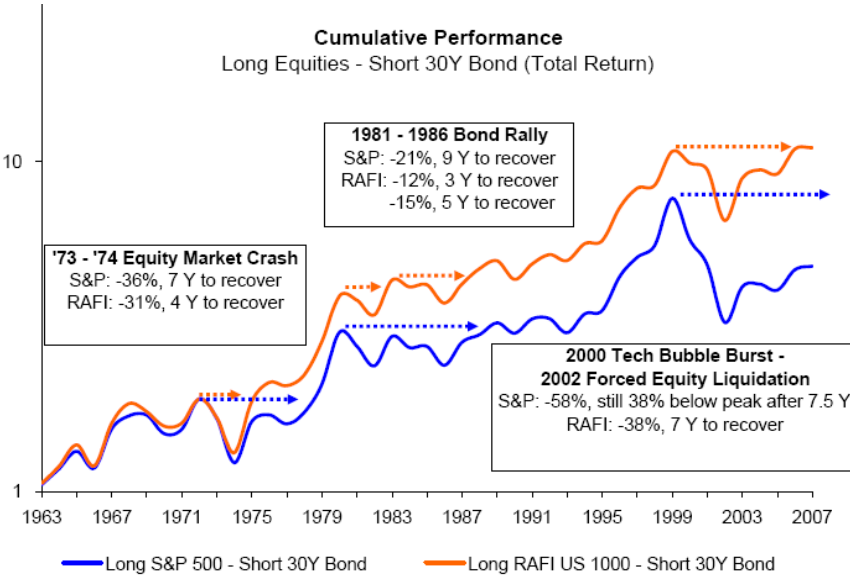


Figure 5. Cumulative Performance of Long Equities - Short 30Y Bond.

### 3. A dynamical ALM exercise for an open ended pension fund

The interest rate sensitivity (in terms of correlation and empirical duration) of the returns of cap-weighted and RAFI indexes, discussed in the previous section, using government bonds as a proxy for a closed ended pension fund's liability profile, showed that stocks have a larger potential to improve the link between assets and liabilities. These indexes have an average empirical duration that is larger than 2. A comparison between cap-weighted indexes and RAFI showed clearly that the later family of indexes does indeed improve the link between assets and liabilities, at materially higher returns.

In this section we investigate whether we could reach a similar conclusion for the case of the liability profile of an open pension fund. In our example new liabilities in terms of pension's rights on salaries are added continuously. The sponsoring company aims to cover half of the new liabilities each year with contributions while the other half is expected to be funded through assets returns exceeding the liability discounting rate. Furthermore, the pension fund is subject to a minimum solvency requirement of 115%, meaning that when there is a shortfall in assets returns so that the solvency level becomes below 115%, the sponsoring company will have to inject sufficient capital in order to increase it to the minimum level. The pension fund has a policy that it should always have a regulatory solvency level of 105% and maximize the equity allocation still adhering to this rule. Each year, the asset portfolio is rebalanced in order to follow this. In the first year the solvency ratio is 115%, which means that in that year no net (more than agreed) capital is required by the sponsor. Finally, it is required that the pension fund should successfully pass stress tests named "Traffic Light" rules meaning that the fund's solvency level should be at a 105% level even if equities suffer a 40% fall and any duration mismatch is stressed by assuming a 30% yield change across the yield curve<sup>4</sup> (in this case, as for most pensions funds, yields are stressed down as if the pension fund's bond holdings would be of short duration). The traffic light rules are similar to the ones being implemented in Denmark, the Netherlands and Sweden as part of the new European risk based solvency regulation (Solvency II). Each subsequent year the starting asset level will be equal to the previous year's portfolio allocation (calculated using "Traffic Light" rules and solvency requirements) invested in the chosen selection of instruments and markets. The primary objective of the sponsor is to minimise the level and volatility of the contributions.

For ease of exposition, we only consider stock returns from S&P 500, RAFI 1000 and RAFI 1000 Enhanced<sup>5</sup>, to check whether an enhancement of a passive index would further improve the funding ratio. A similar study can easily be performed for a much larger number of stock returns such as MSCI etc.

---

<sup>4</sup> The yield changes stress test is not included in the present study, as this will make investing in bonds more attractive relative to investing in cash leaving more risk capital to be invested in more risky, but higher yielding assets, like equity.

<sup>5</sup> Enhancement means that the developments of the passively assigned fundamental weights of the constituents are improved using accounting quality and distress test screening, optimal factor-weighting and dynamic re-weighting.

We first analyse how duration matching would impact the stability of the contributions to the pension fund. Secondly we investigate how switching from S&P-500 to RAFI 1000 and RAFI 1000 Enhanced would impact the behaviour of these contributions.

We consider the following three alternative investment combinations:

- US 30Y Treasury Bonds and S&P 500;
- US 30Y Treasury Bonds and RAFI 1000;
- US 30Y Treasury Bonds and RAFI 1000 Enhanced.

The analysis is conducted on a yearly basis for the periods 1980-2005 and 1990-2005. For each of the above periods the following exhibits are presented:

- Cumulative returns of all the investment instruments;
- Assets versus Liabilities - changes in assets and liabilities during that period;
- Solvency (or funding) ratio (Assets/Liabilities);
- Sponsor's contribution versus target i.e. amount of capital to be injected in order to meet the minimum solvency level.

## Summary of the Results

### The period 1980-2005

During the period 1980-2001, the "Bonds + RAFI 1000 Enhanced" strategy result in the highest value of assets and the second highest value is generated by the "Bonds + RAFI 1000" strategy, leaving "Bond + S&P 500" quite behind.

Not surprisingly, in accordance with what was noticed above, with the exception of 1980, the highest solvency ratio is observed for "Bonds + RAFI 1000 Enhanced" and the second highest for "Bonds + RAFI 1000". The lowest solvency ratio is observed for "Bonds + S&P 500", where under the Post-Bubble period 2002-2004, the size of the required additional capital range between 95% and 241% of the agreed contribution size.

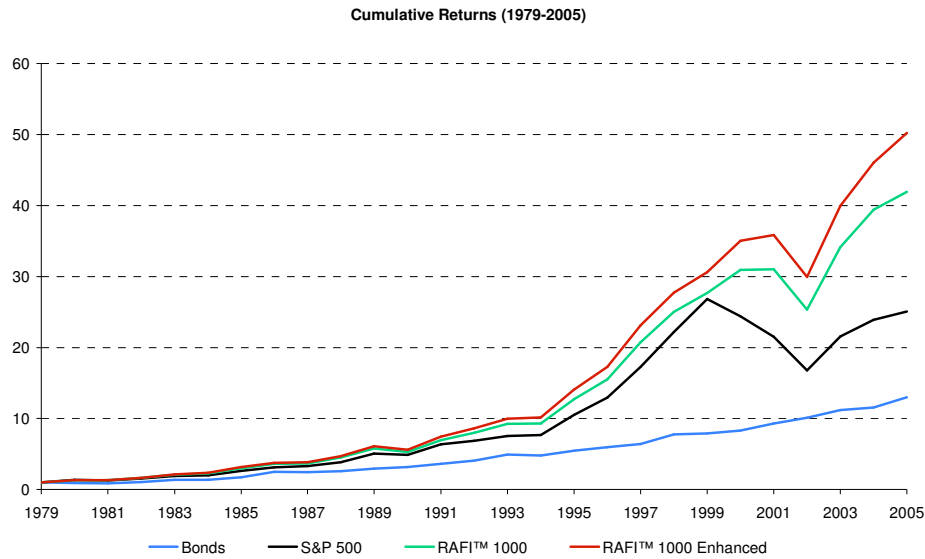


Figure 6. Cumulative Returns in the period 1979-2005.

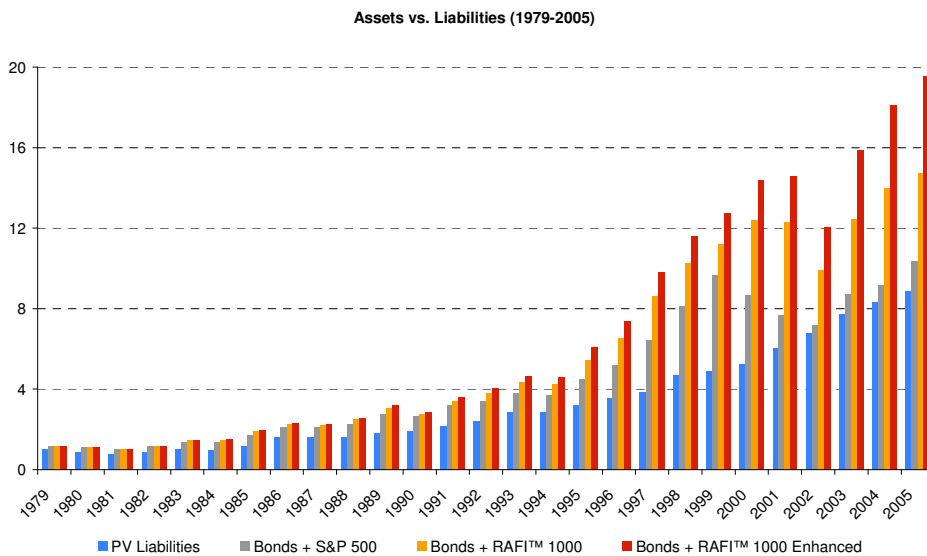


Figure 7. Assets versus Liabilities in the period 1979-2005.

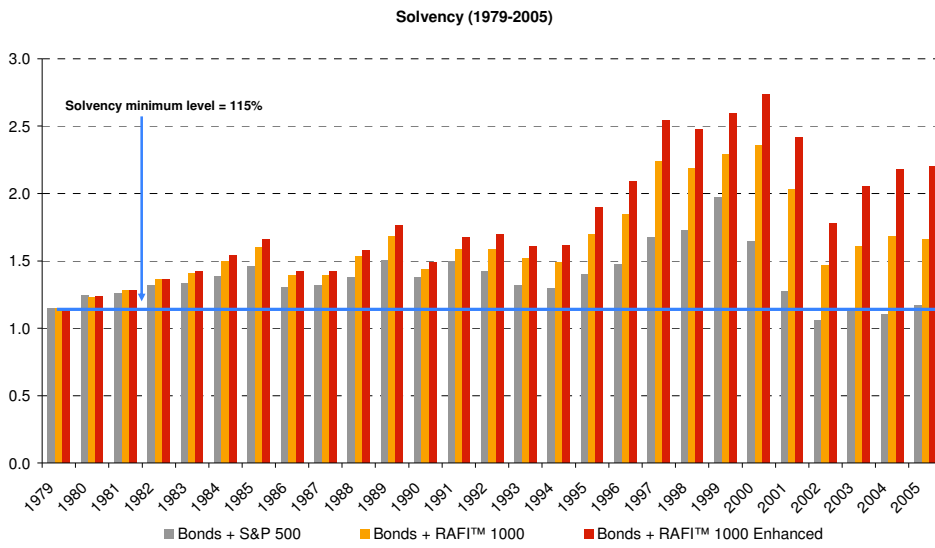


Figure 8. Solvency in the period 1979-2005.

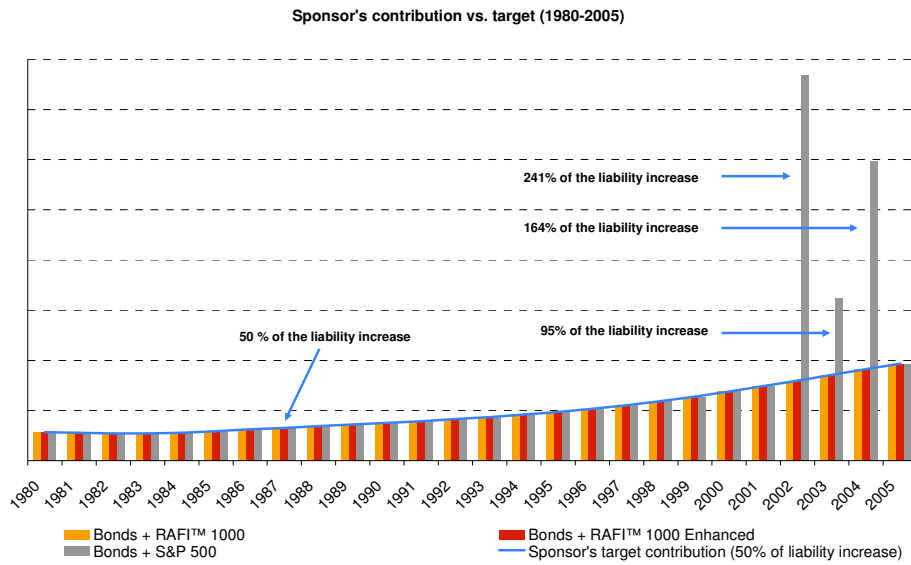


Figure 9. Sponsor's contributions versus target in the period 1980-2005.

The period 1990-2005

In most of the years, "Bonds + RAFI 1000 Enhanced" is the strategy that generates the highest values of assets whereas "Bonds + RAFI 1000" is the second best strategy. Throughout most of the years "Bonds + S&P 500" is the worst performing among the three strategies. Up until 1999 "Bonds + S&P 500" is just slightly worse than the leading strategies, but, experiences a very strong downward tendency in the three following years that can be attributed to the Post-Bubble effect. Nevertheless, RAFI indexes did not suffer from such an effect. Again, the "Bonds + S&P 500" strategy requires additional contribution from the sponsor with an increase ranging between 91% and 183% of the agreed size under the period 2002-2005.

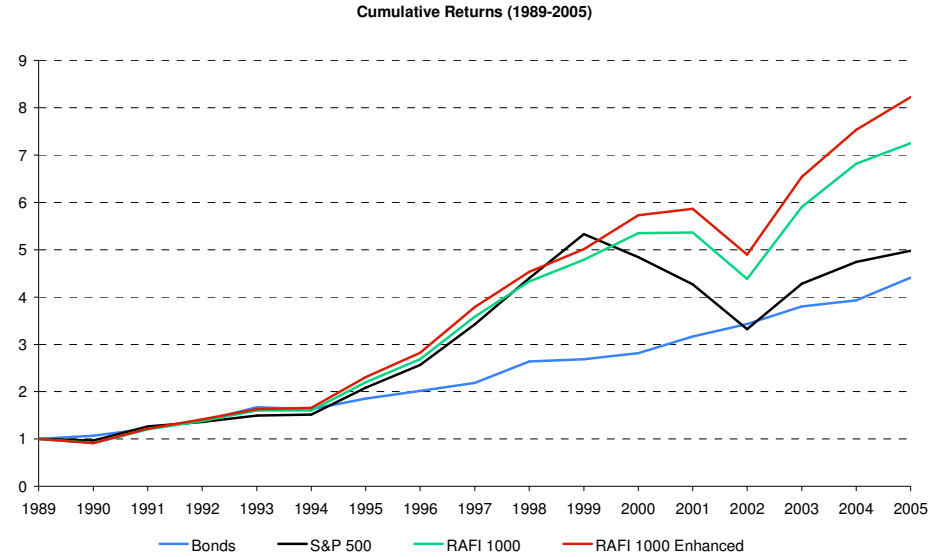


Figure 10. Cumulative Returns in the period 1989-2005.

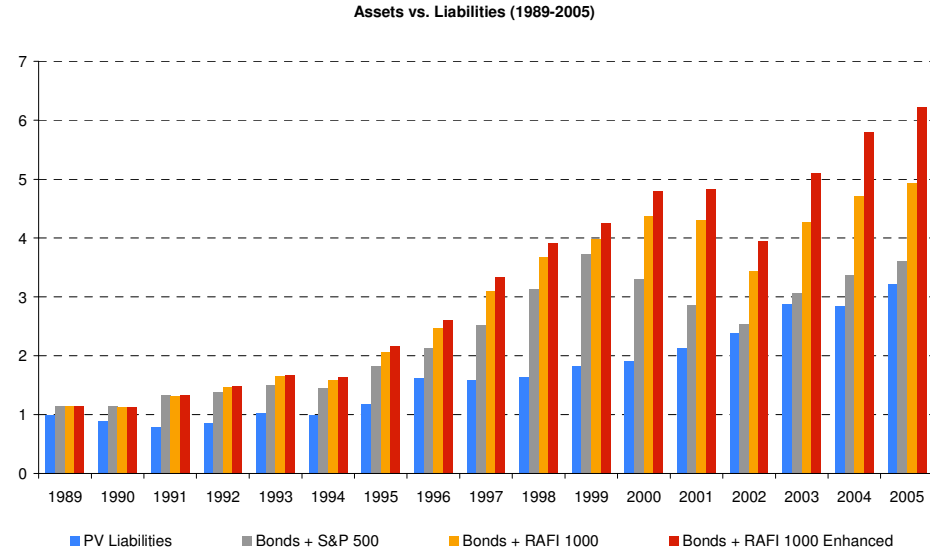


Figure 11. Assets versus Liabilities in the period 1989-2005.

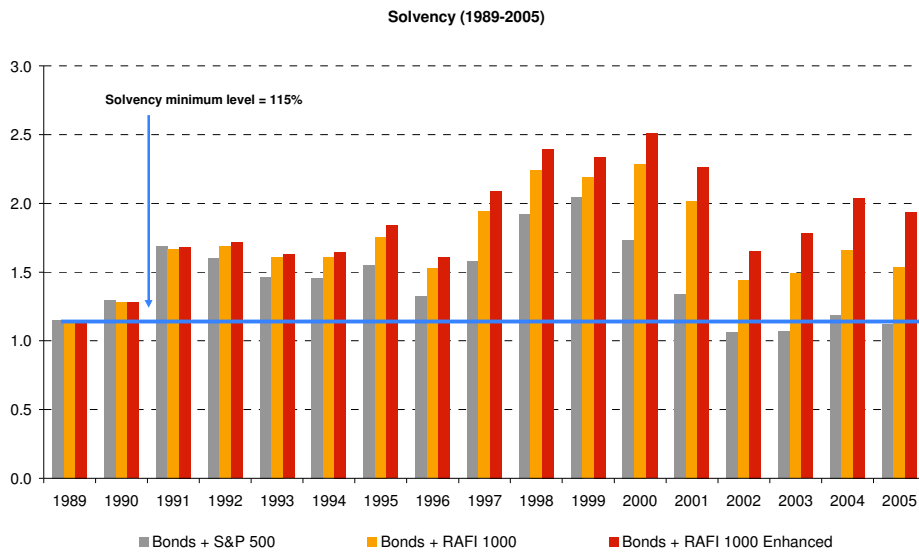


Figure 12. Solvency in the period 1989-2005.

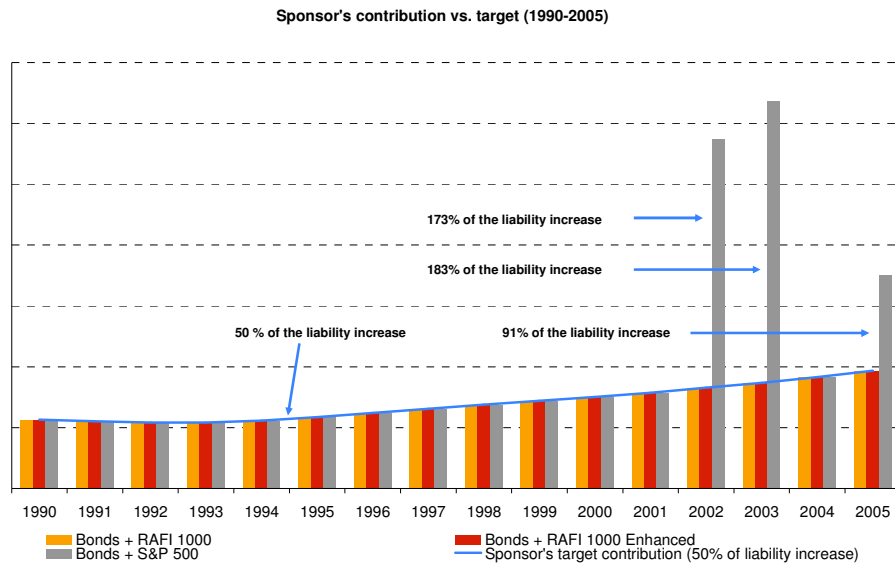


Figure 13. Sponsor's contribution versus target in the period 1990-2005.

#### 4. Conclusion

Through a case study of a liability profile of an open pension fund that is bound to investment restrictions similar to the new 'traffic light rules' recently implemented in some European countries, we addressed the important issue of whether equities can help mend the asset and liability mismatch. For this purpose, we have investigated how market cap-weighted indexes and the new family of fundamentally weighted indexes (RAFI) have the potential to improve the link between assets and liabilities. The analysis of the behaviour of the solvency or the funding ratio showed clearly that interest rate sensitive stocks have a larger potential to improve the link between assets and liabilities, but generally at low returns. The study performed in this notes that a comparison between cap-weighted indexes and RAFI showed clearly that the later family of indexes does indeed improve the link between assets and liabilities, at materially higher returns. Actually, it turns out that "Bonds + S&P 500" is the only portfolio compared to both "Bonds + RAFI 1000" and "Bonds + RAFI 1000 Enhanced", that suffered from the Post-Bubble effect (under the period 2002-2004), forcing the sponsoring company that holds it to inject more capital than agreed. The level of this contribution was substantial.

#### 5. References

- Arnott, R., Hsu, J.C. and Moor, P. (2005): *Fundamental Indexation*. Financial Analyst Journal, 61(2), pp. 83-99.
- Djehiche, B. and Hörfelt, P. (2005): *Standard approaches to asset and liability risk*. Scandinavian Actuarial Journal. (5), pp. 377-400.
- Embrechts, P., Frey, R. and McNeil, A. (2005): *Quantitative risk management: Concepts, Techniques and Tools*. Princeton University Press.
- Hsu, J.C. (2006): *Cap-weighted portfolios are sub-optimal*. J. Investment Management, Q2.
- Leibowitz, M. L. (1986): *Total Portfolio Duration; a new perspective on asset allocation*. Financial Analyst Journal, Vol. 42 (5), pp. 18-29 and page 77.
- OECD (2005): *Pension Markets in Focus*. December 2005, Newsletter ([www.oecd.org/daf/pensions](http://www.oecd.org/daf/pensions)).
- Shimizu, Y. and Tamura, H (2005): *Global fundamental indexes. Do they perform market-cap weighted indexes on a global basis?* Global Quantitative Research, Nomura Securities Co Ltd, Tokyo.
- Treynor, J. (2005): *Why Market- Valuation-Indifferent Indexing Works*, Financial Analysts Journal, vol. 61 (5), 2005.