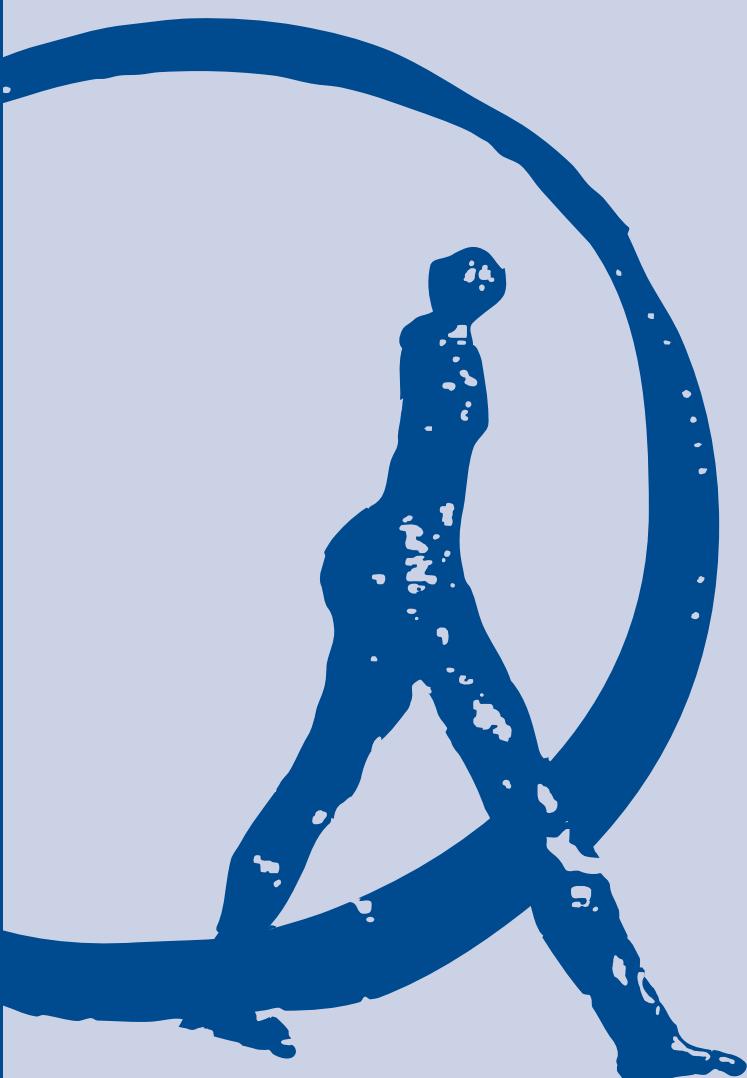


# Dynamic Liability-Driven Investing Strategies: The Emergence of a New Investment Paradigm for Pension Funds?

A survey of the LDI practices for pension funds

February 2014



with the support of

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# Foreword

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In the present publication, which was produced as part of the BNP Paribas Investment Partners research chair at EDHEC-Risk Institute on "ALM and Institutional Investment Management," led by Professor Lionel Martellini, we have attempted to assess the views of pension funds and sponsor companies as they relate to their reactions to dynamic liability-driven investing (LDI) strategies and their desire to integrate this approach into their processes.

Our conclusion is that progress remains to be made in the area of appropriate risk management for pension funds. As such, the survey finds that LDI is popular, but in concrete terms the fund separation approach, which is consistent with the LDI paradigm, is not yet sufficiently widely applied to manage the LDI approach optimally, especially in southern European countries. In the same way, one of the key points in LDI for pension funds is hedging with respect to the duration of the liabilities, but it is not always implemented by pension funds, even though they affirm that they use LDI-type solutions.

The risk allocation approach is gaining ground, not only because it questions the active management offerings in favour of passive investment, which has come up with innovative offerings in the area of factor investing in recent years, but also because it contributes to a better understanding of institutional investors' risks and diversification. From that perspective, we can see an acceleration in the adoption by professionals of concepts that are well documented in the academic world.

Ultimately, too many pension funds are still more concerned with standalone performance than risk management, which explains why they favour tactical allocation or reviews of strategic allocation over risk management in ALM. On this subject, we observe a clear difference in the rates of adoption of dynamic LDI between the north and the south of Europe.

In the end, too many pension funds remain asset-only rather than ALM funds and do not take sufficient account of the impact of their liabilities in their asset allocation policy or risk management.

I would like to thank Professor Martellini's co-authors on the publication, Saad Badaoui, Romain Deguest, and Vincent Milhau, for their work on conducting the survey, analysing the results, and providing the relevant background based on academic research.

I would also like to extend our warmest thanks to BNP Paribas Investment Partners for their ongoing support of this research chair.



Noël Amenc  
Professor of Finance  
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# About the Authors

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# Executive Summary



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A number of profound changes have taken place over the last 15 to 20 years in accounting standards and prudential regulations in most developed countries, and these changes have collectively led to the emergence of a new investment paradigm for pension funds. This paradigm, known as the Liability-Driven Investing (LDI) paradigm, is a general investment framework that advocates the allocation of pension fund assets to two distinct portfolios, a *performance-seeking portfolio* (PSP) and a *liability-hedging portfolio* (LHP), in addition to residual long or short investments in cash. The research conducted at EDHEC-Risk Institute since 2008 in the context of the research chair sponsored by BNP Paribas Investment Partners has outlined a number of important implications of this paradigm for the asset-liability management (ALM) of pension funds. In a nutshell, the main insight from this research programme is to emphasise the benefits of dynamic forms of liability-driven investment strategies, which imply that the split between the risky performance-seeking component and the safe liability-hedging component should evolve over time as a function of changes in market conditions and also as a function of prudential risk budgets defined by the regulators, who have increased their focus in terms of respecting minimum funding ratio levels. In particular, such strategies are shown to allow for the respect of minimum funding ratio constraints with substantially lower opportunity costs compared to static LDI strategies (Martellini and Milhau (2009) and Deguest *et al.* (2013)). Besides, dynamic LDI strategies can be regarded as an effective way to reduce the conflicts of interest between pensioners and shareholders (Martellini and Milhau (2010b)), especially when they

explicitly take into account sponsor risk in the context of an *integrated* approach to LDI strategies (Martellini *et al.* (2012)).

Having documented the benefits of the LDI paradigm and its extensions from a theoretical perspective, we have attempted through this survey to assess the views of pension funds, ALM consultants and sponsor companies as they relate to their reactions to dynamic liability-driven investing (DLDI) strategies and their desire to integrate this approach into their processes. Aside from a few descriptive introductory questions, most of the 55 questions in the survey were organised around three main topics. What is the actual rate of adoption of the LDI paradigm by pension funds, and how are the building blocks (PSP and LHP) constructed? Do participants implement dynamic LDI techniques, and in the affirmative which forms of dynamic LDI strategies are most commonly used? Do participants adopt an integrated ALM perspective by taking into account the relations between the sponsor and the pension fund?

The first section of the document will provide background information for the survey, notably including an overview of the main conceptual and technical foundations for LDI strategies and their extensions in terms of *integrated* LDI and *dynamic* LDI and strategies, while the second section provides a detailed analysis of the responses from a sample of senior representatives pension funds and sponsor companies. This executive summary focuses on the main findings extracted from the responses to the survey. We start by describing respondents' profiles, and then turn to the analysis of the responses on how LDI and DLDI strategies are used in practice and the reasons that

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motivate the adoption or non-adoption of such techniques. Finally, we briefly discuss the survey's results on the integrated LDI strategies with a particular focus on questions related to a better understanding of the management of sponsor risk at the pension fund level.

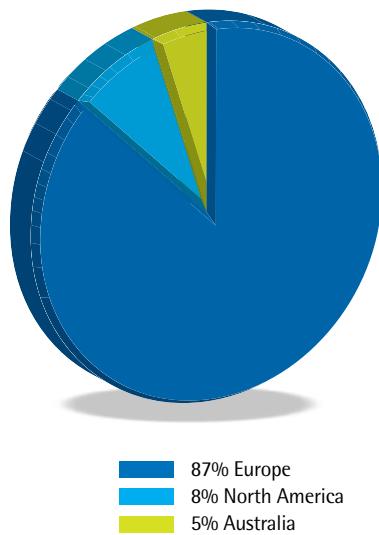
## 1. Respondents' Profiles

### 1.1. A Survey Reflecting LDI Practices of European Pension Funds

Overall, the survey received a total of 104 responses, with a very large majority of participants (87%) emanating from Europe (Exhibit A). Moreover, most of respondents are pension fund managers, while only slightly more than 10% of the respondents are employed by sponsor companies or consultancy firms. It is also worth noting that close to 80% of respondents have a high level of responsibility in their organisation, or are asset management professionals. This figure can be taken as an indicator of the quality of responses: respondents express qualified views on the questions that were asked in the survey.

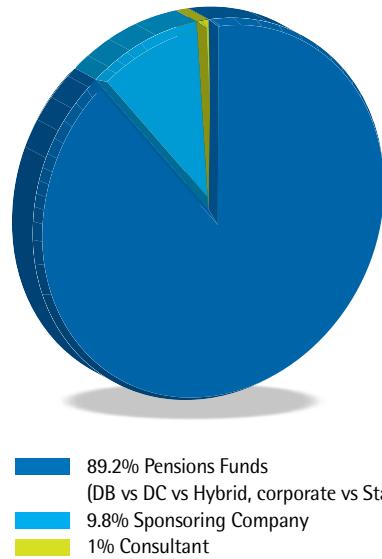
Among the European respondents, some countries are largely over-represented, which of course reflects a larger development of the pension fund industry: United Kingdom (19 respondents); Switzerland (18); Netherlands (12); Denmark (8); and Germany (6). Having a significant number of respondents from the same geographical area is an asset because it allows us to analyse the differences in practices within this region.

*Exhibit A: Breakdown of respondents by continent. This picture gives the percentage of respondents based in each of the mentioned geographical zones. These percentages are based on the 104 answers to the survey.*



*Notes: Europe = Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Ireland, Italy, Liechtenstein, Netherlands, Norway, Portugal, Romania, Sweden, Switzerland, UK. North America = Canada, United States.*

*Exhibit B: What type of institution do you belong to? The exhibit indicates the distribution of respondents according to the institution they belong to. The question was put to the 104 participants, and percentages have been normalised by excluding the non-responses (2 out of 104).*



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## 1.2. A Domination of Defined-Benefit Pension Funds and a Substantial Inclination for Internalising Asset Allocation Decisions

The majority of pension funds (exactly 62.79%) that took part in the survey were defined-benefit (DB) pension funds, while the remaining funds were equally divided between defined-contribution (DC) and hybrid funds. This domination of DB funds has two important consequences for our study. First, since the contributions in a DB fund must adjust to the level of funding, most of the pension funds surveyed largely depend on the contributions from the sponsor, taken in a broad sense as they can encompass contributions from both the employer and the employees. The second consequence is that most of the pension funds that responded to the survey should *a priori* show some focus on ALM techniques that aim to respect minimum funding requirements, in order to ensure that assets are sufficient to cover liabilities. In some countries, these minimum funding levels are imposed by regulation; this is for example the case in the Netherlands, where 11 out of 12 participants explicitly recognise that they face such constraints. We also find that the notion of defined benefits has not entirely disappeared, not

even for DC and hybrid funds since more than half of those respondents to the survey acknowledge the presence of some form of guarantee for beneficiaries.

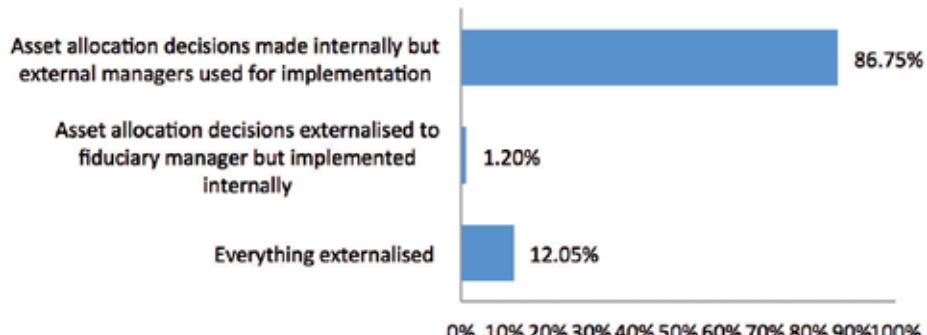
Another important characteristic of the pension funds that we surveyed is their inclination to internalise the asset allocation process (see Exhibit C). 86.75% of them make these choices internally and rely on external managers for their implementation.

## 1.3. A Strong Preference for Market Rate as Discount Rate for Pension Liabilities

The typically long maturity of pension liabilities makes their present value highly sensitive to the discount rate applied to payments. In this context, it is important to know what discount rate is applied by pension funds. The results reveal that close to half of them use a market rate, while hardly 30% of them employ a fixed rate. The former discounting rule is in line with the recommendations of international accounting standards SFAS 87.44 and IAS 19.78.

The preference given to a market rate over a fixed rate has important consequences for the design of an LHP. Indeed, a market

*Exhibit C: Type of management (Pension funds only). The exhibit indicates the distribution of the different types of management adopted by pension funds. The question was put to the 91 pension funds, and percentages have been normalised by excluding the non-responses (8 out of 91).*



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rate is by definition time-varying, and these variations have an impact on liability values that can be measured by the duration of the liabilities. As a result, the volatility of the discount rate accounts for a large fraction of liability volatility. In fact, it explains the totality of volatility if payments are fixed in nominal terms, and it still accounts for the largest part if pension payments are indexed with respect to inflation (see Martellini and Milhau (2013)). Hence, a meaningful LHP has to provide a hedge against unexpected fluctuations in the discount rate.

## 2. A Broad Familiarity with the LDI Paradigm

The LDI paradigm, in its standard form, prescribes that investors endowed with liability-driven objectives need to invest in two distinct portfolios, in addition to cash: one well-diversified PSP, needed to generate access to risk premia, and one LHP, needed to hedge against unpredictable changes in risk factors that impact liability value. While this theoretical model of portfolio choice makes intuitive sense, the separation between performance and liability hedging does not necessarily correspond to the reality of practices in the industry. Therefore,

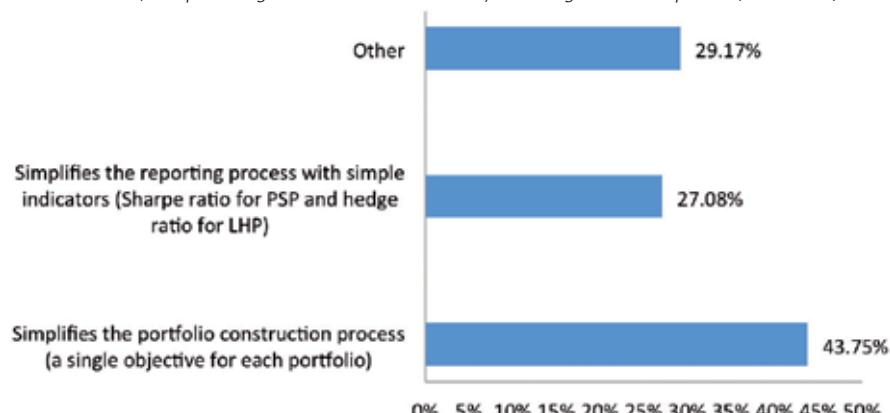
the following questions aim to understand whether or not managers implement LDI strategies, and how they hedge their liabilities and construct their PSP.

### 2.1. Broad Awareness of the LDI Paradigm but Less Widespread Adhesion to Fund Separation

A first key insight from the survey is that a large fraction (80%) of respondents are now fully aware of the LDI paradigm. This figure suggests that this principle has become an accepted norm in ALM for pension funds. Since the LDI principle is deeply rooted in portfolio theory (Martellini and Milhau (2012)), this result can be taken as an indication that the gap between academic prescriptions and practice is narrowing with respect to this particular issue.

Nevertheless, only one half of participants actually implement a formal separation between the PSP and the LHP, although this rate is subject to substantial geographical variations: for instance, most respondents from the United Kingdom and in Denmark adopt it. The reason most often cited (with 43.75%) by respondents who follow this principle is that it simplifies the portfolio construction process (Exhibit

*Exhibit D: Why do you split your portfolio into an LHP and a PSP? The exhibit shows the percentages of the different responses chosen by participants to justify the adoption of the LDI strategy. The question was put to the 50 pension funds that split their portfolio in LHP and PSP, and percentages have been normalised by excluding the non-responses (2 out of 50).*



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D). This result is not very surprising, since each building block in an LDI strategy has a well-defined role, which is the search for risk-adjusted performance for the PSP, and low risk relative to the liabilities for the LHP. A related argument is the induced simplification in the reporting process; since each block is assigned a well-defined objective, it suffices to focus on a criterion that measures the degree of achievement of the objective (e.g. Sharpe ratio for the PSP and hedge ratio for the LHP). Thus, fund separation is seen by most participants as a source of simplification and clarification.

## 2.2. Liability Risk is More Often Measured than Hedged

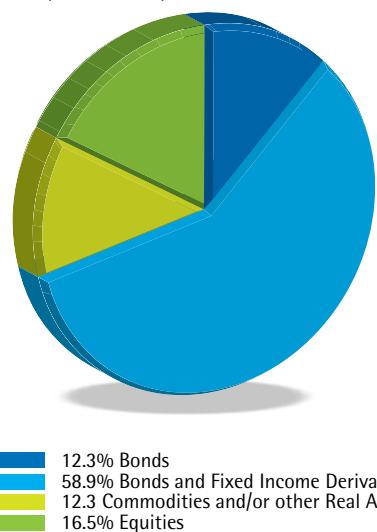
More generally, we also surveyed participants' practices regarding the measurement and the hedging of liability risk. The results show unambiguously that liability risk is much more often measured than hedged. Only 20% of participants do not measure liability risk at all; this is a minority, but still a worryingly high percentage given that this measurement is an essential part of a sound ALM process. Among the 80% who measure liability risk, shortfall probability and expected shortfall are popular measures, since at least one of them is adopted by slightly more than half of participants. On the other hand, when it comes to liability hedging, 54.02% of participants declare that they do not hedge their liabilities, which amounts to using an asset-only investment framework despite the presence of liabilities. A positive finding is that liability hedging is more widespread among those pension funds who discount their liabilities at a market rate (63.41% versus 20% for those who apply a fixed rate), but it is still surprising

to note that a large number of pension funds do not hedge their liabilities.

## 2.3. A Dominant Focus on Interest Rate Risk in the LHP, but Duration Matching not Often Utilised

The purpose of the LHP is to provide a hedge against unexpected changes in the risk factors that impact liability value. Because this value equals the present value of promised pension payments, the relevant risk factors are those that impact either the discount rate (typically interest rate risk and credit risk) or the cash flows (inflation risk for instance). The survey results confirm that interest rate risk is perceived as the main source of risk by most participants, since the LHP is dominated by fixed-income instruments, sovereign bonds, corporate bonds and interest rate derivatives (Exhibit E). This perspective is justified from a theoretical standpoint, because the long maturity of liabilities makes interest rate risk the main contributor to liability volatility, even if payments are indexed on inflation (Martellini and Milhau 2013).

*Exhibit E: How is your liability-hedging portfolio defined?*  
The exhibit presents the percentage composition of the LHP portfolio. The question was put to the 104 participants, and percentages have been normalised by excluding the non-responses (31 out of 104).



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Fixed-income instruments are in fact perceived as attractive not only for their liability-hedging properties, but also for their diversification and performance benefits, and 78.65% of respondents state that they also hold fixed-income instruments in their PSP.

Regarding the construction of the LHP, a striking result is that only 40% of respondents seek to align the duration of the bonds that they hold in their LHP with the duration of liabilities. This is surprising, given that duration matching is usually considered the first step towards the immunisation of the funding ratio against interest rate changes. Of course, this result may simply reflect that many participants do not actually hedge their liabilities (see Section 2.2), but even among those who do hedge, 32.50% do not seek duration alignment, perhaps due to the practical difficulties involved with having access to bonds with sufficiently long maturities. In this context, we also note that roughly the same proportion of participants match the asset and liability exposures to changes in the shape of the yield curve: in other words, there are no more participants who manage

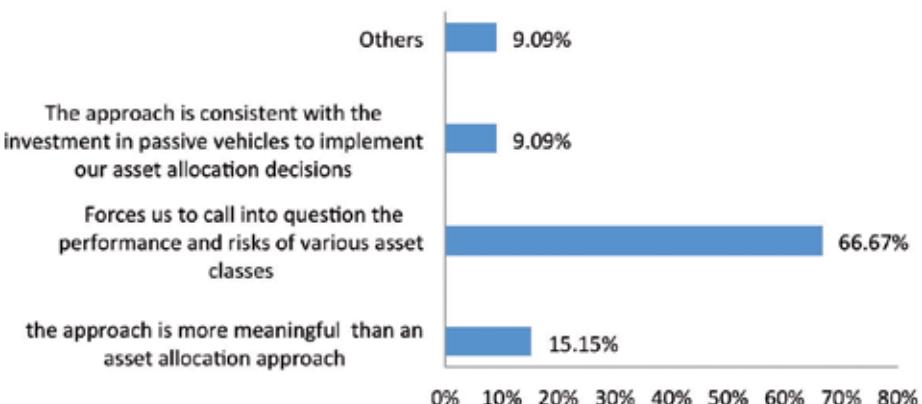
the risks related to first-order factors in yield curve changes (changes in level) than participants who manage the risks related to second- and third-order factors (changes in slope and curvature).

## 2.4. A Significant Interest in Risk Factor Allocation Among Pension Funds

Another important lesson from the survey is that the novel risk factor allocation approach is drawing a significant interest among pension funds. This approach replaces the traditional focus on dollar amounts allocated to asset classes by a focus on the budgets allocated to risk factors. We find that 35.42% of participants have adopted this perspective, a percentage which is far from negligible. In other words, for a significant fraction of respondents, the potential benefits of a factor approach outweigh the implementation challenges that it raises.

For two thirds of those participants who frame the allocation decision in terms of factor exposures (as opposed to asset class exposures), the main motivation is to question the performance and risk

*Exhibit F: If you use a factor allocation framework, what are your motivations? The exhibit shows the percentages of the different responses chosen by participants to justify the adoption of the factor allocation strategy. The question was put to the 34 participants who use a factor allocation framework, and percentages have been normalised by excluding the non-responses (1 out of 34).*



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of asset classes (Exhibit F). This figure indicates that many asset managers are no longer willing to merely rely on historical performance and risk measures for standard asset classes, and are interested in understanding the sources of performance and risk: indeed, the knowledge of factor exposures gives more robust forecasts of the long-term performance of an investment strategy, as well as of the short-term performances across various market conditions. This result should be taken by the passive management industry as a clear invitation to place more emphasis on the disclosure of the factor exposures of their investable indices, not only when these exposures are explicitly sought, but also when they are side effects of the stock selection or weighting process.

It should nevertheless be recognised that implementing a risk factor allocation raises technical issues, which relate to the estimation of exposures of assets and to the translation of factor weights into asset weights. One fifth of participants who have not adopted this approach claim that they lack the necessary expertise, while close to 30% of them point out difficulties in mapping the factor allocation into a realistic asset allocation.

## **3. Dynamic LDI Techniques have not yet been Adopted by the Majority but are Gaining Acceptance Especially in Northern European Countries**

Dynamic LDI differs from static LDI in that it involves periodic revisions of the allocation to the PSP and LHP. From a theoretical perspective, these revisions can

be motivated by changes in current risk and return parameters, and/or by variations in a risk budget, typically defined as the distance between asset value and some floor asset value (for example related to a minimum funding ratio constraint) to be protected at all times. The survey includes a series of questions aimed at analysing the reasons that motivate the adoption or non-adoption of dynamic LDI techniques by pension funds.

### **3.1. Northern European Countries Show A Higher Rate of Adoption of Dynamic LDI Strategies Compared to Other Countries, and Derivatives are Often Used in Implementation**

At the aggregate level, dynamic LDI has been adopted, or is being considered for adoption, by slightly more than 38% of respondents. However, a large geographical heterogeneity exists: the Netherlands, Denmark, the United Kingdom, Germany and North America display more interest than the rest of the sample for this technique. This result indicates a higher level of interest for advanced ALM techniques in these regions.

For half of participants who have adopted or consider adopting a dynamic LDI strategy, the use of derivatives is the preferred implementation approach, while cash positions are used by only one fourth of them. From an academic perspective, it is equivalent to select an option payoff or to choose a dynamic trading strategy (see Cox and Huang (1989)), which itself can be implemented with cash or derivatives instruments (such as futures contracts for instance). In practice, purchasing derivatives only involves the structuring

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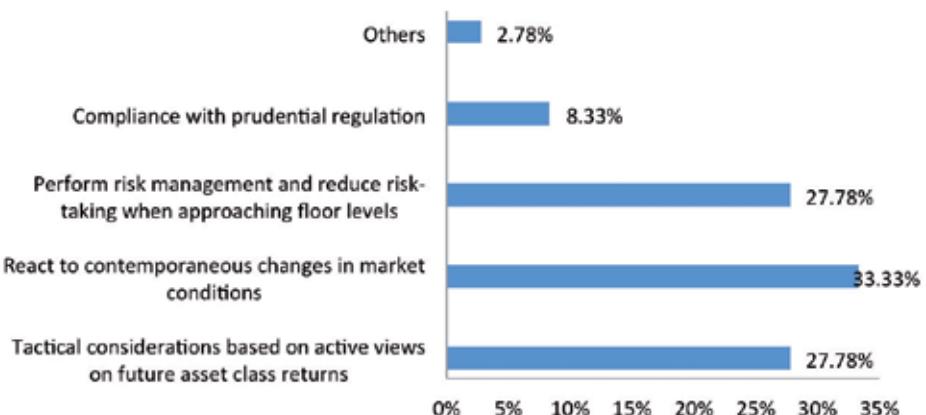
costs, while dynamic trading involves recurring transaction costs. Thus, static positions in derivative products, provided that they are fairly priced, involve less deadweight costs than dynamic cash positions, which may explain why this approach is favoured by many participants. However, derivatives are not equally popular across geographical areas: Denmark and the Netherlands are the two countries that are the most prone to using them in the implementation of a dynamic LDI strategy, while no respondent from North America does so.

### **3.2. Strategic or Tactical Allocation Considerations are More Important Motivations than Risk Management Considerations**

The main motivation for engaging in dynamic LDI is the willingness to make the strategy responsive to changes in the economic environment. One third of those participants who express an interest in dynamic LDI say that they want revisions of the strategic asset allocation as a function of changing objective parameters, such as volatilities,

correlations and risk premia (see Exhibit G). A slightly lower percentage (27.78%) of the respondents invoke tactical considerations: they seek to add value by incorporating their *subjective* views on future returns in the allocation, which may lead to them temporarily deviating from the strategic portfolio. Downside risk management and the respect of floors through a dynamic adjustment of risk budgets are only cited by 27.78% of participants, that is, as many as those who are interested in tactical asset allocation. Overall, this risk management motive is not perceived as important as the considerations for market conditions, which is perhaps surprising given the presence of minimum funding ratio constraints in most countries. The lower importance given to risk management is also seen in the fact that a large majority of respondents (85.26%) do not impose any floor in their allocation process. One might expect that those who face minimum funding regulatory constraints translate the minimum funding levels into floors, but surprisingly, this does not often seem to be the case. Indeed, the

*Exhibit G: If you use, or consider using, dynamic LDI strategies, what are your motivations? The exhibit indicates the percentages of the different responses chosen by participants to justify the adoption of the dynamic LDI strategy. The question was put to the 37 participants who use or consider using dynamic LDI, and percentages have been normalised by excluding the non-responses (1 out of 37).*



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percentage of participants who impose a floor is barely higher among those who face regulatory constraints (16.98%) than in the whole sample (14.74%). A further source of concern is that more than half of those participants who set a floor actually consider an asset-only floor, without an explicit reference to liability value.

Overall, these results show that dynamic LDI strategies are gaining acceptance, especially in Northern European countries, but are not yet adopted by the majority of the pension funds. Among the reasons for the reluctance to adopt a dynamic LDI approach, the first reason cited by participants is the existence of implementation issues, particularly the lack of liquidity of asset classes. These results also suggest that dynamic LDI strategies are currently mostly adopted for asset management reasons, but not for reasons that have to do with the presence of liabilities. They also indicate that the market has not yet fully realised the usefulness of dynamic LDI techniques in the presence of minimum funding requirements.

## 4. Room for a Larger Adoption of Integrated ALM

A non-integrated approach to ALM for pension funds, focusing on the pension fund perspective taken in isolation, fails at capturing the variety of the viewpoints of the many stakeholders involved in the problem, especially in the case of a corporate pension plan: pension fund managers, trustees in charge of allocation decisions and/or execution of these decisions, beneficiaries, employees as well as shareholders of the sponsor company.

It is well known that conflicts of interest can arise between these different groups, and academic research (see in particular Martellini and Milhau (2010b) and Martellini *et al.* (2012)) has shown that certain forms of dynamic strategies can help to mitigate such conflicts of interest. For instance, if equity holders are entitled to receive a fraction of pension surpluses, the use of some form of dynamic LDI strategy seeking to allow for upside potential while protecting a minimum level of coverage at all times is likely to reconcile the preferences of pensioners for safe investment policies and the preferences of equity holders for aggressive, surplus-generating, policies.

Moreover, Martellini and Milhau (2010b) show that the proper valuation of pension liabilities in the context of a DB pension fund where the sponsor has to make up for deficits should explicitly take into account the financial health of the sponsor. The intuition is straightforward: if the sponsor is highly leveraged and is facing decreasing revenues, it is unlikely that it can afford the required extra contribution in the event of a large deficit. In other words, if it is true that in a DB pension plan the sponsor bears the risk of facing unexpected rises in contributions, it is no less true that the pension fund is exposed to the risk of insolvency of the sponsor. The natural implication would be for the pension fund to hedge against sponsor risk (see Martellini *et al.* (2012)).

The last part of the survey is dedicated to these two aspects of integrated ALM. First, we assess whether participants are aware of the presence of possible conflicts of interest between stakeholders, and we

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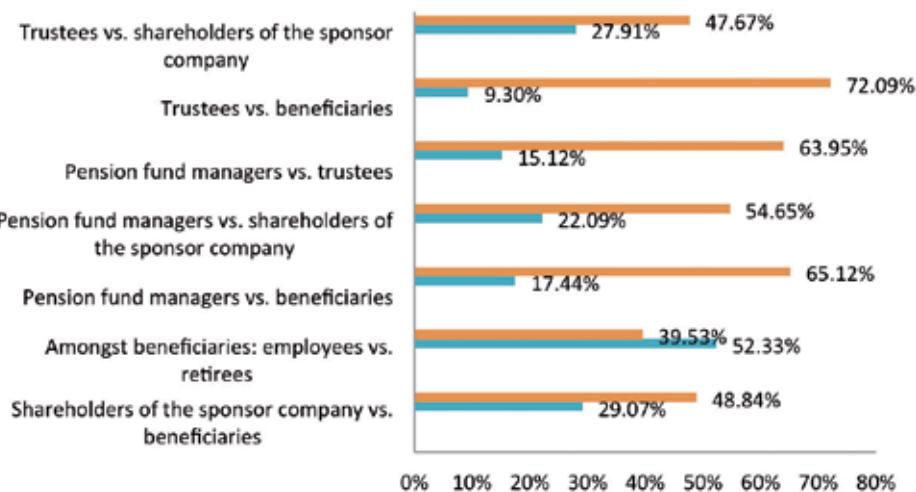
then ask whether sponsor risk is taken into account in the management of pension assets.

## 4.1. A Strong Perception of the Presence of Conflicts of Interest between Various Stakeholders

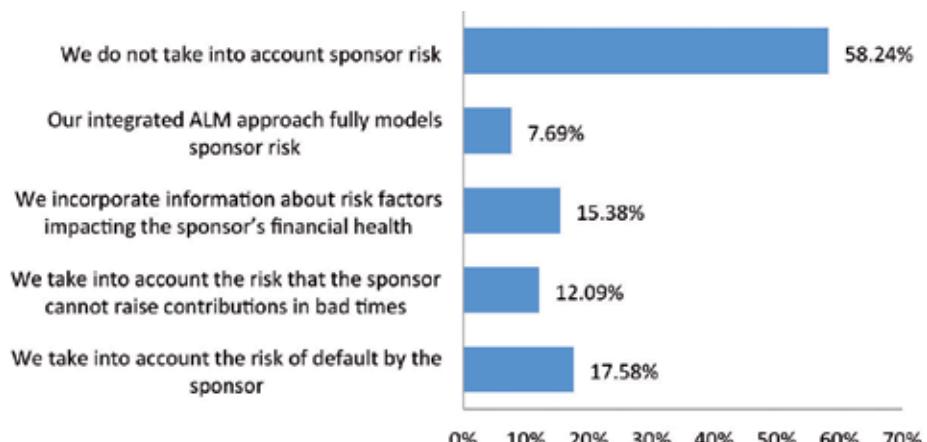
The results in Exhibit H show that many participants recognise the presence of conflicts of interests between stakeholders. The conflict which is most often cited is between employees and

retirees, a point which is unsurprisingly raised mostly by DB pension funds. On the other hand, the aforementioned conflict between beneficiaries and equity holders is not as frequently cited. There are still 29.07% of participants who mention it, which shows that portfolio insurance strategies that guarantee the respect of a minimum funding ratio while opening access to upside performance have a practical usefulness.

*Exhibit H: Do you perceive any evidence of conflict of interests between various stakeholders? The exhibit presents the percentage of responses of participants to this question. The question was put to the 104 participants, and multiple choices were allowed, so the percentages do not add up to 100%. They have been normalised by excluding the non-responses (18 out of 104). The orange (respectively blue) bars represent the answer "No" (respectively "Yes").*



*Exhibit I: Do you hedge against sponsor risk? The exhibit presents the percentages of responses of participants to this question. The question was put to the 104 participants, and multiple responses were allowed, so the percentages do not add up to 100%. They have been normalised by excluding the non-responses (13 out of 104).*



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## 4.2. Limited Awareness of Sponsor Risk

As explained above, the management of sponsor risk is of particular importance in DB pension funds where the sponsor has the contractual obligation to make up for any deficit that may arise. However, Exhibit I shows that the explicit management of sponsor risk is a limited practice: 58.24% of participants simply do not take this risk into account when designing their allocation strategy. We also note that only one third of the respondents assess the probability of default risk on pension payments.

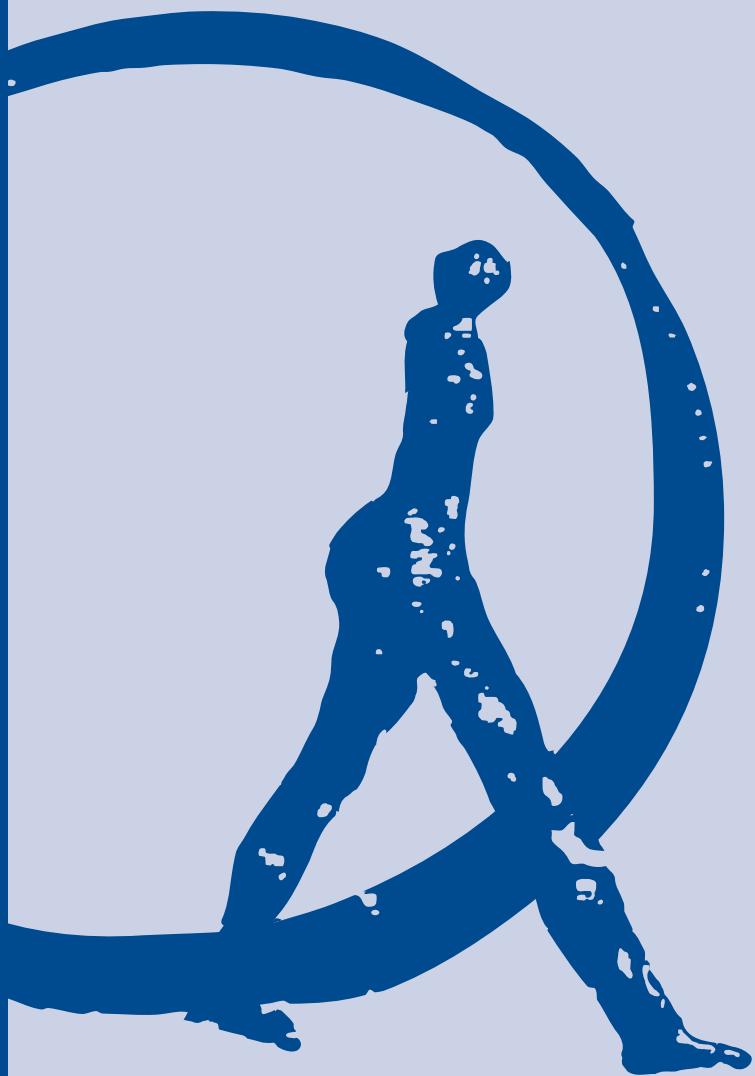
The latter result suggests that the lack of hedging of sponsor risk may be due to an insufficient awareness of that risk. On the other hand, implementation challenges cannot be ignored. In principle, hedging sponsor risk does indeed require the use of securities with returns highly correlated with changes in the real value of the assets of the sponsor company, and it may be difficult for the pension fund to set up strategies in which the sponsor equities are sold short (see Martellini *et al.* (2012)). Derivatives may appear again as a possible way to address some of these issues, but a large majority of respondents do not see them as the best approach to deal with sponsor risk (81.71%), except in Denmark, where close to half of respondents express an interest in using derivatives for that purpose.

seeking versus liability-hedging portfolios is not as widespread. One striking result is that while liability risk is measured in one way or another by about 80% of participants, more than half of all participants declare that they do not hedge their liabilities. It thus seems that there is room for improvement in terms of how the presence of liabilities can be taken into account in the asset management process. A similar observation can be made for dynamic LDI techniques; participants who have adopted them or consider doing so have mostly asset-only motivations, related to changes in market conditions or tactical views. Only a minority of the respondents recognise that dynamic LDI techniques can also be used to reduce the opportunity costs associated with respecting minimum funding ratio constraints. These strategies, which do not only guarantee the respect of floor asset levels, but also open access to the upside potential of risky assets, can contribute greatly to aligning the interests of various stakeholders, including pensioners and equity holders of the sponsor company. Finally, a last field where progress could be made is the explicit incorporation of sponsor risk in the management of pension assets, a problem particularly relevant for DB pension funds.

## Conclusion

Overall, the survey shows that while the basic LDI paradigm has now gained wide acceptance in the pension fund industry, the formal separation of pension fund assets between two distinct performance-

# Introduction



# Introduction

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A number of profound changes have taken place in accounting standards and prudential regulations in most developed countries, which have collectively led to the emergence of a new investment paradigm for pension funds. On the one hand, the shift in most accounting standards (FRS 17, FAS 87, and IAS 19) towards the valuation of pension liabilities at market rates (mark-to-market), instead of fixed discount rates, has resulted in an increase in liability portfolio volatility. As a consequence, pension funds have had to increase their focus on liability risk management so as to reduce the volatility of their funding ratio. On the other hand, this new constraint has been reinforced in parallel by stricter solvency requirements that followed the 2000-2003 pension fund crisis.

Such changes have taken place at a time when asset allocation practices were firmly grounded around one overarching foundational concept, the *policy portfolio*, which had dominated pension fund investment practices for decades. This policy portfolio, a theoretical reference portfolio allocated among asset classes according to a mix deemed to be most appropriate for the pension fund, was constructed either from a simple asset-only perspective, or from a more sophisticated *surplus optimisation* perspective. In the latter case, the focus was to efficiently allocate to various risky asset classes so as to achieve the best possible compromise between the risk relative to the pension fund liabilities and the excess return that the investor can hope to obtain through the exposure to rewarded risk factors.

Over the past 15 years or so, this old paradigm has progressively been recognised as obsolete for at least two major, independent, reasons. The first driving force behind the paradigm shift has been the progressive recognition, accompanying the increased focus on liability risk management, that pension fund investments should not be framed in terms of one all-encompassing reference policy portfolio, but instead in terms of two distinct reference portfolios. These two portfolios are, respectively, a liability-hedging portfolio (LHP), the sole purpose of which is to hedge away as effectively as possible the impact of unexpected changes in risk factors affecting liability values (most notably interest rate and inflation risks), and a performance-seeking portfolio (PSP), for which the focus is to provide investors with an optimal risk-return trade-off, without any constraints related to a possible liability mismatch. This dual portfolio approach is consistent with the "fund separation theorems", which lie at the core of asset pricing theory and which advocate a separate management of performance and risk-control objectives that is entirely inconsistent with the prescription of surplus optimisation methodologies. The second driving force has been the death of the policy portfolio as a relevant approach to strategic asset allocation decisions, regardless of the absence of liabilities. This *death of the policy portfolio*, which was announced, or rather predicted, by Peter Bernstein in the March 2003 edition of his "Economics and Portfolio Strategy" newsletter, independently of the emergence of an increased focus on liability risk management, has resulted from the recognition that there is no

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such thing as a meaningful policy portfolio; one should instead think in terms of a meaningful dynamic policy portfolio strategy. The claim here is that the presence of a substantial amount of *predictability* in time-varying risk and return parameters for financial assets invalidates the relevance of any portfolio that would be held constant by investors for a sustained period of time, with no revisions of the portfolio as a function of changes in market conditions.<sup>1</sup>

Taken together, these two driving forces have led to the progressive emergence of a modern approach to asset-liability management (ALM) for pension funds. This new approach has been labelled the "dynamic liability-driven investing" (DLDI) approach, where the *liability-driven investing* (LDI) element reflects the need to frame the pension fund portfolio strategy in terms of two main building blocks, the safe LHP and the risky PSP, and where the *dynamic* element suggests that this split should evolve over time as a function of changes in market conditions and also as a function of prudential risk budgets defined by the regulators, who have increased their focus with respect to minimum funding ratio levels.

In the view of such profound changes, the purpose of this survey is to assess the views of pension funds, ALM consultants and sponsor companies as they relate to their reactions to DLDI strategies and their desire to integrate this approach into their processes. This document contains two separate sections: the first will provide background information for the survey, notably including an overview of the main conceptual and technical foundations

for LDI strategies and their extensions in terms of *integrated* LDI and *dynamic* LDI and strategies; the second section will contain an analysis of the responses to the survey itself, so as measure the rate of adoption of these changes, question the main approaches used by pension funds to implement them, and understand the hurdles in the adoption of these strategies by pension funds that are still reluctant to implement them.

<sup>1</sup> It is perhaps useful to emphasise at this point that the word "predictability" is somewhat of a misnomer here. The point is not so much about implementing high-frequency *tactical* adjustments to the strategic asset allocation decision based on *forecasts* for future realised returns on various asset classes. It is instead to implement *revisions* of the strategic asset allocation based on the evidence of changes in the *contemporaneous* values of risk and return parameters.

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# I. Conceptual Background



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The ambition of the conceptual background is not to provide a thorough technical treatment of all questions related to dynamic liability-driven investing (LDI) strategies. It is instead to provide an overview of the key conceptual challenges involved in this subject. We refer interested readers to the articles referenced hereafter, and in particular to Martellini and Milhau (2009), Martellini and Milhau (2010a, 2010b), Martellini, Milhau and Tarelli (2012) and Deguest, Martellini and Milhau (2013), for further information regarding any detailed aspect they might be interested in, including technical details and proofs of some of the stated results.

The remainder of the Background section of the document is as follows. We first analyse the impact of the presence of pension liabilities in the design of the pension fund investment strategy. This analysis will focus on the *liability-driven investing* (LDI) paradigm, which we will first present in its standard form, before discussing one important extension, based upon a proper explicit treatment of the presence of the sponsor company for corporate pension plans in the context of a comprehensive integrated (as opposed to isolated) LDI framework. This analysis builds upon an analysis of pension claims as defaultable claims on the underlying value of the sponsor company.

In a second step, we analyse the impact of long horizons on pension plan portfolio strategies, distinguishing between the need to periodically revise the composition of, and allocation to, the risky and safe building blocks as a function of changes in market conditions, and the need to hedge against unexpected changes in the risk premia to

be expected from investing in risky asset classes. We refer to the proper integration of these two elements within a pension fund portfolio strategy as the *life-cycle investing* (LCI) paradigm.<sup>2</sup>

In a third and last step dedicated to the so-called *risk-controlled investing* (RCI) paradigm, we analyse the impact of the presence of short-term risk constraints either imposed by the regulator or self-imposed by fund managers. The last two sections provide two independent motivations (namely reacting to changes in market conditions versus reacting to changes in outstanding risk budgets) for moving away from static LDI strategies and adopting truly dynamic LDI strategies, which lie at the core of the modern approach to pension fund investing.

<sup>2</sup> While this terminology is perhaps more naturally used in the context of individual investment decisions, and as such more meaningful for individual retirement accounts and defined-contribution plans versus collective investment decisions by defined-benefit pension plan assets, we use it in this document to refer to any long-term investment strategy that explicitly accounts for the presence of time horizon in asset allocation decisions.

## I.1 Accounting for Pension Liabilities via the Liability-Driven Investing Paradigm: From Asset Management to Asset-Liability Management

The first and most important dimension to take into account when dealing with pension fund investment problems is the impact of the presence of pension liabilities on the allocation strategy. This question has naturally raised substantial attention in academic research, where it has given rise to the emergence of two separate strands of the literature.

A first strand of the literature, mostly from the field of operations research, has focused on developing early comprehensive models of uncertainty in an ALM context, which have served a formal basis for the development of surplus optimisation methodologies. These methodologies have been developed within

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the stochastic programming approach to ALM, with early attempts by Kallberg *et al.* (1982), Kusy and Ziemba (1986), or Mulvey and Vladimirou (1992). This strand of the literature is relatively close to industry practice, with one of the first successful commercial multistage stochastic programming applications appearing in the Russell-Yasuda Kasai Model (Cariño *et al.* (1994, 1998), Cariño and Ziemba (1998)). Other successful commercial applications include the Towers Perrin-Tillinghast ALM system of Mulvey *et al.* (2000), the fixed-income portfolio management models of Zenios (1995) and Beltratti *et al.* (1999), and the InnoALM system of Geyer *et al.* (2008). A good number of applications in asset-liability management are provided in Ziemba and Mulvey (1998) and Ziemba (2003). In most cases, stochastic programming models require the uncertainties be approximated by a scenario tree with a finite number of states of the world at each time. Important practical issues such as transaction costs, multiple state variables, market incompleteness due to uncertainty in liability streams that is not spanned by existing securities, taxes and trading limits, regulatory restrictions and corporate policy requirements can be handled within the stochastic programming framework. However, this additional flexibility comes at the cost of tractability. Analytical solutions are not possible, and stochastic programming models need to be solved via numerical optimisation.

On the other hand, several researchers in finance have attempted in parallel to cast the ALM problem in a stylised continuous-time framework, and extend Merton's intertemporal selection analysis (see Merton (1969, 1971)) to account for the presence of

liability constraints in the asset allocation policy. A first step in the application of optimal portfolio selection theory to the problem of pension funds has been taken by Merton (1990) himself, who studies the allocation decision of a University that manages an endowment fund. In a similar spirit, Boulier *et al.* (1995) have formulated a continuous-time dynamic programming model of pension fund management, which contains some of the basic elements for modelling dynamic pension fund behaviour, and can be solved by means of analytical methods (see also Siegmann and Lucas (2002)). Rudolf and Ziemba (2004) extend these results to the case of a time-varying opportunity set, where state variables are interpreted as currency rates that affect the value of the pension's asset portfolio. Also related is a paper by Sundaresan and Zapatero (1997), which is specifically aimed at asset allocation and retirement decisions in the case of a pension fund. More recently, Detemple and Rindisbacher (2008), Martellini and Milhau (2009), Martellini, Milhau and Tarelli (2012) and Deguest, Martellini and Milhau (2013) have analysed pension fund investment strategies in a continuous-time setting and in the presence of short-term risk constraints. This continuous-time stochastic control approach to ALM is appealing because it enjoys the desirable property of tractability and simplicity, allowing one to fully and explicitly understand the various mechanisms affecting the optimal allocation strategy. However, because of the simplicity of the modelling approach, such continuous-time models do not allow for a full and realistic account of uncertainty facing institutions in the context of ALM. In an attempt to circumvent the concern of the back-box flavour of stochastic programming

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models, while preserving some of the core insights obtained with the continuous-time models, it is feasible to test for the optimality of various rule-based strategies within the context of a comprehensive and realistic ALM model (see for example Mulvey *et al.* (2005)). As a result, these two approaches can be perceived more as complementing each other, as opposed to competing with one another.

The most useful insight to be obtained from the continuous-time stochastic control approach to ALM is undoubtedly the existence of a *fund separation theorem*. This fund separation theorem in ALM provides formal justification for the LDI approach to ALM, which has rapidly gained interest with pension funds, insurance companies, and investment consultants alike. While they can vary significantly across providers, LDI solutions typically involve a focus on matching the risk exposures of the pension liabilities within the pension fund asset portfolio via dedicated fixed-income LHPs, while keeping some assets free for investing in higher yielding asset classes. In this context, surplus optimisation appears as a somewhat inefficient investment approach which can be regarded as an attempt at *diversifying* liability risk away, while the proper way to manage liability risk is to *hedge* it away. On the other hand, if a dedicated LHP is added to the menu of risky assets within a stochastic programming surplus optimisation model, then the insights obtained are broadly consistent with the LDI paradigm.

## I.1.1 Introducing the Basic LDI Paradigm

The LDI paradigm prescribes that investors endowed with liability-driven objectives need to invest in two distinct portfolios,

in addition to the risk-free asset, which can always be held long or short (in the latter case, we obtain a *leveraged* version of the LDI strategy): one well-diversified PSP, needed to generate access to risk premia; and one LHP, needed to hedge against unpredictable changes in risk factors that impact pension liability values. The presence of these two portfolios reflects the dual focus in investment management namely, on the one hand, the desire to generate performance so as to alleviate the burden on contributions, and on the other hand, the need for safety. Overall, the basic LDI paradigm is defined in terms of three main ingredients, a safe LHP – a risky PSP, and an allocation to these two building blocks as well as the risk-free asset.

### *I.1.1.1 Designing Meaningful Liability-Hedging Portfolios*

Risk diversification is only one possible form of risk management, focusing merely on achieving the best risk/return trade-off regardless of investment objectives and constraints. However, it should be recognised that diversification is simply not the appropriate tool when it comes to protecting long-term liability needs. In particular, it is clear that the risk factors impacting pension liability values should be hedged rather than diversified away. Three of these factors stand out (namely interest rate risk, credit risk and inflation risk).

#### I.1.1.1.1 Matching Interest Rate Risk Exposures of the Liabilities

A first approach to interest rate risk management for pension funds, known as *cash-flow matching*, involves ensuring a perfect static match between the cash flows from the asset portfolio and the pension commitments on the liability side. Let us

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assume for example that a pension fund has a commitment to pay out a monthly pension to a number of retirees. Leaving aside the complexity relating to the uncertain life expectancy of the retirees, the structure of the liabilities is defined simply as a series of cash outflows to be paid, the value of which is known today if we assume away inflation indexation (see Section I.1.1.1.3.). It is possible, in theory, to construct a portfolio of assets which will have future cash flows identical to this structure of pension liability commitments. To do so (assuming that securities of that kind exist on the market) would involve purchasing pure discount bonds with a maturity corresponding to the dates on which the monthly pension instalments are paid out, with amounts that are proportional to the amount of the pension commitments.

This technique, which provides the advantage of simplicity and allows, in theory, for perfect risk management, nevertheless presents at least two main limitations from a practical perspective. First of all, it will generally prove impossible to find fixed-income instruments whose maturity dates correspond exactly to the dates of the pension payments. Moreover, most of those securities pay out coupons, thereby leading to the problem of reinvesting the coupons. To the extent that perfect matching is not possible, pension fund managers can resort to a technique called *immunisation*, which allows the residual interest rate risk created by the imperfect match between the assets and liabilities to be managed in a dynamic way. Broadly speaking, the key difference is that immunisation strategies aim at ensuring a match between factor exposures on the asset and liability sides, which is a weaker requirement than ensuring a

match between cash-flow payments; in other words cash-flow matching obviously implies interest rate exposure matching, while the converse is not true.

While the most basic form of implementation of the immunisation approach can be performed in terms of duration matching, the interest rate risk management technique extends to more general contexts, including for example hedging larger changes in interest rates (through the introduction of a convexity adjustment) or hedging against changes in the shape of the yield curve (see for example Fabozzi, Martellini and Priaulet (2005) for interest rate risk management in the presence of non-parallel yield curve shifts).

It should be noted that these approaches can be implemented either via cash instruments, typically sovereign bonds, or via derivatives such as interest rates swaps or futures contracts. The use of derivatives can prove a useful way to implement a leveraged version of the strategy, whereby 100% of the assets of the pension plan can be dedicated to liability hedging while still leaving some non-zero access to the upside potential of risk assets.

## I.1.1.1.2. Matching Credit Risk Exposures of the Liabilities

According to international accounting standards SFAS 87.44 and IAS 19.78, which recommend that pension obligations be valued on the basis of a discount rate equal to the market yield on AA bonds, the most straightforward way for pension funds to match liability payments is actually to build a portfolio of long-dated, investment grade corporate bonds, as opposed to sovereign bonds. The fact that liabilities are discounted

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at the risk-free rate plus a credit spread implies that the regulatory value of pension liabilities is impacted by the presence of unexpected changes in credit spreads, in addition to unexpected changes in interest rates. It also implies that a portfolio of AA corporate bonds hedge liability risk better than sovereign bonds do, precisely because their yield includes a credit spread component that evolves in line with the discount rate on liabilities.<sup>3</sup> It should be emphasised, however, that pension funds need dedicated corporate bond portfolios, as opposed to off-the-shelf corporate bond indices. Indeed, there is an inherent conflict of interest between issuers and investors about the duration of corporate bonds, which is known as the duration problem. Each pension fund has a need for a specific time horizon equal to the duration of its pension liabilities, and there is no reason to expect that these needs correspond to the optimal financing plan of the issuers. For pension funds that have some fixed typically long-term liabilities originating from their defined-benefit (DB) plans, long-term bonds are a much better hedge than short-term debt. On the other hand, the duration structure of outstanding bonds reflects the preferences of the issuers in their aim to minimise the cost of capital. Since the duration of the indices is nonetheless a result of the sell-side of corporate bonds, corporate bond indices are typically not well suited to serving as benchmarks for liability-driven investors. More worrisome perhaps, is that the characteristics of corporate bond indices can change unpredictably over time (see Campani and Goltz (2011)). In this context, efforts are required to design stable corporate bond indices optimised in an attempt not only to maximise their risk-adjusted performance but also to

achieve a target duration and rating class composition over time.

## I.1.1.1.3. Matching Inflation (and Expected Inflation) Risk Exposures of the Liabilities

Liabilities of DB pension funds often include a clause of indexation on consumer prices or wage levels. The presence of uncertainty in future prices and wages raises the problem of finding appropriate hedging instruments for these risks. The theoretical cash-flow matching portfolio consists of a set of pure discount bonds with maturities and face values matching the liability commitments, and a principal repayment indexed on the reference index. However, this strategy is hard to set up in practice, for various reasons. First, as far as wage inflation is concerned, perfectly indexed financial securities may not exist. Second, for consumer price inflation, although inflation-indexed bonds are available, mainly issued by sovereign states, the market may not have the sufficient capacity to meet the demand from institutional investors. In this context, OTC derivatives (such as inflation swaps) can be used as substitutes for indexed bonds, but they involve a counterparty risk that not all institutional investors are willing to bear. The practical difficulties encountered in the construction of a cash-flow matching portfolio motivate the search for asset classes with good inflation-hedging properties. A vast empirical literature has examined the inflation-hedging ability of traditional and alternative asset classes, but the results are mixed. Broad stock and bond indices are not good inflation hedgers in the short run (see Hoevenaars *et al.* (2008) and Martellini and Milbau (2013)), and individual stocks have highly time-varying inflation betas, making their

<sup>3</sup> – While this analysis suggests that corporate bonds are attractive additions to pension fund LHPs, it should be noted that corporate bonds are also useful within PSPs because of their diversification benefits with respect to other asset classes, and also because of the access they offer to the credit risk premium.

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inflation-hedging properties difficult to forecast. Conclusions are more positive for commodities, which display good correlation with inflation at all horizons (see Hoevenaars *et al.* (2008), Amenc *et al.* (2009)).

However, the quest for inflation-hedging assets should not divert investors from the construction of an LHP. In fact, liability hedging and inflation hedging are two objectives that should not be confused in general, even for inflation-indexed liabilities. When liability maturity approaches zero, the discount factor is close to one, so the present value of promised payments almost coincides with the payment itself, and hedging liability risk and hedging realised inflation risk are two equivalent objectives. On the other hand, for a mature pension fund, with long-term commitments, liability maturity is long, so value of liabilities largely depends on the interest rate. Martellini and Milhau (2013) show that in this context, interest rate risk accounts for the largest part of total liability risk, a fraction which is growing in the maturity. The practical implication of this finding is that the LHP should not merely be an inflation-hedging portfolio, but should contain a substantial fraction of bonds, which are assets with easily measurable interest rate exposure. Failing to include them in the LHP leaves a large part of liability risk unhedged, which leads to funding ratio high volatility, and makes it more difficult to respect the short-term funding constraints imposed by many regulations and otherwise scrutinised by stakeholders of the pension plan (trustees, CFO of the sponsor company, etc.).

A further difficulty arises if one takes into account the difference between nominal

and real interest rates. Indeed, the interest rate risk present in inflation-linked liabilities is real interest rate risk, while nominal bonds are by definition hedgers for nominal interest rate risk. This difference would not be a problem if the breakeven inflation rate, that is the nominal rate minus the real rate, were constant, but the fact that it is time-varying implies that nominal bonds do not perfectly hedge real rate risk. In mathematical terms, the investor faces a duration mismatch problem: nominal bonds have non-zero duration with respect to expected inflation, while this duration is zero for indexed bonds (Fabozzi and Xu (2012)). The risk is thus to experience a rise in expected inflation with a constant real rate, which will lead to a bear market for nominal bonds, while liability value will remain constant. The potential result is a drop in the funding ratio.

As a conclusion, the construction of an LHP for inflation-linked liabilities in the absence of perfectly indexed securities is a non-trivial problem, which requires finding assets with satisfactory inflation-hedging properties, and mixing them with bonds to hedge interest rate risk.

## *I.1.1.2 Designing Meaningful Performance-Seeking Portfolios*

The purpose of the LHP is to provide *hedging* with respect to changes in the liability value. If 100% of the portfolio is invested in the LHP, and if the LHP is a perfect hedging portfolio for the liabilities, then the current funding ratio will be locked forever, with no relative upside potential with respect to the value of the liabilities in the absence of additional contributions. Given the need to alleviate the required burden on contributions, it is in general

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desirable for pension funds to allocate a non-vanishing fraction of their assets to a PSP, in an attempt to benefit from risk premia on risky assets across financial markets.

*Diversification* (as opposed to *hedging*, which is used to manage liability risk, or *insurance*, which is used to manage short-term risk constraints – see Section I.3) is the risk management technique that allows investors to efficiently extract long-term risk premia out of performance-seeking assets. Indeed, by holding well-diversified portfolios, investors may be able to eliminate or at least reduce (*diversify away*) unrewarded risk in their portfolios, which allows them to enjoy higher rewards per unit of risk, and therefore a higher average funding ratio at horizon for a given risk budget.

<sup>4</sup> – See Deguest, Martellini and Meucci (2013) for a detailed introduction to factor risk parity strategies based on a formal analysis of what is the true meaning of "many" and "baskets".

## I.1.1.2.1. Portfolio Diversification and the Quest for Efficient Portfolios

While the benefits of diversification are intuitively clear, there is no straightforward definition of what exactly a well-diversified portfolio is. The most common intuitive explanation of *naive* diversification is that it is the practice of not "putting all eggs in one basket". Having eggs (dollars) spread across many baskets is, however, a rather loose prescription.<sup>4</sup> It should be noted, fortunately, that a fully unambiguous definition of *scientific* diversification has been provided by modern portfolio theory: more precisely, the prescription is that the PSP should be obtained as the result of a portfolio optimisation procedure aiming to generate the highest risk-reward ratio. Portfolio optimisation is a straightforward procedure, at least in principle. In a mean-variance setting, for example,

the prescription consists of generating a maximum Sharpe ratio (MSR) portfolio based on expected return, volatility, and pairwise correlation parameters for all assets to be included in the portfolio. One key issue is the presence of estimation risk in parameter estimates, which is particularly true for expected return parameters (see Merton (1980)). Once a set of input parameters are given, the optimisation procedure can be handled analytically in the absence of portfolio constraints, as can be seen in the material contained in the "technical material" box below. More generally, it can be handled numerically in the presence of minimum and maximum weight constraints. Introducing weight constraints can actually be regarded as a way to reduce estimation risk (see for example Jagannathan and Ma (2003)).

The mathematical expression for the MSR portfolios shown in the "technical material" box below is useful because, in principle, it provides a straightforward expression for the optimal portfolio starting from a set of  $N$  risky assets. In the presence of a realistically large number  $N$  of securities, the curse of dimensionality, however, makes it practically impossible for investors to implement such direct one-step portfolio optimisation decisions involving all individual components of the asset mix.

## I.1.1.2.2 Portfolio Diversification Across and Within Asset Classes

The standard alternative approach widely adopted in investment practice consists instead of first grouping individual securities in various asset classes as well as sub-classes according to various dimensions, e.g. country, sector, and/or style within the equity universe, or country, maturity, and credit rating within the bond universe,

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## Technical Material

We assume that the investor is facing the following investment opportunity set: a riskless asset paying the risk-free rate  $r_f$  and a set of  $N$  risky assets with expected return vector  $\mu$  (of size  $N$ ) and covariance matrix  $\Sigma$  (of size  $N \times N$ ), all assumed constant so far. Consider the portfolio Sharpe ratio (where we further let  $e$  be a vector of ones of size  $N$ ):

$$SR_p = \frac{\mu_p - r_f}{\sigma_p} = \frac{w'(\mu - re)}{(w'\Sigma w)^{1/2}}$$

where  $w$  is the vector of optimal weight allocated to various risky assets,  $\mu_p$  is the portfolio expected return, and  $\sigma_p$  the portfolio volatility.

With these notations, the portfolio expected return and volatility respectively are given by:

$$\begin{aligned}\mu_p &= w'(\mu - re) + r_f \\ \sigma_p^2 &= w'\Sigma w\end{aligned}$$

In this context, it is straightforward to show that the weight vector of the maximum Sharpe ratio PSP, also known as the tangency portfolio, is given by:

$$w^{PSP} = \frac{\Sigma^{-1}(\mu - r_f e)}{e'\Sigma^{-1}(\mu - r_f e)}$$

and subsequently generating the optimal portfolio through a two-stage process. On the one hand, investable proxies are generated for MSR portfolios within each asset class in the investment universe. We call this step, which is typically delegated to professional money managers, the *portfolio construction step*. While market cap indices are natural default choices as asset class benchmarks, academic and industry research has offered convincing empirical evidence that these indices tend to exhibit a poor risk-adjusted performance, because of the presence of an excessive amount of unrewarded risk due to their extreme concentration in the largest cap securities in a given universe, as well as the absence of a well-managed set of exposures with respect to rewarded risk factors (for example, cap-weighted indices have a natural large cap and growth bias, while academic research (e.g. the seminal work by

Fama and French (1992) has found that small cap and value were instead the positively rewarded biases). The combination of these empirical and theoretical developments has significantly weakened the case for market cap-weighted indices (Amenc, Goltz and Le Sourd (2006)), and a consensus is slowly but surely emerging regarding the inadequacy of market cap-weighted indices as efficient investment benchmarks. In this context, a new paradigm known as smart beta equity investing has been proposed, the emergence of which blurs the traditional clear-cut split between active versus passive equity portfolio management (see for example Amenc *et al.* (2012)).

After efficient benchmarks have been designed for various asset classes, these building blocks can be assembled in a second step, the asset allocation step, to build a well-designed multi-class PSP.

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Although the same methodologies can in principle be applied in both portfolio construction and asset allocation contexts, a number of key differences should be emphasised. In particular, the number of constituents (asset classes) is small in the asset allocation context, and the curse of dimensionality is not as problematic. In this context, attempts to capture time- and state-dependencies in risk and return parameters using sophisticated covariance matrix estimates based on GARCH or Markov Regime Switching models are legitimate and likely to add value (e.g. Ang and Bekaert (2002)). On the other hand, such refinement does not necessarily improve the situation in portfolio construction contexts, in which the number of constituents is large, as they lead to an additional increase in the number of parameters to estimate.

Similarly, although it is not in general feasible to perform portfolio optimisation with higher-order moments in a portfolio construction context, due to the dramatic increase in the number of parameters to estimate (co-skewness and co-kurtosis parameters, in addition to covariance parameters), it is feasible to go beyond mean-variance analysis in an asset allocation context, in which the number of constituents is limited (Martellini and Ziemann (2010)).

## I.1.1.2.3 From Asset Allocation to Risk Allocation

It should be noted that an interesting new framework, known as *risk allocation* framework, is currently gaining popularity among large sophisticated pension funds as a modern approach to the design of PSPs. This trend is related to the recognition, supported by recent research (e.g. Ang

*et al.* (2009)), that risk and allocation decisions could be best expressed in terms of rewarded risk factors, as opposed to standard asset class decompositions, which can be somewhat arbitrary. For example, convertible bond returns are subject to equity risk, volatility risk, interest rate risk and credit risk. As a consequence, analysing the optimal allocation to such hybrid securities as part of a broad bond portfolio is not likely to lead to particularly useful insights. Conversely, a seemingly well-diversified allocation to many asset classes that essentially load on the same risk factor (e.g. equity risk) can eventually generate a portfolio with very concentrated risk exposure. More generally, given that security and asset class returns can be explained by their exposure to pervasive systematic risk factors, looking through the asset class decomposition level to focus on the underlying factor decomposition level appears to be a perfectly legitimate approach, which is supported by standard asset pricing models such as the intertemporal CAPM (Merton (1973b)) or the arbitrage pricing theory (Ross (1976)). Asset pricing theory also suggests that factors are (positively) rewarded if and only if they perform poorly during bad times, and more than compensate during good times so as to generate a positive excess return on average across all possible market conditions.

In academic jargon, the expected excess return on a factor is proportional to the negative of the factor covariance with the *pricing kernel*, given by marginal utility of consumption for a representative agent (see for example Cochrane (2000) for more details). Hence, if a factor generates an uncertain pay-off that is uncorrelated to

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the pricing kernel, then the factor will earn no reward even though there is uncertainty involved in holding the pay-off. On the other hand, if a factor pay-off co-varies positively with the pricing kernel, it means that it tends to be high when marginal utility is high, that is when economic agents are relatively poor. Because it serves as a hedge by providing income during bad times, when marginal utility of consumption is high, investors are actually willing to pay a premium for holding this pay-off. Standard examples of such rewarded factors in the equity space are the "HML" or "value" factor (represented by a portfolio going long value stocks and short growth stocks) and the "SMB" or "size" factor (represented by a portfolio going long small cap stocks and short large cap stocks), which can be regarded as possible proxies for a "distress" factor (Fama and French (1992)).

In this context, one can argue that the ultimate goal of portfolio construction techniques is to invest in risky assets so as to ensure an efficient diversification of specific and systematic risks within the portfolio. Note that the word "diversification" is used with two different meanings. When the focus is on the diversification of specific risks, "diversification" means *reduction* of specific risk exposures, which are not desirable because they are not rewarded. On the other hand, when the focus is on the diversification of systematic risks, "diversification" means *efficient allocation* to factors that bear a positive long-term reward, with modern portfolio theory suggesting that efficient allocation is in fact maximum risk-reward allocation (maximum Sharpe ratio in a mean-variance context). If the whole focus of portfolio construction is ultimately to harvest risk premia that can

be expected from holding an exposure to rewarded factors, it seems natural indeed to express the allocation decision in terms of such risk factors. In this context, the term "factor allocation" is a new paradigm advocating that investment decisions should usefully be cast in terms of risk factor allocation decisions, as opposed to asset class allocation decisions, which are based on somewhat arbitrary classifications. A second interpretation for what the *risk allocation paradigm* might mean is to precisely define it as a portfolio construction technique that can be used to estimate what an efficient allocation to underlying components (which could be asset classes or underlying risk factors) should be. The starting point for this novel approach to portfolio construction is the recognition that a heavily concentrated set of risk exposures can be hidden behind a seemingly well-diversified allocation. In this context, the risk allocation approach to portfolio construction, also known as the risk budgeting approach, consists in advocating a focus on risk, as opposed to dollar, allocation. In a nutshell, the goal of the risk allocation methodology is to ensure that the contribution of each constituent to the overall risk of the portfolio is equal to a target risk budget. In the specific case when the allocated risk budget is identical for all constituents of the portfolio, the strategy is known as *risk parity*, which stands in contrast to an equally-weighted strategy that would recommend an equal contribution in terms of dollar budgets (see Roncalli (2013) for further details). To better understand the connection between this portfolio construction technique and standard recommendations from modern portfolio selection techniques, it is useful to recognise that, when applied

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to uncorrelated factors, risk budgeting is consistent with mean-variance portfolio optimisation under the assumption that Sharpe ratios are proportional to risk budgets.<sup>5</sup> Thus, risk parity is a specific case of risk budgeting, a natural neutral starting point that is consistent for uncorrelated factors with Sharpe ratio optimisation assuming constant Sharpe ratios at the factor level.

Overall, it appears that risk allocation can be thought of as *both* a new investment paradigm advocating a focus on allocating to uncorrelated rewarded risk factors, as opposed to correlated asset classes, and a portfolio construction technique stipulating how to optimally allocate to these risk factors (see Amenc and Martellini (2014) for a discussion). It should be noted in closing that the existence of uncorrelated long-short factor-replicating portfolios is *not* a necessary condition to perform risk budgeting, which is fortunate since such uncorrelated pure factors are hardly investable in practice. Indeed, one can use any set of well-diversified portfolios as constituents, as opposed to factor-replicating portfolios, thus leaving the hurdle to reach target factor exposures until the asset allocation stage. For example, Amenc, Deguest and Martellini (2013) use long-only factor-tilted smart beta benchmarks as constituents and choose the allocation to these constituents so as to ensure that the contribution of standard rewarded equity factors to the tracking error of the portfolio with respect to the cap-weighted benchmark are all equal.

In the end, two main benefits can be expected from shifting to a representation expressed in terms of risk factors, as opposed

to asset classes. On the one hand, allocating to risk factors may provide a cheaper, as well as more liquid and transparent, access to underlying sources of returns in markets where the value added by existing active investment vehicles has been put in question. For example, Ang *et al.* (2009) argue in favour of replicating mutual fund returns with suitably designed portfolios of factor exposures such as the value, small cap and momentum factors. On the other hand, allocating to risk factors should provide a better risk management mechanism, in that it allows investors to achieve an ex-ante control of the factor exposure of their portfolios, as opposed to merely relying on ex-post measures of such exposures.

Therefore, while working at the level of underlying risk factors that impact/explain the returns on all asset classes appears to be an intuitively meaningful approach, the practical challenges of this paradigm shift for the organisation of the asset allocation processes are substantial, and more work is needed to turn this paradigm into a fully-operational approach that can be used by pension funds to construct their PSP.

## I.1.1.3 Designing Meaningful Allocation to PSP and LHP Portfolios

Once the PSP and LHP have been carefully designed, using some of the aforementioned portfolio construction techniques, the next step is to determine what percentage of the pension fund asset should be allocated to each one of these building blocks. Portfolio theory provides useful guidance with respect to the question of the optimal allocation to the safe LHP versus risky PSP building blocks, as can be seen in the "Technical Material" box below.

<sup>5</sup> – Orthogonalising the factors is useful to avoid the arbitrary attribution of overlapping correlated components in the definition of risk budgets allocated to each of these factors. Principal component analysis (PCA) can be used to extract uncorrelated versions of the factors starting from correlated asset or factor returns (see for example Deguest, Martellini and Meucci (2013)). Alternatively, to avoid the difficulties related to the lack of stability and interpretability of principal components, and to generate uncorrelated factors that are as close as possible to the original assets or factors, one can use the minimal linear torsion (MLT) approach recently introduced in Meucci *et al.* (2013).

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## Technical Material

In what follows, we assume that the pension fund manager has access to  $N$  risky assets and one risk-free asset paying the interest rate  $r$ , assumed to be constant for simplicity. We let  $S_t$  be the  $N \times 1$  vector of risky asset prices and  $B_t$  be the price of the risk-free asset. The dynamics of these prices are given by:

$$\begin{cases} dS_t = \text{diag}(S_t)[(re + \sigma_s^\top \lambda_s)dt + \sigma_s^\top dz_t] \\ \frac{dB_t}{B_t} = rdt \Leftrightarrow B_t = B_0 e^{rt} \end{cases}$$

In these equations,  $z$  is a standard  $N$ -dimensional Brownian motion process,  $\text{diag}(S_t)$  is the diagonal matrix of risky asset prices,  $\lambda_s$  is the price of risk vector for the  $N$  assets and  $\sigma_s$  is the volatility matrix. The investor needs to finance the payment of a liability portfolio whose value is modelled here as an exogenous geometric Brownian motion process:<sup>6</sup>

$$dL_t = L_t [\mu_L dt + \sigma_L^\top dz_t]$$

Let  $w_t$  be the  $N \times 1$  vector of weights invested in the risky assets on date  $t$  and  $e$  be the vector of ones of the same size. The asset value process for a given (self-financed) portfolio strategy is given by:

$$dA_t = A_t \left[ w_t^\top \frac{dS_t}{S_t} + (1 - w_t^\top e) \frac{dB_t}{B_t} \right] = A_t [(r + w_t^\top \sigma_s^\top \lambda_s)dt + w_t^\top \sigma_s^\top dz_t]$$

We also assume that pension fund manager seeks to find the allocation strategy that generates the highest expected value for the funding ratio at some horizon (e.g. taken to be the duration of the liabilities) for a given uncertainty over the distribution of the funding ratio. Such a risk-return trade-off in terms of returns relative to the pension liabilities (as opposed to a trade-off expressed in terms of absolute returns) can be captured within a standard expected utility maximisation framework: we use *constant relative risk aversion* (CRRA) preferences represented by the following utility function  $u(x) = x^{1-\gamma}/(1-\gamma)$ , where  $\gamma$  is the relative risk aversion coefficient. In this context, the optimal allocation strategy is given by:

$$\max_{(w_t)} E \left[ u \left( \frac{A_T}{L_T} \right) \right] \Rightarrow w_t^* = \frac{\lambda}{\gamma \sigma} w^{PSP} + \left( 1 - \frac{1}{\gamma} \right) \beta w^{LHP} \quad (1)$$

Here, the *PSP* is again the portfolio that achieves the highest Sharpe ratio, and we let  $\lambda$  be its Sharpe ratio and  $\sigma$  its volatility. The *LHP* is the portfolio that achieves the highest correlation with the liability process and  $\beta$  is the beta of changes in the liability portfolio value with respect to changes in the LHP value.

The proof of this result can be obtained by applying the martingale approach of Cox and Huang (1989).<sup>7</sup> First, the dynamic portfolio problem is mapped into a static problem where the control variable is the terminal wealth:

$$\max_{A_T} E \left[ \left( \frac{A_T}{L_T} \right) \right], \quad \text{s.t. } E[M_T A_T] = A_0$$

<sup>6</sup> – For defined-benefit pension funds, the liability process  $L$  can be endogenously identified as the present value of future liability payments (see for example Martellini and Milhau (2009)).

<sup>7</sup> – For notational simplicity, we present the proof in the case in which the market is dynamically complete (i.e. the volatility matrix  $\sigma_s$  is square and invertible). The result is not impacted by this assumption; the proof in the general case of a possibly incomplete market would proceed exactly as in the complete case, up to some notational modifications (see He and Pearson (1991) for a presentation of the martingale approach in incomplete markets).

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where  $M_T$  is the pricing kernel:

$$M_T = \exp\left[-\left(r + \frac{\|\lambda_s\|^2}{2}\right)T - \lambda_s' z_T\right]$$

The optimal terminal wealth reads:

$$A_T^* = \frac{A_0}{E\left[(M_T L_T)^{1-\frac{1}{\gamma}}\right]} M_T^{-\frac{1}{\gamma}} L_T^{1-\frac{1}{\gamma}}$$

and the optimal wealth process is:

$$A_t^* = \frac{A_0}{E\left[(M_T L_T)^{1-\frac{1}{\gamma}}\right]} E_t\left[\left(\frac{M_T L_T}{M_t L_t}\right)^{1-\frac{1}{\gamma}}\right] M_t^{-\frac{1}{\gamma}} L_t^{1-\frac{1}{\gamma}}$$

Applying Ito's lemma to both sides of this equality and matching the diffusion terms, one obtains the optimal portfolio (see Martellini and Milhau (2009) for more details).

<sup>8</sup> – As recalled previously, leverage is often implemented through derivatives based matching of interest rate (and potentially inflation) risk exposures within the LHP.

The expression in Equation (1) for the optimal portfolio strategy is known as a *fund separation theorem* in asset pricing theory. In this expression, the allocation to the "risky" building block appears to be an increasing function of the PSP Sharpe ratio, denoted by  $\lambda$ , and a decreasing function of the PSP volatility, denoted by  $\sigma$ , as intuitively expected. The allocation to the "safe" building block, on the other hand, is an increasing function of the beta  $\beta$  of liability portfolio with respect to the LHP. If there is an asset portfolio that perfectly matches the liability portfolio, then the beta is 1.

Overall, the allocation to the performance-seeking portfolio is not only a function of objective parameters, the PSP volatility and Sharpe ratio and the beta of the LHP with respect to the liabilities, but it is also a function of one subjective parameter, the investor's risk aversion  $\gamma$ . As expected, the optimal allocation to the PSP should be inversely proportional to the investor's risk aversion. If risk aversion rises to infinity,

the investor only holds the safe LHP. This is consistent with the intuition that for an investor facing liability commitments the LHP, as opposed to cash, is the true risk-free asset. On the other hand, cash is still used to make the balance (if non-zero) between the total amount invested in the PSP and LHP building blocks and the pension fund assets. In case, a short position in cash is obtained, then the pension fund is implementing a leverage version of the LDI strategy.<sup>8</sup> It is important at this stage to emphasise that the risk aversion parameter is not observable, and not even well-defined for institutional investors; it should in fact be treated as a *degree of freedom* which value can be inferred from a given risk budget, often expressed in terms of expected shortfall with respect to liabilities.

## I.1.2 From Isolated to Integrated LDI

One of the limitations of the analysis presented thus far is that it has a sole focus on the pension fund situation, taken somewhat in isolation. This is a severe simplification in particular for corporate

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pension plans, where it is expected that the presence of the sponsor company can help solve underfunding problems through additional contributions if and when needed. Conversely, one of the main risks for plan participants, actually the only source of uncertainty for a DB plan with unconditional liability payments, is that of sponsor bankruptcy when the pension plan is underfunded. In an attempt to address this concern, a number of dramatic changes have occurred over the past few decades in the legal, regulatory, accounting and fiscal environments of corporate pension funds. These changes which have collectively led to significantly-heightened scrutiny over the valuation of pension liabilities, with a focus on greater transparency in terms of the impact of both the market and credit risk components on pension obligation values.

Correctly assessing the value of a pension plan in deficit with a weak sponsor company remains, however, a real challenge given that no comprehensive model is currently available for the joint quantitative analysis of capital structure choices, pension fund allocation decisions and their impact on rational pricing of liability streams. In fact, international accounting standards SFAS 87.44 and IAS 19.78 recommend, as recalled in the Introduction, that pension obligations be valued on the basis of a discount rate equal to the market yield on AA corporate bonds, the same rate for all firms. While the use of a market rate is arguably a progress with respect to using a constant rate (including a credit spread component or not) independently of market conditions, the use of the same market rate to discount all pension liabilities regardless of the sponsor credit rating, pension funding

situations and asset allocation policy is not likely to lead to a correct assessment by the various stakeholders of the impact of specific default risk on the value of pension obligations.

This question can be addressed by recognising that pension liabilities can be regarded as defaultable claims issued by the sponsor company to workers and pensioners in the context of an integrated model of capital structure (Martellini and Milhau (2010b)). The analysis focuses on the interaction between the allocation decisions of the pension plan and the valuation of these liabilities, thereby extending the capital structure literature and the defaultable bond pricing literature to account for the presence of a pension plan. Such a model is a stylised representation of the relationships between various stakeholders of a company with a pension plan, notably including shareholders of the sponsor company, bondholders and beneficiaries of the pension fund (workers and pensioners).

The model can be summarised as follows. The sponsor company issues a debt with face value  $D$ , and also issues pension claims, perceived as a collateralised form of debt held by workers and pensioners with face value  $L$ . The initial capital of the firm is allocated to funding investment projects (company asset value denoted by  $V$ ) and to funding the pension plan (pension asset value denoted by  $A$ ). The pension fund allocates a fraction  $\omega$  of the initial endowment to some PSP and a fraction  $1-\omega$  to some LHP. In case the assets of the pension fund  $A$  are insufficient to deliver the promised pension payment  $L$ , the sponsor makes a contribution equal to

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the deficit  $L-A$ . If the sponsor is unable to make this contribution, default is triggered. If the pension fund enjoys a surplus, equity holders receive a fraction  $\gamma$  of this surplus, which can be used to pay back bondholders. If debt cannot be fully repaid, bankruptcy is also triggered. When default has not been triggered, equity holders are left with the remaining assets of the pension fund and the sponsor, plus their access to surpluses. Otherwise, they receive nothing. One can also incorporate tax effects, bankruptcy costs, as well as contributions triggered by the presence of regulatory funding ratio constraints.

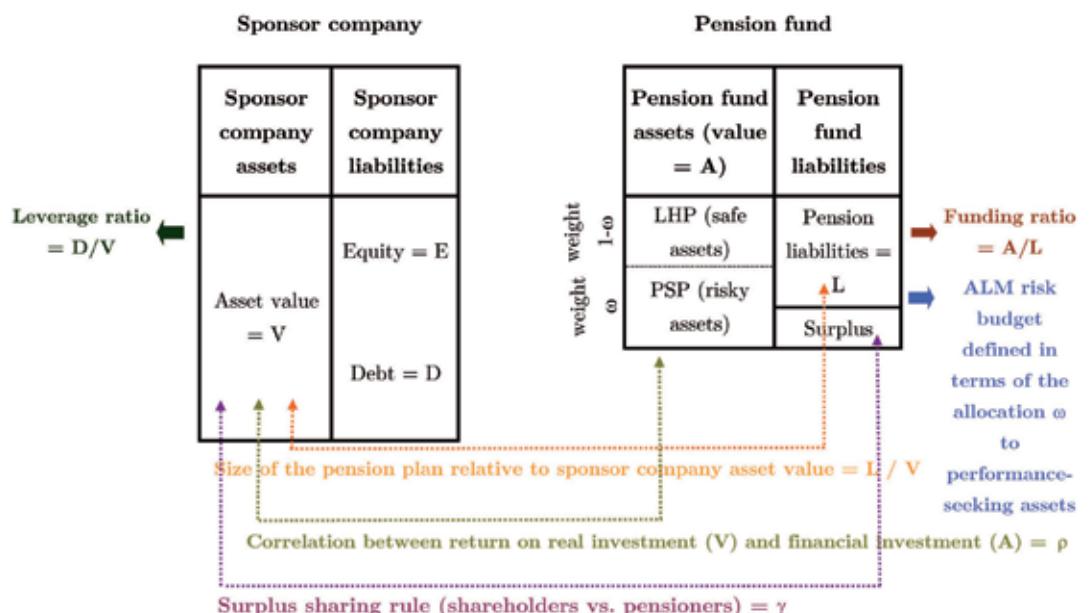
9 - Institutional elements such as those governing the surplus sharing rule, the tax rate and the bankruptcy costs will also have an impact on the numerical results.

Under standard assumptions regarding the dynamics followed by all variables of interest, including the return on the performance-seeking portfolio and the return on the real assets held by the firm, one can use option pricing theory to find the rational value of the claims held by all stakeholders, and also analyse the impact on the value of these claims of funding and leverage decisions at the sponsor company

level, as well as asset allocation decisions at the pension fund level. The main ingredients of the model are the size of the pension fund relative to the assets of the sponsor company ( $L/V$ ), the relative size of the pension assets with respect to the pension liabilities (a.k.a. the funding ratio  $A/L$ ), and the relative size of the outstanding debt of the sponsor company relative to the assets of the sponsor company (a.k.a. the leverage ratio  $D/V$ ). Other important parameters are those that define the allocation strategy of the pension fund, as well as the correlation between the return on pension assets and the return on the sponsor company assets (see Exhibit 1).<sup>9</sup>

These findings have two main kinds of implications, macro implications on the one hand, with a number of possible policy recommendations for pension fund regulators, and micro implications on the other hand, with a number of strategy recommendations for pension fund managers. Focusing on the latter dimension we analyse in what follows how

Exhibit 1: An integrated ALM framework



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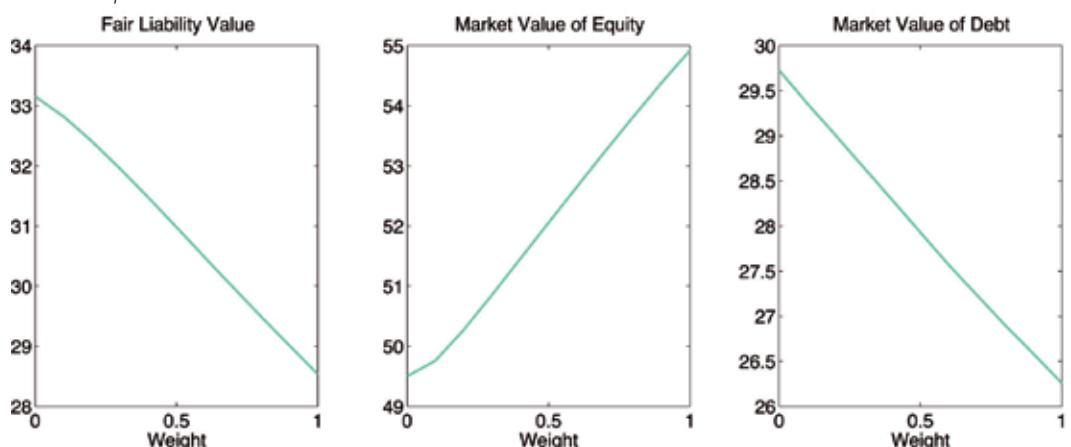
investment decisions at the pension level impact stakeholders' wealth.

When the correlation between the value of the firm process and the stock index return process is positive, we find that the fair value of promised payments to bondholders and pensioners is a decreasing function of the allocation to risky assets by the pension fund. This is a clear case of asset substitution, since a higher allocation to risky assets leads to an increase in the total riskiness of the total assets held by the firm (financial assets held off the balance sheet through the pension funds and real assets directly held on the balance sheet), which is the underlying state variable on which the value of such claims is based. When the correlation is negative, however, a higher allocation to risky assets may induce diversification benefits. This competition between the asset substitution effect and the diversification effect, which has never been analysed in the related literature, leads to an interior optimal solution with respect to maximising total firm value (and also with respect to maximising pensioners' value), at least for reasonably low funding ratios. Overall, there is in general clear evidence of conflicts of interest between the various

stakeholders, and in particular between shareholders and pensioners. Assuming they do not have access to any surplus of the pension fund, risk-taking is detrimental from the pensioners' perspective, because it involves increasing the likelihood of partial recovery of pension claims, while risk-taking allows shareholders to reduce the burden on contributions needed to meet expected pension payments due to exposure to the upside potential of the performance-seeking assets (see Exhibit 2).

These conflicts of interest could be mitigated by granting pensioners some partial access to the surplus (see conditional indexation rules in the Netherlands), thereby allowing plan beneficiaries to benefit from the increases in expected performance related to more aggressive investment strategies. More generally, our results have implications in terms of the optimal design of pension plans, since they advocate the emergence of more subtle surplus sharing rules, which could include for example the use of hybrid retirement plans, and/or the use of contribution holidays for DB plans, that would allow equity holders to reduce the burden of contributions while protecting the interests of pensioners.

*Exhibit 2: Impact of allocation decisions on stakeholders' welfare.*



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We also find that an effective way to align the incentives of shareholders and pensioners without any complex adjustment to the pension plan structure consists of enlarging the set of admissible investment strategies so as to include dynamic risk-controlled strategies such as constant-proportion portfolio insurance (CPPI) strategies, or their extension in a pension management context sometimes referred to as contingent immunisation strategies or dynamic LDI strategies. In fact, implementing risk-controlled strategies aiming to insure a minimum funding ratio level above 100% allows shareholders to get some (limited) access to the upside performance of risky assets, while ensuring that pensioners will not be hurt by the induced increase in risk (see Exhibit 2). In Section I.3, we shall revisit the benefits of sophisticated forms of welfare improving dynamic LDI strategies, including strategies with a floor given as a function of the value of the liability portfolio.

## I.2 Accounting for Long Horizons via the Life-Cycle Investing Paradigm: From Policy Portfolios to Policy Portfolio Strategies

One important element of pension investing is the presence of long horizons. Indeed, except for very mature pension plans close to termination, the duration of pension liabilities tends to be long, sometimes exceeding 20 or 30 years. It is therefore important to analyse what the impact is, if any, of the presence of such long horizons on the LDI paradigm that has been presented so far.

Although it may be acceptable to assume a constant opportunity set when investors

have a short-term horizon, the presence of a long horizon makes it necessary to go beyond Markowitz's static portfolio selection analysis. The next important step after Markowitz (1952) is Merton (1969, 1971), who introduced dynamic programming techniques in a continuous-time setting to solve dynamic portfolio optimisation problems.

In terms of industry implications, the development of dynamic asset pricing theory has led to the emergence of improved investment solutions that take into account the changing nature of investment opportunities, which we discuss in what follows.

### I.2.1 Benefits of Fixed-Mixed Strategies versus Buy-and-Hold Strategies

As explained earlier, investors with consumption/liability objectives need to invest in two distinct portfolios, in addition to cash: one PSP and one LHP, for which construction methods have been discussed in previous sections. Formally, under the assumption of a constant opportunity set, we have also obtained the following expression (see Equation (1)) for the fund separation theorem in the intertemporal context when trading is possible between current date and investment horizon:

**Fixed-Mix LDI strategy:**

$$w = \frac{\lambda}{\gamma\sigma} w^{PSP} + \left(1 - \frac{1}{\gamma}\right) \beta w^{LHP}$$

where we recall that  $w$  is the vector of weights allocated to the risky assets,  $w^{PSP}$  is the vector of weights of the PSP, is that of the  $w^{LHP}$ ,  $\lambda$  and  $\sigma$  are respectively the Sharpe ratio and the volatility of the PSP,

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$\beta$  is the beta of liabilities with respect to the LHP, and  $\gamma$  is the relative risk aversion. Note that in this expression, parameters  $\lambda$ ,  $\sigma$  and  $\beta$  are constant.

It is important to emphasise at this stage that Equation (1) is already the solution to a *dynamic* optimisation problem (note the explicit dependency on time that has been introduced in the expression of the optimal strategy on the left-hand side of Equation (1)) where the corresponding strategy is a fixed-mix strategy with trading taking place periodically to rebalance the portfolio allocation back to the constant target. This stands in contrast with buy-and-hold strategies, where an initial trade is performed so as to implement a given policy portfolio, which is left unbalanced so that the current portfolio weights progressively drift away from the target, as expressed in the following equation:

10 - Note that our simulated portfolios are rebalanced on a quarterly basis, and to robustify the numerical experiments, we set lower and upper bounds at 0.25 and 0.75, respectively, for the simulated equity Sharpe ratio and 0.05 and 0.65, respectively, for volatility before implementing dynamic allocation strategies.

## Buy- and-Hold LDI strategy:

$$w_0 = \frac{\lambda}{\gamma\sigma} w^{PSP} + \left(1 - \frac{1}{\gamma}\right) \beta w^{LHP}.$$

In fact, fixed-mix strategies are superior in general to buy-and-hold strategies, and the gains obtained from rebalancing can be very substantial for long horizons. To illustrate the superiority of fixed-mix strategies with respect to buy-and-hold strategies, we simulate the long-term performance of a hypothetical pension fund allocating an initial amount normalised at \$100 to a stock index and a bond index. More precisely, we run 10,000 Monte Carlo simulations using a general model with stochastic equity Sharpe ratio, volatility and interest rates. The parameters used to generate the sample paths are taken from Deguest, Martellini and Milhau (2013) and recalled in Exhibit 3.<sup>10</sup>

Exhibit 3: Long-term parameter values

This table displays the parameter values used in the numerical experiments. For each stochastic process (nominal short-term rate, equity Sharpe ratio and equity variance), the dynamics is recalled: the three processes  $z^r$ ,  $z^\lambda$  and  $z^V$  are three correlated Brownian motions. The last panel contains the values of the instantaneous correlations between the three stochastic processes and the stock price process.

<b>Nominal Short-Term Rate</b>	
$dr_t$	$= a(b - r_t)dt + \sigma_r dz_t^r$
$b$	3.06 %
$a$	0.13
$\sigma_r$	0.98%
$\lambda_r$	-53.00%
<b>Equity Sharpe Ratio</b>	
$d\lambda_t$	$= \kappa(\bar{\lambda} - \lambda_t)dt + \sigma_\lambda dz_t^\lambda$
$\kappa$	0.35
$\sigma_\lambda$	23.22%
$\bar{\lambda}$	40%
<b>Equity Volatility</b>	
$V_t$	$= (\sigma_V)^2, \quad dV_t = \alpha(\bar{V} - V_t)dt + \sigma_V \sqrt{V_t} dz_t^V$
$\alpha$	5.07
$\sigma_V$	48.00%
$\bar{V}$	21.38%
<b>Correlations</b>	
$\rho^{s\lambda}$	-1
$\rho^{sr}$	0
$\rho^{sv}$	-76.70%
$\rho^{rv}$	0

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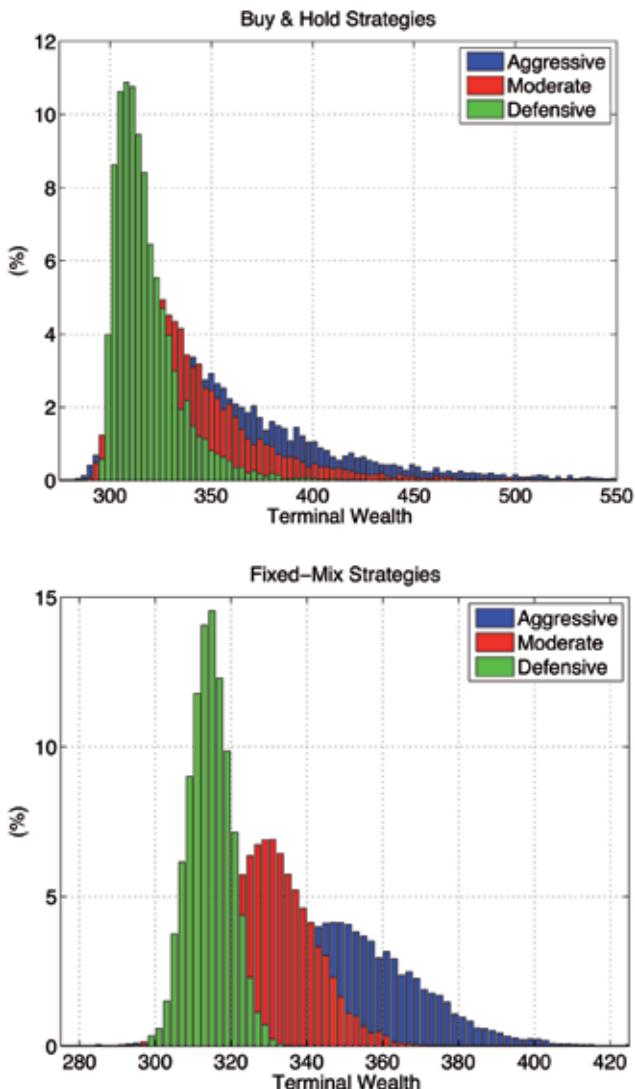
We first assume that the pension fund manager incorrectly infers that risk and return parameters are constant, and implements either the buy-and-hold LDI strategy or the fixed-mix LDI strategy. We subsequently turn in Section I.2.2. to a situation where the pension fund manager properly recognises that risk and return parameters vary through time and benefits from time-varying policy portfolio strategies.

In this numerical illustration, we take the time horizon to be equal to 20 years, while

the risk aversion parameter, which is not observable, is calibrated in such a way that the average allocation to equity for the optimal dynamic portfolio strategy (see Section I.2.2.) over the 20-year life of the strategy is equal to a target of 10%, 20% or 30%. The three corresponding strategies will be referred to as defensive, moderate and aggressive, respectively.

In Exhibit 4, we show the distribution of wealth levels obtained at horizon for 3 pension funds, corresponding to the defensive, moderate and aggressive risk

*Exhibit 4: Distributions of Terminal Wealth for Buy-and-Hold and Fixed-Mix Strategies.*



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aversion levels, following a buy-and-hold versus a fixed-mix strategy.

We first find the usual risk-return trade-off for both the buy-and-hold and fixed-mix strategies: strategies implemented by less risk-averse investors will contain a higher allocation to equities, which will result in a higher average wealth level as well as a higher uncertainty around the terminal wealth level.

The analysis of the results in Exhibit 4 also shows a very different wealth distribution at horizon for the buy-and-hold strategy and for the fixed-mix strategy. Broadly speaking, it appears that fixed-mix strategies lead to much narrower distributions for average levels that are somewhat equivalent to those generated by buy-and-hold strategies. For example, for the pension fund following a so-called aggressive strategy, the average wealth level at a 20-year horizon is \$348.18 for the fixed-mix strategy, while it reaches \$357.61 for the buy-and-hold strategy, which represents a mere 2.87% higher value. On the other hand, the standard deviation of the wealth level distribution is only \$19.99 for the fixed-mix strategy, while it is more than twice as high at \$53.24 for the buy-and-hold strategy!

From this analysis, one can expect that the welfare gains from implementing fixed-mix strategies as opposed by buy-and-hold strategies would be substantial for risk-averse investors.<sup>11</sup> It should be noted that this conclusion, which has been obtained in the case of a very simple experiment with no frictions, would also hold true in case realistic levels of transaction costs were introduced.

<sup>11</sup> See Exhibit 6 in Section I.2.2 for a formal confirmation.

## I.2.2 Benefits of Time-Varying Strategies versus Fixed-Mixed Strategies

A large body of empirical research has shown that interest and inflation rates, as well as expected return, volatility, and correlation parameters are stochastically time-varying, as a function of key state variables that describe the state of the business cycle. Unexpected changes in these variables have an impact on portfolio risk and performance (through changes in interest rates and risk premium process parameters), which should be managed optimally. We now analyse how the allocation strategy is optimally impacted by the explicit recognition of the presence of time-variation in expected return and volatility for the risky assets entering the composition of the PSP.

One can show that the explicit recognition of the presence of time-variation in risk and return parameters has two main implications for dynamic asset allocation problems. On the one hand, the presence of time-variation of risk and return parameters implies that the target split between the PSP and LHP, as well as the composition of these two building blocks, become explicit functions of time. In other words, Equation (1) is replaced with the following so-called *myopic* strategy:

### Myopic dynamic LDI strategy:

$$w_t = \frac{\lambda_t}{\gamma\sigma_t} w_t^{PSP} + \left(1 - \frac{1}{\gamma}\right) \beta_t w_t^{LHP}$$

It turns out that, in general, this time-varying strategy is not the optimal strategy. Indeed, in the presence of stochastic equity volatility and an equity risk premium, the optimal strategy involves the introduction of a new hedging demand, in addition to

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the LHP, dedicated to the optimal hedging of the state variables impacting the equity risk premium process, as can be seen from Equation (2) from the technical material in the following box.<sup>12</sup>

return of equities, given that everything else equal equity prices have become more (respectively, less) expensive following the increase (respectively, decrease) in stock prices. In this context, it is hardly surprising

## Technical Material

We assume that the equity risk premium is time-varying with the business cycle, with a mean-reverting component. We let  $\sigma_\lambda$  be the volatility of the equity risk premium process and  $\rho_{\lambda S}$  be the correlation between changes in the Sharpe ratio  $\lambda_S$  of the equity index and the return on the stock index  $S$ . A negative correlation means that high realised return periods tend to be followed by low expected return periods. This strongly negative relationship between expected and realised equity returns is supported by empirical evidence.

It can then be shown that the corresponding optimal weight vector is of the following form (see Deguest, Martellini and Milhau (2013) for the proof and the detailed expression of the hedging demand  $HD_{t,T}^\lambda$ ):

$$\begin{aligned} w_t^* &= \frac{\lambda_t}{\gamma\sigma_t} w_t^{PSP} + \beta_t \left(1 - \frac{1}{\gamma}\right) w_t^{LHP} + HD_{t,T}^\lambda \\ &= \underbrace{\frac{\bar{\lambda}}{\gamma\sigma} w}_{\text{long-term strategic portfolio}} - \underbrace{\frac{\bar{\lambda}}{\gamma\sigma} w^{PSP}}_{\text{short-term (tactical) deviations}} + \underbrace{\beta_t \left(1 - \frac{1}{\gamma}\right) w_t^{LHP}}_{\text{hedging against unexpected changes in liability values}} + \underbrace{HD_{t,T}^\lambda}_{\text{hedging against unexpected changes in risk premia values}} \end{aligned} \quad (2)$$

One can also show that the intertemporal hedging demand  $HD_{t,T}^\lambda$  has the following properties (for  $\gamma > 0$  and  $\lambda > 1$ ):

- (i) The investor with  $\gamma > 1$  holds more stocks when equity Sharpe ratio is mean-reverting than when it is constant ( $\sigma_\lambda = 0$ );
- (ii) The hedging demand disappears if there is no equity risk premium risk ( $\sigma_\lambda = 0$ ), or if the risk exists but cannot be hedged away ( $\rho_{\lambda S} = 0$ );
- (iii) The hedging demand disappears when approaching horizon  $T$ .

The hedging demand against unexpected changes in the equity risk premium is the portfolio of risky assets that has the highest squared correlation with changes in the equity risk premium. The design of that portfolio is a matter of empirical calibration. It is widely accepted that an increase (respectively, decrease) in realised returns on equities implies a corresponding decrease (respectively, increase) in expected

that empirical research has found a strong negative correlation between expected returns on stocks and realised returns on stocks (Kim and Omberg (1996)). As a result, the intertemporal hedging demand against changes in the equity risk premium mostly contains a long equity position. More generally, a dedicated hedging demand is needed for each variable impacting the interest rate or risk premium process of

<sup>12</sup> – In principle one could also allow for the presence of time variation in the investor's risk aversion.

# I. Conceptual Background

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any of the risky asset classes (Detemple and Rindischbacher (2008)). For example, let us assume that the expected return on most risky assets is, for example, negatively impacted by increases in oil prices. To compensate for the deterioration of the investment opportunity set in the event of a sharp increase in oil prices, the investor will benefit from holding a long position in a portfolio optimised to exhibit the highest possible correlation with oil prices.

To provide a numerical analysis of the benefits of time-varying strategies over fixed-mix strategies, we test the following strategies, introduced in increasing order of complexity.

1. Strategies based on time-changes in equity volatility only, assuming a constant equity risk premium - such strategies are often referred to as *target volatility strategies* and defined by the following expression:<sup>13</sup>

$$w_t = \frac{\lambda}{\gamma \sigma_t} w_t^{PSP} + \left(1 - \frac{1}{\gamma}\right) \beta_t w_t^{LHP}$$

2. Strategies based on time-changes in equity volatility and equity risk premium, without the introduction of a dedicated hedging demand - such strategies are referred to as *myopic dynamic strategies* and defined by the following expression:

$$w_t = \frac{\lambda}{\gamma \sigma_t} w_t^{PSP} + \left(1 - \frac{1}{\gamma}\right) \beta_t w_t^{LHP}$$

3. Strategies based on time-changes in equity volatility and equity risk premium, with the introduction of a dedicated hedging demand; - such strategies are referred to as *optimal dynamic strategies* and defined by the following expression:

$$w_t^* = \frac{\lambda_t}{\gamma \sigma_t} w_t^{PSP} + \beta_t \left(1 - \frac{1}{\gamma}\right) w_t^{LHP} + HD_{t,T}^\lambda$$

We show in Exhibit 5 the resulting distribution of terminal wealth for various risk aversion levels. Comparing Exhibit 5 to Exhibit 4, it appears that the benefits obtained from implementing dynamic portfolio strategies are spectacular either in terms of increases in average wealth levels or in terms of decreases in uncertainty around these average wealth levels, or both. This can be seen in Exhibit 6, where we show the average and standard deviation for the distribution of wealth levels at horizon for the three considered levels of risk aversion and for the various LDI strategies, including the buy-and-hold (B&H) LDI strategy, the fixed-mix (FM) LDI strategy, the target volatility (TV) dynamic LDI strategy, the myopic dynamic (MD) LDI strategy and the optimal dynamic LDI strategy. In Exhibit 6, we also report the opportunity cost for each tested strategy with respect to the optimal dynamic LDI strategy. This *opportunity cost* is measured as the percentage of initial wealth necessary for sub-optimal strategies to reach the same average terminal wealth as the optimal strategy for the same standard deviation as the optimal strategy.<sup>14</sup> Conversely, we also report the opportunity gain for each tested strategy with respect to the buy-and-hold LDI strategy. This *opportunity gain* is measured as the percentage of initial wealth that can be saved by an investor willing to implement a better strategy so as to reach the same terminal wealth level as the buy-and-hold strategy for the same standard deviation as the buy-and-hold strategy.

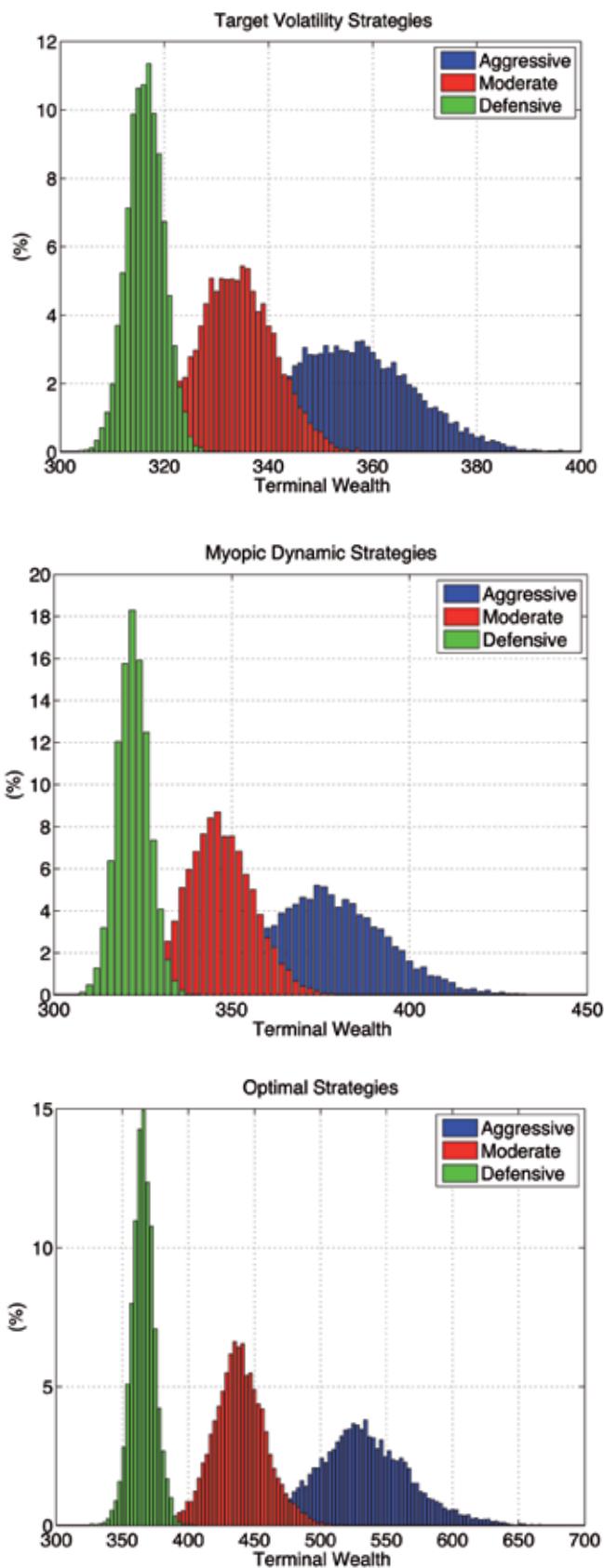
13 - In all these strategies, the beta of the liability portfolio with respect to the LHP is assumed to be time-varying. In practice, interest rate risk is the main driving force for the liability returns, and this beta often corresponds to the portfolio duration, which is indeed dynamically managed by internal or external fixed-income money managers.

14 - In details, we mix the sub-optimal strategy with a long or short allocation to the 20-year pure discount bond so as to match the standard deviation for the distribution of the terminal wealth level for a given sub-optimal strategy and for the optimal strategy. We then record differences in average wealth levels, and report the percentage of initial contribution needed as an additional contribution to generate with the suboptimal strategy mixed with the pure discount bond the same average wealth level as with the optimal strategy.

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*Exhibit 5: Distributions of dynamic optimal and sub-optimal LDI strategies.*



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The opportunity gains obtained from shifting to increasingly sophisticated strategies are substantial. For example, we learn that a pension fund wishing to implement an aggressive strategy can save up to 16.44% with a fixed-mix policy portfolio strategy compared to the corresponding buy-and hold policy portfolio. The opportunity gain is then multiplied by a factor of almost 2, to reach 32.73%, if the pension fund manager is willing to utilise information about time-varying volatility levels. This result suggests that adjusting the policy mix as a function of changes in equity volatility is a valuable improvement over implementing a simple fixed-mix strategy. Such an improvement in policy portfolio implementation does not really require any additional skills given that volatility

has been made quasi-observable with the existence of volatility indices such as the VIX index, and can be safely estimated using various proven econometric techniques such as GARCH models for example. On the other hand, adjusting the strategy in a myopic way as a response to changes in the equity risk premium appears to only generate modest additional benefits, with an opportunity gain that increases in the aggressive case from 32.73% to 34.34%; this is an interesting result given that changes in the equity risk premium, which is not observable, are much harder to track compared to changes in equity volatility. Intuitively, this result can be related to the fact that the volatility of changes in equity volatility is more than twice as high as that of changes in the equity risk premium

*Exhibit 6: Statistics and risk measures for long-term LDI strategies.*

This table displays over a 20-year horizon the average terminal wealth together with its standard deviation for five long-term allocation strategies, and three different levels of riskiness: aggressive, moderate and defensive. It also shows the maximum drawdown at a 99.5% level (0.5% of the worst max DD have been discarded).\*

Panel A: Aggressive Strategy					
	Optimal	MD	TV	FM	B&H
Av. Wealth	530.87	376.62	355.09	348.18	357.61
Std of Wealth	38.02	16.64	12.63	19.99	53.24
Max DD at 99.5%*	23.45%	15.87%	15.94%	16.42%	19.41%
Opportunity Cost	0	11.83%	14.07%	35.62%	55.59%
Opportunity Gain	42.62%	34.34%	32.73%	16.44%	0
Panel B: Moderate Strategy					
	Optimal	MD	TV	FM	B&H
Av. Wealth	438.49	346.29	333.67	329.61	336.09
Std of Wealth	20.59	9.66	7.44	11.85	33.28
Max DD at 99.5%*	19.06%	16.13%	16.11%	16.33%	16.93%
Opportunity Cost	0	10.07%	11.63%	24.84%	36.01%
Opportunity Gain	35.83%	26.77%	25.30%	12.18%	0
Panel C: Defensive Strategy					
	Optimal	MD	TV	FM	B&H
Av. Wealth	365.66	322.22	316.34	314.44	317.88
Std of Wealth	8.84	4.46	3.48	5.58	16.38
Max DD at 99.5%*	16.51%	16.45%	16.59%	16.81%	16.72%
Opportunity Cost	0	6.35%	7.17%	13.29%	18.05%
Opportunity Gain	24.57%	16.56%	15.49%	7.05%	0

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given the assumed parameter values that are reported in Exhibit 3. On the other hand, it appears that a substantial welfare gain is generated when the intertemporal hedging demand is accounted for in the optimal strategy, with an opportunity gain increasing from 34.34% to 42.62%.

In the end, the loss for an investor sticking to a standard buy-and-hold strategy reaches more than 50% (more precisely 55.59%) given the assumed parameter values compared to a more sophisticated investor who would implement the optimal dynamic LDI strategies. The opportunity gains/losses are naturally smaller for less aggressive investors, and would converge to zero in the limit of an infinite risk aversion, since all strategies would then converge towards a 100% allocation to the LHP. On the other hand, they remain substantial for realistically high levels of risk aversion, with opportunity gains as high as 35.83% for the moderate investor and 24.57% for the defensive investor. While these results again have been obtained in the absence of transaction costs and other forms of frictions, the magnitude of the welfare gains involved in dynamic versus static strategies are so substantial that they are expected to be of economic significance even after accounting for implementation constraints.

## I.2.3 From Deterministic to Stochastic Glide Paths: Improved Forms of Target-Date Funds

One of the key insights from the previous analysis of long-term allocation decisions with mean-reverting equity returns is the fact that equities serve as a hedge against unfavourable equity returns in the presence of mean-reverting equity returns. As a

result, the optimal allocation to stocks is higher compared to the myopic case, and investors with longer time horizons hold more stocks compared to investors with shorter horizons. This prescription has very often been taken at face value by target-date funds or life-cycle funds, an investment solution advocating a deterministic decrease of equity allocations (glide path) when approaching retirement date. For example, a popular asset allocation strategy for managing equity risk on behalf of a private investor in the context of a DC pension plan is known as deterministic life investing. In the early stages, when the retirement date is far away, the contributions are invested entirely in equities. Then, beginning on a predetermined date (say, ten years) before retirement, the assets are switched gradually to bonds at some pre-defined rate (say, 10% a year). By the date of retirement, all the assets are held in bonds.<sup>15</sup> This is somewhat reminiscent of the rule of thumb put forward by Shiller (2005), advocating a percentage allocation to equity given by 100 minus the investor's age in years.

Embedding the life-cycle allocation decisions within a one-stop decision is a valuable attempt at providing added value to unsophisticated investors who otherwise will likely make sub-optimal decisions. However, current forms of target-date funds are not the right answer to the problem at hand. An initial limitation with (most) existing target-date funds is the fact that they do not account for risk aversion. In other words, life-style investing funds (balanced funds) focusing purely on differences in risk aversion across investors, have been replaced by life-cycle funds (target-date funds) focusing purely on differences in time horizon across investors.

<sup>15</sup> – In fact, the rationale behind the strategy is to reduce the impact on the pension of a catastrophic fall in the stock market just before the plan member retires and to hedge the interest-rate risk inherent to the pension-related liability value. As we will argue later, holding no exposure to equity is a very trivial way of managing equity risk, and one that keeps investors from enjoying equity upside potential.

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Obviously, one needs to encompass both dimensions in the design of a family of funds to address a wide range of investor needs. Another, arguably more important, restriction is that existing target-date funds do not allow for revisions of the asset allocation as a function of changes in market conditions. This is entirely inconsistent with aforementioned academic prescriptions, and also common sense, which both suggest that the optimal strategy should also display an element of dependence on the state of the economy. In particular, in the presence of a mean-reverting equity premium, the allocation to equities should be increased when equities become cheap, and it should be decreased when they become expensive, as measured through a proxy like the dividend yield or price-earnings ratios (see for example Campbell and Viceira (1999), Chacko and Viceira (2005), or Munk, Sørensen, and Vinther (2004)). These life-cycle strategies can be extended to account for uncertainty in income streams, as outlined by Cocco, Gomes and Maenhout, (2005) or Viceira (2001), among others. Abundant academic research (see for example Cairns, Blake, and Dowd (2006), Viceira and Field (2007), Basu (2009), Bodie, Detemple, and Rindisbacher (2009) or Martellini and Milhau (2010a)) has documented that omitting to take market conditions into account in life-cycle investing, as is the case with available target-date funds, leads to genuine under-performance of the funds. Overall, the extended forms of life-cycle strategies that adjust the allocation to equities, not only as a function of time horizon but also as a function of the current value of equity volatility as well as risk premium as proxied by the relative cheapness of equity markets, strongly dominates the standard approaches

by avoiding buying too high and selling too low. This argument has been made explicit in the following quote extracted from Viceira and Field (2007): "Research suggests that long-term equity investors should invest more on average in equities than their short-horizon counterparts, but they should also consider periodic revisions of this allocation as market conditions change. It is logically inconsistent to count on reduced long-term risk while ignoring the variation in returns that produces it. This market-sensitive allocation policy is very different from the asset allocation policy of life-cycle funds, whose target mix moves mechanically away from stocks as an inverse function of investment horizon, regardless of market conditions. Thus mean-reversion arguments provide, if anything, only a partial justification for the roll-down schedule characteristic of life-cycle funds."

## **I.3 Accounting for Short-Term Constraints via the Risk-Controlled Investing Paradigm: From Asset-Liability Management to Risk and Asset-Liability Management**

As recalled in Section I.2, one of the key insights from the academic literature on long-term allocation decisions with mean-reverting equity returns is the fact that a long-term allocation to equities serves as a hedge against unfavourable short-term equity returns in the presence of mean-reverting equity returns. As a result, the optimal allocation to stocks is higher compared to the myopic case, and investors with longer time horizons hold more stocks compared to investors with shorter horizons. This prescription has very often been taken at face value by target-

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date funds or life-cycle funds an investment solution advocating a deterministic decrease of equity allocations (also known as glide path) when approaching retirement date.

One key problem, however, is that this prescription can lead to extremely difficult situations when risk is assessed from a shorter-term perspective, in particular in the context of a severe bear equity market such as the one experienced in 2008. Hence it appears that the key element missing from the analysis presented so far is the incorporation of short-term constraints to the design of the optimal allocation strategy by pension funds.

## I.3.1 Introducing Short-Term Funding Ratio Constraints

The introduction of funding ratio constraints is not only an obviously desirable feature from a risk management standpoint, but has also been the focus of recent regulation in most developed countries. For example, in the United States, the Pension Benefit Guaranty Corporation (PBGC), which provides a partial insurance of pensions, charges a higher premium to funds that report a funding level of under 90% of current liabilities; this consequently provides strong incentives for maintaining the funding ratio over that minimum 90% threshold. In the UK, there was a formal general Minimum Funding Requirement (MFR) that came into effect in 1995, which eventually was replaced in the 2004 Pensions Bill with a scheme-specific statutory funding objective to be determined by the sponsoring firm and fund trustees. A regulatory requirement over a minimum funding ratio rule is also present in other European countries, e.g. in Germany where Pensionskassen and

Pensionsfonds must be fully funded at all times to the extent of the guarantees they have given, in Switzerland where the minimum funding level is 100%, with an incentive to conservative management (investment in equities, for example, is limited to 30% of total assets for funds with less than 110% coverage ratio), or in the Netherlands where the minimum funding level is 105% plus additional buffers for investment risks.

These regulatory pushes towards an increased focus on risk management by pension funds, has given rise to a fierce debate between advocates of a tighter regulation and those arguing that imposing short-term constraints to long-term investors would only result in a severe welfare loss. For example, in a report prepared on pension funding rules for the OECD, Pugh (2008) makes the following argument: "Minimum funding standards in many countries are designed around (...) current market yields on long-term bonds. In order to avoid problems, especially in jurisdictions that require immediate correction of the (perceived) underfunding, a plan sponsor is tempted to over-invest in such long-term bonds. (...) However, pension plans in the long term (...) need substantial investments in equities. Otherwise, the investments may be inefficient, and the cost of the pension plan to the plan sponsor will therefore increase. (...)"

In the area of minimum funding, as with other areas of legislation, there is a fine line between (over)protecting the interests of DB plan members and destroying the incentives for employers to sponsor such plans. (...) In many countries, the minimum funding standards focus on the pension fund

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assets exceeding the pension plan's accrued liabilities on every measurement date. (...) If an asset/liability type of minimum funding measure is to be introduced or retained, then legislation should not require the immediate and complete correction of any underfunding that the test purports to reveal. Asset values fluctuate, and funding shortfalls may disappear as quickly as they had appeared. It is counterproductive for a plan sponsor to make high additional contributions and then find (one or two years later) that the markets have recovered and the plan now has an embarrassing funding excess."

The conflict between the presence of long-term objectives and short-term constraints is in fact one of the most critical challenges faced by long-term investors. Focusing on equity investments, the dilemma can be summarised as follows. On the one hand, investing substantial fractions of their wealth in equity markets makes it difficult for investors to ensure the respect of short-term risk budgets, and leads to a dominant allocation to safe assets that show a better correlation with the investors' liabilities. On the other hand, shying away from investing in equity involves a substantial opportunity cost, especially for long-term investors, because the equity risk premium is positive, hence attractive for all investors, but also mean-reverting, hence even more attractive for long-term investors. More generally, it is widely perceived that a tension exists between a focus on hedging long-term risk and a focus on insurance with respect to short-term constraints: typically, dynamic risk-controlled strategies, which imply a reduction to equity allocation when a drop of equity prices has led to a substantial diminution of the risk

budget, have often been blamed for their pro-cyclical nature, and long-term investors are often reluctant to sell equity holdings in those states of the world where equity markets have become particularly attractive in the presence of mean-reversion in the equity risk premium.

## I.3.2 Managing Short-Term Constraints

While a tension exists between hedging against long-term risks and insuring against short-term risks, it can be shown that long-term objectives and short-term constraints need not be mutually exclusive and can be integrated in a comprehensive asset allocation framework (see Deguest, Martellini and Milhau (2013)). Depending on market conditions and parameter values, the pro-cyclical risk-control motivation may outweigh the revision of strategic asset allocation motivation, or vice-versa. On the other hand, risk management always ultimately prevails in the sense that when the margin for error has entirely disappeared the optimal strategy in the presence of risk constraints requires the use of a secure investment strategy.

This argument is based on the recognition that short-term risk constraints are best managed not through *diversification* strategies (which are dedicated to the design of the PSP) or *hedging* strategies (which are dedicated to the design of the hedging demand against unexpected changes in liability values or to the design of the hedging demand against unexpected changes in the equity risk premium) but through *insurance* strategies.

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From a technical standpoint, the introduction of short-term constraints can be formalised in a portfolio selection problem based on a key insight into the profound correspondence between pricing and portfolio problems. On the one hand, asset pricing problems are equivalent to dynamic asset allocation problems: Merton's (1973a) interpretation of the Black and Scholes (1973) option pricing formula. On the other hand, dynamic asset allocation problems (Merton 1973a) are equivalent to asset pricing problems: the *martingale* or *convex duality* approach to dynamic asset allocation problems (Karatzas, Lehoczky, and Shreve (1997) and Cox and Huang (1989)).

As can be seen in the "technical material" box below, the practical implication of the introduction of short-term constraints is that the optimal investment in the PSP becomes a function not only of risk aversion but also of risk budgets (defined as the distance of minimum funding floors regarded as an estimate for the margin for error), as well as of the likelihood of the risk budget being spent before the horizon. In a nutshell, a pre-commitment to risk management allows pension fund to adjust their risk exposure in an optimal state-dependent manner, and therefore to generate the highest exposure to upside potential of the PSP while respecting risk constraints.

## Technical Material

In the presence of short-term constraints, represented by a floor  $F_t = kL_t$ , where  $k$  is the minimum funding ratio requirement, pension funds still optimally invest in two distinct portfolios: the "risky" and the "safe" building blocks and their allocation to the risky block must still be increasing in the PSP Sharpe ratio  $\lambda$  and decreasing in the investor's risk aversion  $\gamma$  and PSP volatility  $\sigma$ : The difference with the unconstrained strategy that does not incorporate minimum funding ratio requirements that the amounts allocated to the PSP and to the LHP are now also a function of the risk budget, a quantity defined as the difference between the asset value  $A_t$  and a (probability-weighted) floor  $p_{t,T}F_t$ . When implemented in continuous-time, this portfolio strategy makes it possible to truncate the distribution of the funding ratio to the minimum funding ratio denoted by  $k$ .

Formally, we consider the problem of maximisation of expected CRRA utility of the terminal funding ratio subjects to the minimum funding ratio constraints:

$$\max_{(w_t)} E \left[ \left( \frac{A_T}{L_T} \right) \right], \text{such that } A_t \geq kL_t \text{ for all } t \leq T$$

The solution to this problem is given by (see Deguest, Martellini and Milhau (2013)):

$$w_t^{*c} = \frac{\lambda_t}{\gamma\sigma_t} \left( 1 - p_{t,T} \frac{F_t}{A_t} \right) w_t^{PSP} + \left( 1 - \frac{1}{\gamma} \left( 1 - p_{t,T} \frac{F_t}{A_t} \right) \right) \beta w_t^{LHP} + \left( 1 - p_{t,T} \frac{F_t}{A_t} \right) HD_t^\lambda \quad (3)$$

A simplified version consists of the following expression:

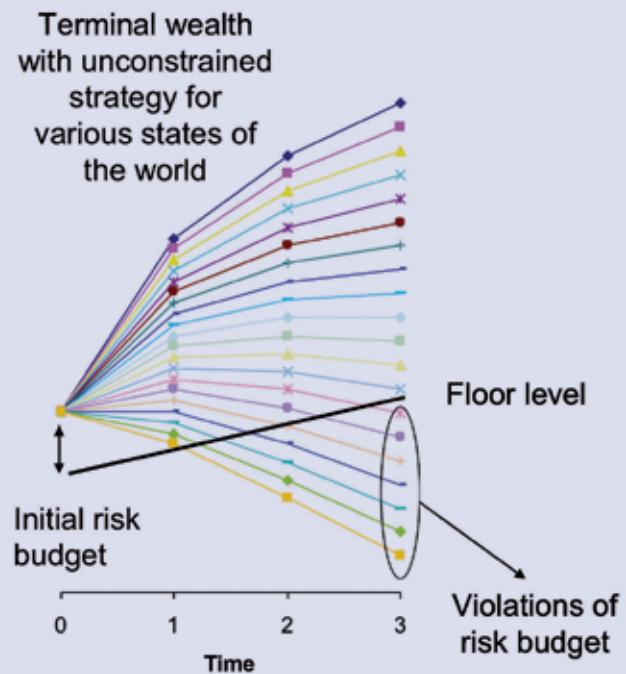
$$w_t^{*c} = \frac{\lambda_t}{\gamma\sigma_t} \left( 1 - \frac{F_t}{A_t} \right) w_t^{PSP} + \left( 1 - \frac{1}{\gamma} \left( 1 - \frac{F_t}{A_t} \right) \right) \beta w_t^{LHP} + \left( 1 - \frac{F_t}{A_t} \right) HD_t^\lambda \quad (4)$$

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The allocation strategy presented in Equation (4) has a constant-proportion portfolio insurance (CPPI) flavour: the dollar allocation to the risky PSP is not a function of risk aversion, PSP volatility, and the Sharpe ratio alone; it is also a function of the risk budget (or margin for error) defined as the distance between the asset value  $A_t$  and the short-term floor  $F_t$  (typically known as the "cushion" in CPPI terminology). When the margin for error disappears, i.e. when the investor's short-term risk budget is spent, the allocation to the PSP becomes 0.

Equation (3) defines a more general allocation strategy, with a more aggressive spending of the risk budget. Indeed, the risk budget is  $A_t - p_{t,T}F_t$  which is different from, and in general greater than,  $A_t - F_t$ , given that the number  $p_{t,T}$  can be shown to lie between 0 and 1. This number can be interpreted as the estimated (risk-neutral) probability that the risk budget will be violated by the corresponding unconstrained strategy (see Exhibit 7 for an illustration).

*Exhibit 7: Violations of risk budgets with unconstrained strategies.*



Although the risk budget  $A_t - p_{t,T}F_t > A_t - F_t$  looks higher than the investor would like, we still have that  $A_t \geq F_t$  for all  $t$  because  $p_{t,T}$  adjusts in an optimal manner in the sense that  $p_{t,T} \rightarrow 1$  when and if the PSP performance is so poor that asset value converges to the minimum funding ratio floor and the risk budget is almost entirely spent. Conversely, when the margin for error increases, we have that  $p_{t,T} \rightarrow 0$ , hence allowing fuller access to the upside potential of the satellite. Intuitively, it is straightforward to understand that state-dependent expenditure of the risk budget is better than a deterministic (constant) spending scheme. Having constant spending of the risk budget is in general sub-optimal and has an opportunity cost for the investor with a finite time horizon.

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In fact, Equation (3) describes an asset allocation strategy that is somewhat reminiscent of (a dynamic replication of) option-based portfolio insurance (OBPI) strategies, which it extends in a number of dimensions. First, the underlying asset is not a risky asset but the underlying optimal unconstrained strategy. Moreover, the risk-free asset is not cash but in general the investor's liability benchmark, an exchange option flavour that allows one to transport the structure to relative risk management.

Formally, the terminal wealth  $A_T^{*c}$  obtained by using the optimal constrained strategy can be written as:

$$A_T^{*c} = F_t + \max(\xi A_T^{*u} - F_t, 0)$$

Here,  $F_t$  is the floor and  $A_T^{*u}$  is the terminal wealth generated by the optimal unconstrained strategy. This unconstrained strategy is fixed-mix when the opportunity set is constant (Section I.1.), and in general has a life-cycle component in the presence of a stochastic opportunity set (Section I.2.).

Overall, the key insight is that the pay-off of the optimal strategy in the presence of minimum funding ratio constraints can be regarded as an option on the pay-off of the strategy that is optimal in the absence of such constraints. Obviously, no such long-maturity options written on customised dynamic LDI/LCI strategies can be found, even as OTC contracts, and investors will have to implement some form of dynamic allocation strategy that will allow replication of the optimal pay-off. While the original approach was developed in a simple framework with a focus on respecting a minimum funding ratio floor, it can be extended in a number of important directions, allowing for the introduction of more complex floors. A large variety of floors, such as capital guarantee floors or maximum drawdown floors for example, can in fact be introduced (simultaneously if necessary) so as to accommodate the needs of different pension funds. The maximum drawdown floor, which allows pension fund managers to set a strict limit on maximum consecutive losses, is arguably of particular importance in practice, and it is the one that

will be used in the illustration that follows in the next sub-section.

### I.3.3 Reducing the Cost of Insurance against Short-Term Constraints

In addition to accounting for the presence of floors, the dynamic risk-controlled strategies can also accommodate the presence of various forms of *caps* or *ceilings*. These strategies recognise that the investor has no utility over a *cap* target level of wealth, which represents the investor's goal (actually a cap), which can be a constant, deterministic or stochastic function of time. From a conceptual standpoint, it is not clear *a priori* why any investor should want to impose a strict limit on upside potential. The intuition is that by forgoing performance beyond a certain threshold, where they have relatively lower utility from higher wealth, investors benefit from a decrease in the cost of the downside protection. This is equivalent to adding a short position in a convex pay-off in addition to the long position, so as to generate a collar-like pay-off, with a truncation of the wealth level distribution on the left-hand side (below

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the minimum funding ratio constraint) as well as on the right hand side (above the maximum funding ratio constraint). Putting it differently, without the performance cap, investors have a greater chance of failing an almost attained-goal when their wealth level is very high. It should be noted that the presence of upper (in addition to lower) bounds on performance, consistent with the kind of utility satiation often exhibited by long-term investors, is another, independent, reason why a fall in equity prices should not always lead to a decrease of equity allocation, even without mean-reverting equity risk premium. As a result, general risk-controlled strategies do not necessarily share the pro-cyclical aspect of basic forms of risk-controlled strategies such as standard CPPI strategies.

The quintessence of investment management is essentially about finding optimal ways to spend risk budgets that investors are reluctantly willing to set, with a focus on allowing for the highest possible access to performance potential while respecting such risk budgets. Risk diversification, risk hedging and risk insurance are three useful approaches to optimal spending of investors' risk budgets. In this context, improved forms of LDI strategies rely on a sophisticated exploitation of the benefits of the three competing approaches to risk management, namely risk diversification (key ingredient in the design of better benchmarks for PSPs), risk hedging (key ingredient in the design of better benchmarks for hedging portfolios) and risk insurance (key ingredient in the design of better dynamic asset allocation benchmarks for long-term investors facing short-term constraints). In the end, risk management, which focuses on maximising the probability of achieving investors'

long-term objectives while respecting the short-term constraints they face, appears to be the key source of added value in investment management.

More generally, one can show that the opportunity costs implied by the short-term constraints are significantly lower when these constraints are optimally addressed through insurance strategies, as opposed to being inefficiently addressed through excessive hedging and an unconditional decrease of the equity allocation. These insights confirm that dynamic asset allocation benchmarks can be designed so as to allow for a more efficient spending of investors' risk budgets. Intuitively, this is because the pre-commitment to reduce the allocation to equity in times and market conditions that require such a reduction so as to avoid over-spending risk budgets, allows investors to invest on average more in equities compared to a simple static strategy that is calibrated so as to respect the same risk budget constraints. The welfare gains involved in this higher allocation to equities are found to be substantial for reasonable parameter values, especially for long-term horizons and in the presence of a mean-reverting equity risk premium. As a numerical illustration of the benefits of risk-controlled strategies, and their benefits in terms of reduction of the opportunity cost implied by the presence of short-term risk constraints, we consider the three long-term unconstrained optimal dynamic strategies analysed in Section I.2., and which were referred to as defensive (leading to an average stock weight of 10%), moderate (leading to an average stock weight of 20%) and aggressive (leading to an average stock weight of 30%), respectively.

# I. Conceptual Background

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While these long-term strategies are engineered to achieve optimal risk/return trade-offs over the long term, short-term losses and drawdown levels can remain extremely large, especially for the aggressive investor, with a maximum drawdown at 23.45%, as can be seen from Exhibit 6. A pension fund wishing to (or obliged to) maintain the maximum drawdown at a level for example around 15% would have to opt for the defensive strategy, which has a reported drawdown of 16.51%, even if the average level of wealth achieved with this strategy is much less attractive at \$365.66 than what is allowed by the aggressive strategy (\$530.87). The objective measure of the opportunity cost associated with a max drawdown limit set at around 15% can be formally defined as the additional initial contribution needed by the defensive strategy to reach the same average wealth level as with the aggressive strategy for the same dispersion level, a cost which turns out to be a prohibitive 45.18% in this particular example (see Exhibit 8). As a result, we find that the pension that would need to finance a liability pay-off around \$500 at the 20-year horizon is facing a challenge and a dilemma. On the one hand, implementing a defensive strategy would

16 - 0.5% of the worst drawdowns have been discarded.

(almost) allow for the respect of the 15% short-term max drawdown risk budget, but it would imply a violation of the \$100 initial contribution dollar budget since it would require an additional initial contribution of more than \$45 to reach an average wealth level at horizon sufficient on average to cover the required pension payment. On the other hand, implementing an aggressive strategy would allow for achieving (in fact exceeding) the target average wealth level of \$500 while respecting the \$100 initial dollar contribution budget, but it would imply a severe violation of the 15% short-term max drawdown risk budget, with a max drawdown estimated at 23.45% on the Monte Carlo simulated paths.

The only way out of this dilemma is to recognise that a more efficient, less costly, approach to the management of the short-term max drawdown risk budget is to use insurance, as opposed to hedging. Hence, as an alternative to opting for the defensive strategy, the investor can choose the aggressive strategy, which allows for a much higher access to the equity risk premium, to which will be added the implementation of a dynamic risk-controlled investing overlay (as per Equation 3) designed to ensure

*Exhibit 8: Statistics and risk measures of long-term strategies with maximum drawdown constraints.*

This table displays over a 20-year horizon the average terminal wealth together with its standard deviation for four long-term allocation strategies, and three different levels of riskiness: aggressive, moderate and defensive. It also shows the maximum drawdown at a 99.5% level.<sup>16</sup> Also, we compute the opportunity cost, which is the percentage of initial wealth necessary for each strategy to reach the same average terminal wealth as the optimal aggressive strategy for the same standard deviation. Additionally, we compute the opportunity gain, which is the percentage of initial wealth saved if one decides to invest in non-defensive strategies to reach the same average terminal wealth as the defensive optimal strategy for the same standard deviation.

	Optimal Aggressive	Opt Agg w/ 15% MDD Control	Opt Agg w/ 10% MDD Control	Optimal Defensive
Av. Wealth	530.87	501.10	401.92	365.66
Std of Wealth	38.02	41.09	38.24	8.84
Max DD at 99.5%*	23.45%	14.57%	10.05%	16.51%
Opportunity Cost	0	5.94%	32.08%	45.18%
Opportunity Gain	31.12%	27.03%	9.02%	0

# I. Conceptual Background

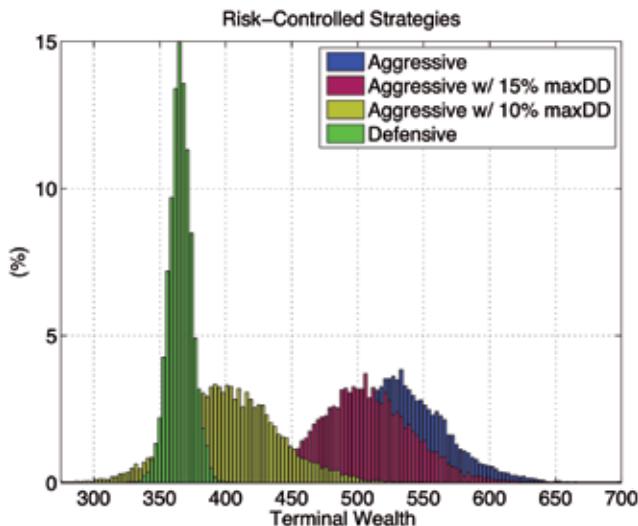
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that the maximum drawdown will be kept below 15% (see Exhibit 9 for the resulting distribution of terminal wealth, where we have also tested maximum drawdown levels at 10%). We now observe from Exhibit 8 that the average wealth of the aggressive strategy with a 15% maximum drawdown constraint is substantially higher than the unconstrained defensive one, for essentially the same level of extreme losses (in fact the max drawdown is kept below 15% for this risk-controlled strategy while it did exceed 15% for the defensive strategy without risk explicit risk controls). This result makes a strong case for the management of short-term constraints through dynamic risk budgeting rather than through the choice of unnecessarily conservative investment policies. So as to provide an objective assessment of the opportunity cost of imposing stricter drawdown constraints when these constraints are optimally managed through insurance techniques, we find that the use of the aggressive strategy with a maximum drawdown constraint of 15% requires a mere 5.94% of additional investment to reach the same average

wealth level as with the aggressive strategy without maximum drawdown constraints. This value compares very favourably to the aforementioned 45.18% opportunity cost involved in managing maximum drawdown constraints inefficiently through an excessive level of hedging.

In fact, one can achieve a higher wealth level compared to the defensive strategy in case one uses the aggressive strategy as an underlying for a risk-control layer with a target max drawdown at a mere 10%, with a corresponding utility cost at 32.08% versus 42.18% for the defensive strategy. Overall, these results illustrate that not disentangling long-term risk aversion and short-term loss-aversion may lead to poor investment decisions. Relatively simple solutions exist that can be implemented as dynamic asset allocation strategies in order to control short-term risk levels while maintaining an access to long-term sources of performance. These solutions are a substantial improvement with respect to traditional strategies without dynamic risk-control, which inevitably lead to under-

*Exhibit 9: Distributions of terminal wealth generated by long-term investment strategies in the presence of maximum drawdown constraints.*



## I. Conceptual Background

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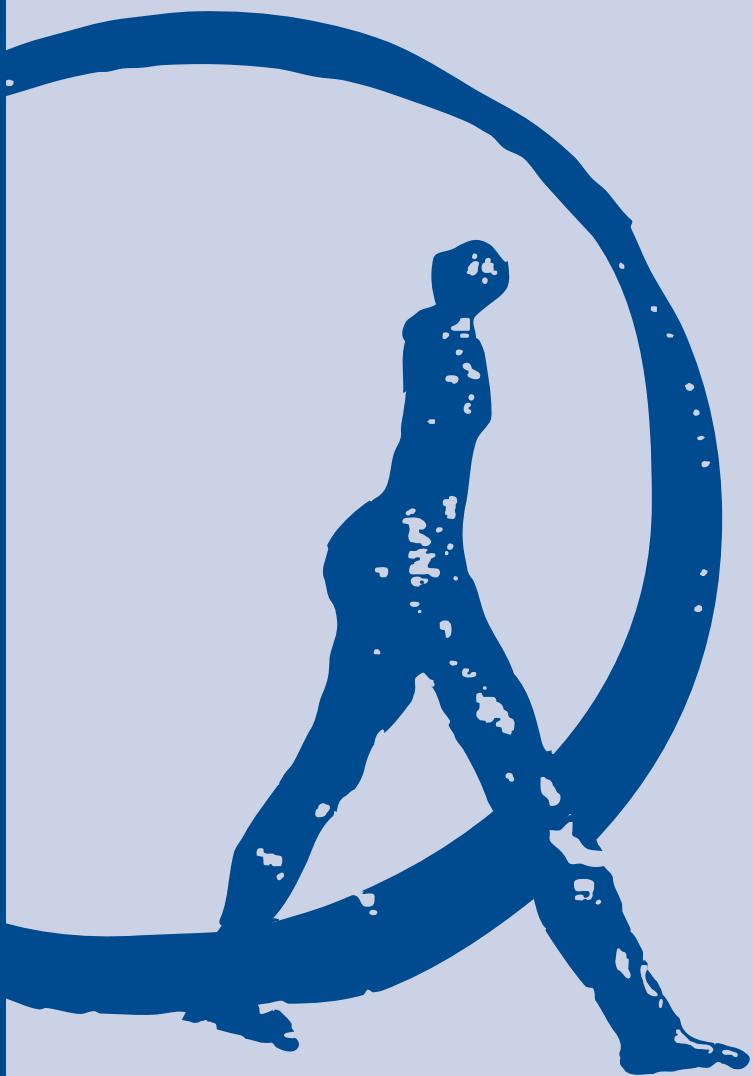
spending of investors' risk budgets in normal market conditions, with a strong associated opportunity cost, and over-spending of investors' risk budgets in extreme market conditions.

Our conclusion is that rising to the challenges of modern investment practice for pension funds involves designing new forms of investment solutions relying on improved, more efficient PSP and LHP building blocks, as well as on improved dynamic allocation strategies. Although each of these ingredients can be found in current investment products, it is only by putting the pieces of the puzzle together and by combining all these sources of expertise that the asset management industry will address investors' needs satisfactorily. From the technical perspective, these advanced investment solutions rely on a sophisticated exploitation of the benefits of the three competing approaches to risk management: risk diversification (a key ingredient in the design of better benchmarks for PSPs), risk hedging (a key ingredient in the design of better benchmarks for hedging portfolios), and risk insurance (a key ingredient in the design of better dynamic asset allocation benchmarks for long-term investors facing short term constraints), each of which represents a hitherto largely unexplored potential source of added value for the asset management industry.

Risk *management* is often mistaken for risk *measurement*. This is a problem since the ability to measure risk properly is at best a necessary but not sufficient condition to ensure proper risk management. Another misconception is that risk management is about risk reduction. In fact, risk management is at least as much about

return enhancement as it is about risk reduction. Indeed, risk management is about maximising the probability of achieving investors' long-term objectives while respecting the short-term constraints they face. In the end, the traditional static LDI strategies without dynamic risk-controlled ingredient inevitably lead to under-spending investors' risk budgets in normal market conditions, with a high associated opportunity cost, and over-spending their risk budgets in extreme market conditions.

## II. Analysis of the Responses to the Survey



## II. Analysis of the Responses to the Survey

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The first part of the document contains background information related to a number of academic insights that can be used by pension funds to implement sophisticated risk and asset allocation decisions within a new investment paradigm broadly known as the dynamic LDI paradigm. In this second part of the document, we turn to a detailed analysis of the responses to a survey that was meant to analyse how such dynamic LDI strategies are used in practice, and what the possible limits to implementation are. In Section II.1, we briefly recall the methodology employed to conduct the survey, and we provide a description of the respondents' profiles. The following sections analyse the responses by following the division of the questionnaire into four parts (the first part being purely descriptive). In Section II.2, we analyse the responses to broad questions related to the LDI paradigm, and more generally, to the asset allocation and portfolio construction principles followed by respondents. Section II.3 is devoted to dynamic LDI, and investigates the reasons that motivate the adoption or non-adoption of this more advanced paradigm. Finally, Section II.4 introduces an integrated ALM perspective with questions related to a better understanding the management of sponsor risk at the pension fund level.

### **II.1 Methodology and Description of Respondents**

#### **II.1.1 Methodology**

The questionnaire was prepared in electronic form; a link was sent by email to targeted professionals, and a phone campaign completed this emailing phase. The first email was sent out on 15 November 2013,

and the last response was received on 24 January 2014. The questionnaire contained a total of 55 questions, but some of them were put to a specific category of respondents only. For instance, some questions were visible only by participants who answered "Yes" or "No" to a particular question (e.g. "Do you hedge your liabilities?" followed by, "If no, how is the asset allocation process defined?" as shown in the second part of questionnaire). All of the questions were multiple-choice questions. Most of them required a single answer and a few others (5 out of 55) allowed for several choices.

#### **II.1.2 Respondents' Profiles**

The survey was aimed at top pension funds in Europe, Australia and North America. We received a total of 104 responses, which is a good rate given the selective focus of the survey and the high level of seniority of the respondents (see Exhibit 12).<sup>17</sup> Exhibit 10 displays the geographical breakdown of responses. A very large majority of them (87%) emanate from Europe, so the responses to the survey are mostly representative of LDI practices of European pension funds. The exhibit also shows the repartition of European participants. For this purpose, the continent was divided into five zones: three countries (Netherlands, Switzerland and the UK) account for more than half of responses; 42% of responses came from other countries of North and Central Europe, Germany and Denmark being the most two represented countries among them; and only four responses are associated with South Europe countries. Overall, this geographical breakdown reflects the larger development, as well as the higher level of sophistication, of the pension fund industry in Northern Europe compared to the rest of the continent.

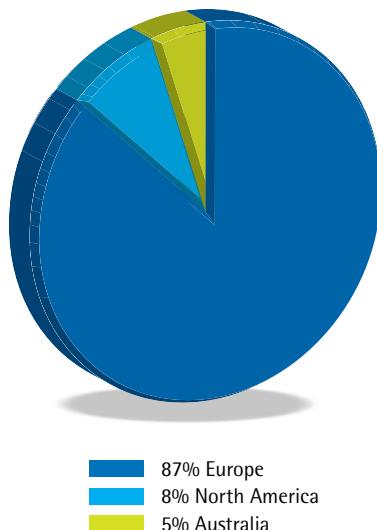
<sup>17</sup> - For comparison, the previous survey undertaken by EDHEC in the field of ALM was the 2010 survey on the ALM practices of European pension funds, which attracted 129 responses.

## II. Analysis of the Responses to the Survey

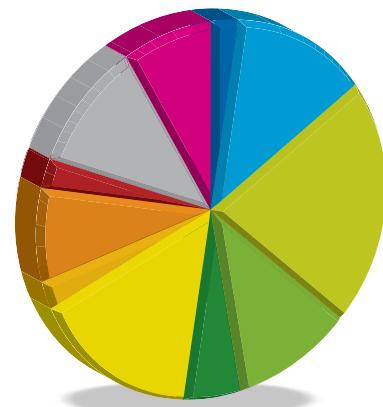
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*Exhibit 10a: Breakdown of respondents by continent. This picture gives the percentage of respondents based in each of the mentioned geographical zones. These percentages are based on the 104 answers to the survey.*

*Notes: Europe = Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Ireland, Italy, Liechtenstein, Netherlands, Norway, Portugal, Romania, Sweden, Switzerland, UK.  
North America = Canada, United States.*



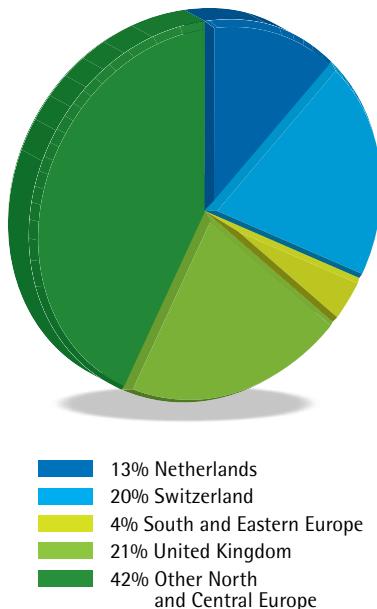
*Exhibit 10c: Breakdown of respondents from Other North and Central Europe by country. This picture gives the number of respondents who have their activity in each of the mentioned countries. These numbers sum to 38, which is the number of respondents from Other North and Central Europe.*



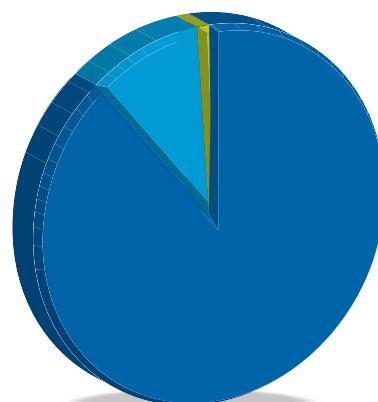
1 - Austria	1 - Hungary
5 - Belgium	3 - Ireland
8 - Denmark	1 - Liechtenstein
4 - Finland	4 - Norway
2 - France	3 - Sweden
6 - Germany	

*Exhibit 10b: Breakdown of European respondents by geographical area. This picture gives the percentage of respondents who have their activity in each of the mentioned geographical zones. These percentages are based on the 91 European respondents.*

*Notes: South and Eastern Europe = Italy, Portugal, Romania.  
Other North and Central Europe = Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Ireland, Liechtenstein, Norway, Sweden, Switzerland.*



*Exhibit 11: Type of institution you belong to? The exhibit indicates the distribution of respondents according to the institution they belong to. The question was put to the 104 participants, and percentages have been normalised by excluding the non-responses (2 out of 104).*



89.2% Pensions Funds (DB vs DC vs Hybrid, corporate vs State)
9.8% Sponsoring Company
1% Consultant

As is apparent from Exhibit 11, the panel of respondents consists mostly of pension fund representatives (89.22%). Only one

## II. Analysis of the Responses to the Survey

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tenth of them introduced themselves as members of the sponsor company. Finally, only one was a consultant.

Participants were then invited to describe their function (Exhibit 12). The two most represented categories are CIO/CFO/Treasurer (44%) and Head of Asset Allocation/Head of Portfolio Management (16%). Chief Risk Officers (CRO) or Heads of Risk Management account for 7% of respondents. Hence, at least 67% of participants have very senior positions in their organisation, and are thus likely to be involved in strategic investment choices. It can also be noted that another 12% occupy a function of portfolio manager or fund manager. Overall, close to 80% of respondents have a high level of responsibility in their organisation, or are asset management professionals. This figure shows that respondents express qualified views on the questions that they were asked.

### II.1.3 Classification of Pension Funds

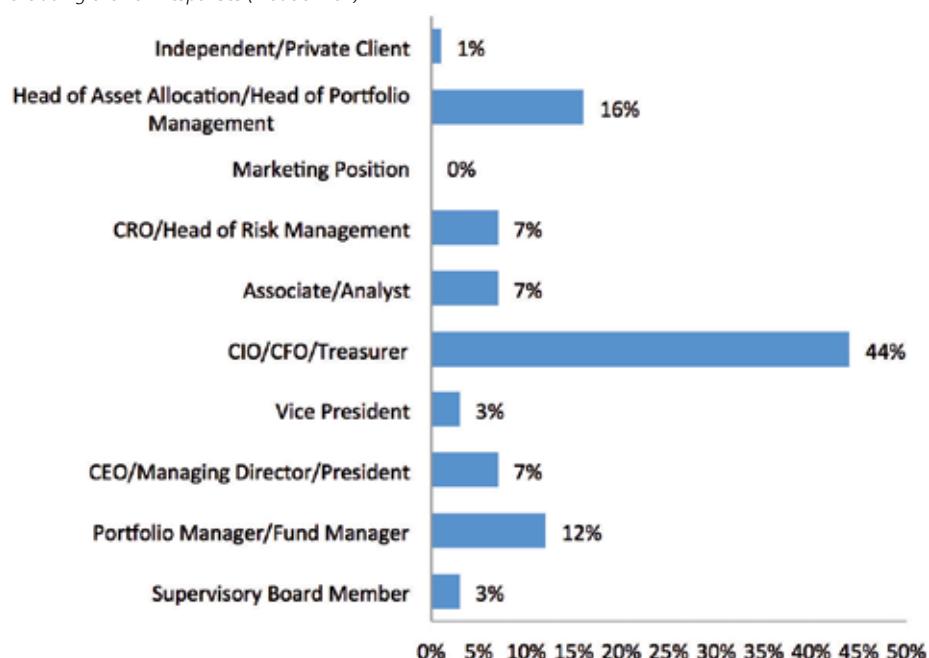
The next series of questions aimed at drawing a classification of the pension funds that responded to the survey.

#### *II.1.3.1 Questions for all Pension Funds*

A standard measure of pension fund size is given by the amount of assets under management, which is reported in Exhibit 13. More than 95% of funds manage less than €50 billion assets, and responses are rather evenly distributed within this category. Hence, our results are not biased towards any particular segment of size.

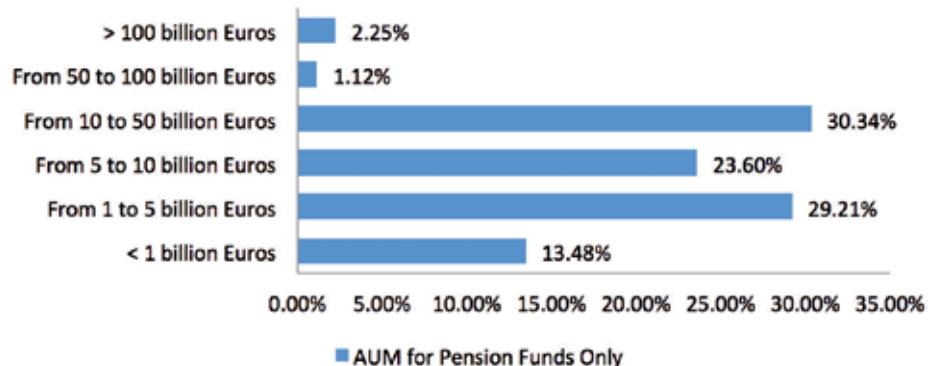
An important distinction is also to be made between defined-benefit (DB) and defined-contribution (DC) pension plans. In a DB plan, the fund pre-commits to a certain amount of pension payments, and has to require additional contributions from the sponsor to fill in the funding gap in the event of an underfunding. In

*Exhibit 12: Position or function that best describes you within your company. The exhibit indicates the distribution of respondents according to their professional activities. The question was put to the 104 participants, and percentages have been normalised by excluding the non-responses (4 out of 104).*



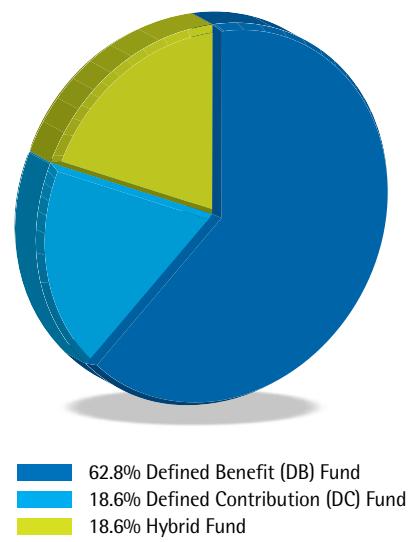
## II. Analysis of the Responses to the Survey

*Exhibit 13: Assets under management (Pension funds only). The exhibit indicates the distribution of respondents based on the asset under management which they reported. The question was put to the 91 pension funds, and percentages have been normalised by excluding the non-responses (2 out of 91).*



a DC plan, contributions are fixed, and it is the benefits that are adjusted to the funding level. Roughly speaking, the risk is borne by the sponsor in a DB plan (since contributions may have to rise in order to deliver the contractual payments), and by beneficiaries in a DC plan (since benefits can be decreased in case of underfunding). There also exist hybrid schemes, in which the risk is shared in various ways among sponsors and beneficiaries. From Exhibit 14, it appears that most of the pension funds who responded to the survey are DB funds (62.79%), and the remaining participants are DC funds or hybrid funds in equal proportions. The general movement from DB to DC plans that has been taking place in most developed countries over the past few years has not resulted in a domination of DC or hybrid plans within the pool of respondents. Of course, it is likely that DB pension fund managers show a more substantial interest in sophisticated LDI investment strategies compared to DC fund managers given the regulatory requirement to maintain a minimum level of funding that the former face in most countries. In Sections II.1.3.2 and II.1.3.3 below, we study in more detail the typologies of DB and DC funds that have responded to the survey.

*Exhibit 14: Type of fund (Pension funds only). The exhibit indicates the distribution of the different types of pension funds. The question was put to the 91 pension funds, and percentages have been normalised by excluding the non-responses (5 out of 91).*



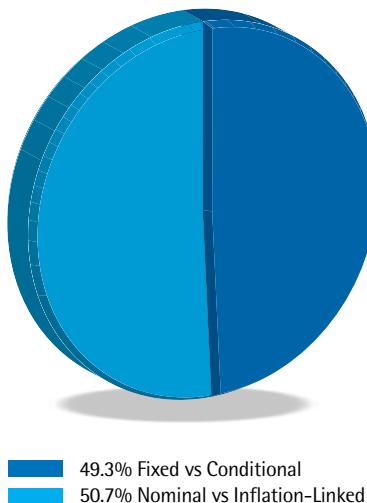
Liabilities can be classified according to several criteria. They can be fixed, in which case they are independent from the funding status of the pension plan, or conditional: for instance, beneficiaries may have access to surpluses, or a fraction of surpluses, in the event of an overfunding. One can also make a distinction between liabilities that are fixed in nominal terms, and liabilities that are indexed on inflation. The latter distinction has important implications for the design of an LHP: if liabilities are

## II. Analysis of the Responses to the Survey

nominal, then the ideal perfect LHP consists of nominal bonds that pay fixed cash flows on the liability payment dates; if liabilities are fixed in real terms, the perfect LHP is a portfolio of inflation-linked bonds that pay inflation-adjusted cash flows on these dates. Exhibit 15 shows that half of respondents adopt the distinction between fixed and conditional liabilities, while the other half focus on the denomination of liabilities, in nominal or real terms.

*Exhibit 15: Type of liabilities (Pension funds only). The exhibit indicates the distribution of the different types of liabilities held by pension funds. The question was put to the 91 pension funds, and percentages have been normalised by excluding the non-responses (12 out of 91).*

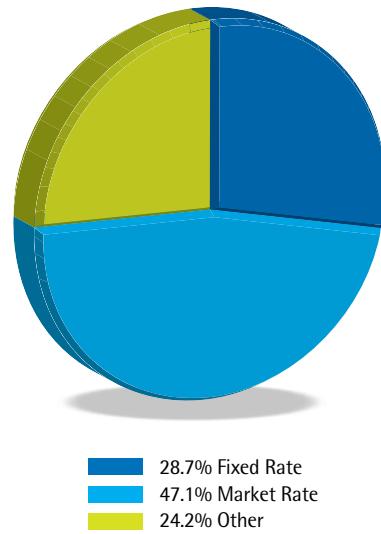
18 – As a first-order approximation, the relative change in the value of liabilities is proportional to their duration, and duration is itself an increasing function of maturity. It has long been recognised that duration, not maturity, is the relevant indicator for measuring the response of a bond price to a change in interest rates (Hopewell and Kaufman, 1973).



By definition, liability value is equal to the present value of future promised payments. Because the liabilities of a pension fund typically have a long maturity (that is, pension payments are due for a long period of time), in general longer than 10 years, their value is largely sensitive to the discount rate applied to the payments. The basic principle is that a decrease in the discount rate increases liability value, and the magnitude of this change is increasing in the liability maturity.<sup>18</sup> We therefore asked participants which discount rate

they use (Exhibit 16). 28.74% of them declare that they use a fixed rate, but a much larger fraction (47.13%) employs a market rate, the latter practice being in line with the recommendations of international accounting standards SFAS 87.44 and IAS 19.78. But as explained in the Background section (see Section I.1.1.1.2), the choice of a market rate has important implications for the design of the LHP, which should include instruments that provide a hedge against the fluctuations in this rate. It also has important implications for the estimates of the surpluses and deficits, which are quantities that may be treated as explicit ingredients within dynamic LDI strategies.

*Exhibit 16: How are liabilities discounted? (Pension funds only)*  
*The exhibit indicates the distribution of the different discount rates used by pension funds to discount their liabilities. The question was put to the 91 pension funds, and percentages have been normalised by excluding the non-responses (4 out of 91).*



Finally, we asked all pension funds to what extent they externalise the asset allocation decisions and/or the management of pension assets. A large majority of them (86.75% in Exhibit 17) makes allocation choices internally and delegate the implementation of their decisions to external managers.

## II. Analysis of the Responses to the Survey

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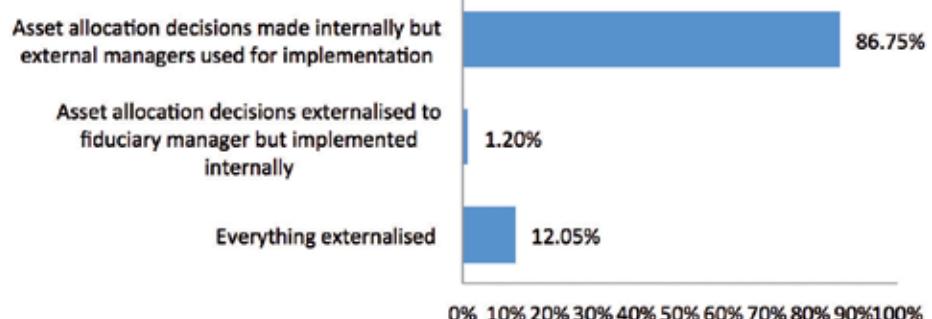
A very small minority (one respondent, or 1.20% of the total of 82 respondents) does the opposite, namely externalise asset allocation decisions and rely on internal expertise to implement them. A larger proportion of the respondents to this question, but still a minority (12.05%), have both processes externalised. These figures show that pension funds are more willing to leave the implementation of asset allocation choices, than the choices themselves, to external partners. This is consistent with the dominant paradigm in pension fund management, which stipulates that the first-order decisions, namely the allocation decisions, are made internally while the implementation of such decisions can be externalised, in particular for pension funds lacking the sufficient size to warrant a cost-effective implementation process. On the other hand, we note that the development of fiduciary management processes lead some smaller pension funds to also externalise asset allocation decisions.

is exposed to the risk of an underfunding, because it may have to face unexpectedly high contributions. Conversely, the pension fund is exposed to sponsor risk, since the sponsor might not be able to make the required payment in the event of a large funding gap if the underfunding happens at a time when the sponsor company's financial health is weak. In an extreme situation, the gap might be so large that the sponsor company would be forced to bankruptcy. The existence of these interlinked risks justifies the development of a specific framework in order to analyse the impacts of decisions from the sponsor company and its pension plan; this is the "integrated ALM framework" that was presented in the Background section of this survey (see Section I.1.2), which stands in contrast with an analysis of pension fund decisions taken in isolation. Of course, this question is not relevant for DC funds, since in these plans, it is the benefits that are adjusted downwards when the funding status deteriorates.

### *II.1.3.2 Question for DB Pension Funds*

In most DB pension plans, the sponsor is called to contribute in the case of an underfunding (56.60% of responses in Exhibit 18). In those situations, the sponsor

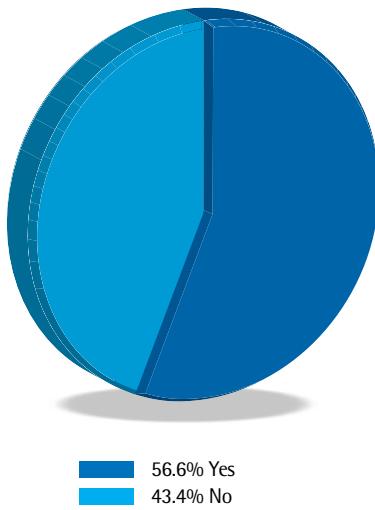
*Exhibit 17: Type of management (Pension funds only). The exhibit indicates the distribution of the different types of management adopted by pension funds. The question was put to the 91 pension funds, and percentages have been normalised by excluding the non-responses (8 out of 91).*



## II. Analysis of the Responses to the Survey

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*Exhibit 18: Is the sponsor forced to contribute in the case of underfunding? (DB pension funds only). The exhibit indicates the percentage of responses of DB pension funds on the contribution in case of underfunding of the pension fund. The question was put to the 54 DB pension funds, and percentages have been normalised by excluding the unique non-response.*



### II.1.3.3 Questions for DC and Hybrid Pension Funds

We now focus specifically on DC funds. In such a system, it is the performance generated by the investment of pension contributions that ultimately sets the level of pension benefits upon retirement. This can be done through individual accounts, where employees rely on their own investment decisions, or through collective accounts, where collective investment solutions are made in a centralised manner. One advantage of a collective DC plan over

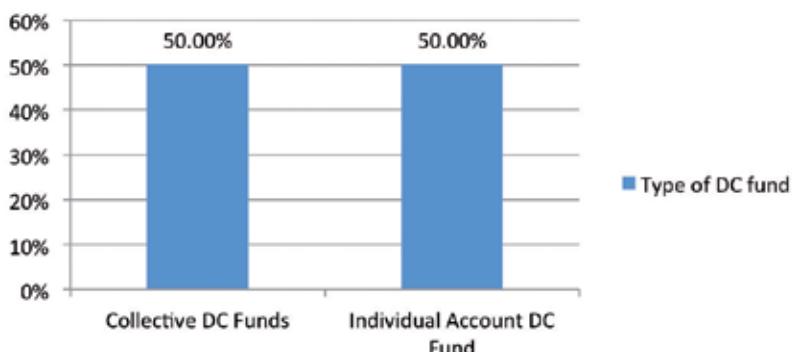
an individual one is that employees can generally benefit from reduced fees when many of them invest in a given product. One additional advantage is that beneficiaries, who typically lack the investment expertise to make sophisticated investment decisions can delegate such decisions to professional money managers. Exhibit 19 shows that the two types of accounts are equally popular among DC funds.

In order not to leave beneficiaries with the risk of potentially large losses, DC funds in general and hybrid funds in particular may choose to offer some form of guarantee. The purpose is to guarantee that beneficiaries will receive at least a minimum amount of benefits for them to afford a minimum standard of living. As shown by Exhibit 20, only 58.06% of DC funds implement such a guarantee.

## II.2 Adoption and Implementation of the LDI Paradigm

As recalled in the Background section, the LDI paradigm is a general investment principle which, in its basic form, advocates splitting pension fund assets between a PSP, an LHP and cash (see Section I.1.1.3, Equation (1)). The main merit of this approach is perhaps to clarify the roles

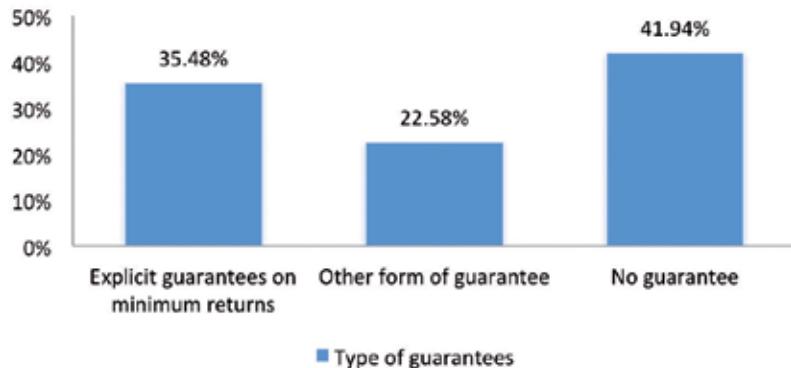
*Exhibit 19: Type of DC funds. The exhibit indicates the distribution of the different types of DC funds. The question was put to the 91 pension funds, and there was no non-response for this question.*



## II. Analysis of the Responses to the Survey

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*Exhibit 20: Type of guarantees (DC and hybrid funds). The exhibit indicates the distribution of the different types of guarantees in the DC and hybrid funds. The question was put to the 32 DC or hybrid pension funds, and percentages have been normalised by excluding the unique non-response.*



of building blocks with respect to the two conflicting objectives generally assigned to a pension fund manager, which are on the one hand the maximisation of risk-adjusted performance so as alleviate the burden on required contributions, and on the other hand minimisation of relative risk with respect to liabilities. This theoretical model of portfolio choice makes intuitive sense, but the separation between performance and liability hedging, does not necessarily correspond to the reality of practices in the industry, where the old surplus optimisation paradigm, which mixes the objectives of diversification and hedging within single reference portfolio, is still used by some pension fund managers. The first goal of the following questions asked in this part of the survey is thus to understand the objectives of managers, and to know whether or they do implement LDI allocations and explicitly split their assets in two separate buckets. Moreover, the theoretical approach to the LDI principle stipulates that the PSP should maximise the Sharpe ratio, and that the LHP should maximise the correlation with liabilities. In practice, pension fund managers may have a different approach to hedge liabilities or to search for performance and even those

who have adopted the LDI principle are unlikely to adhere strictly to the model recommendations. The second goal of the questions is therefore to investigate how managers hedge their liabilities and construct their PSP. The remainder of Section II.2 is organised as follows. In Section II.2.1, we study the general allocation process of pension funds. Section II.2.2 is dedicated to the analysis of LHP construction, and more generally to liability hedging practices. Section II.2.3 contains questions on the use of leverage. In Section II.2.4, we turn to the construction of the PSP. Finally, Section II.2.5 is dedicated to the adoption of risk factor allocation techniques.

### II.2.1 Investment Principles and Adhesion to the LDI Paradigm

A variety of risk measures are available in order to measure "liability risk". The first question we asked to participants is which measure(s) they use to assess liability risk. Exhibit 21 first shows that if a large majority of respondents (81.37%) do measure liability risk, a non-negligible proportion of them declare that they do not. This result is perhaps surprising, since the measurement of the relative risk of the

## II. Analysis of the Responses to the Survey

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portfolio with respect to liabilities appears to be a critically important element in the monitoring of a portfolio in the presence of liabilities.

Risk measures such as the shortfall probability and the expected shortfall are popular, being used respectively by 39.22% and 29.41% of respondents; the former measure is defined as the probability that assets underperform liabilities, and the latter is the average amount by which assets fall short of liabilities in such a situation. These risk measures focus on downside risk with respect to the liabilities, that is, risk of losses relative to the liability portfolio value. This stands in sharp contrast to measures such as volatility, which captures both upside and downside risk, although only the former is obviously a concern, and which are based on an asset-only assessment of the portfolio risk. More than 40% of respondents say that they also use other methods, in place of or in addition to shortfall measures. One can assume that volatility, in spite of the aforementioned shortcoming, and Value-at-Risk or Conditional Value-at-Risk, which are also asset-only risk indicators, but with a focus on downside risk, are among the techniques often adopted.

Once liability risk has been measured, one may wonder if this risk is in effect taken into account in the allocation. To this end, we asked participants whether they hedge or not their liabilities. The results in Exhibit 22 are striking, given that a large half (54.02%) of respondents answer that they do not hedge liabilities. Not hedging liabilities at all implies having a pure asset-only focus, which is a serious concern given that the *absolute* risk properties of an asset class (e.g. their volatilities) are in general very distinct from their *relative* risk properties (e.g. their volatility relative to liabilities, which depends to a large extent to their correlation with liabilities). It should be noted that the adoption of liability hedging is largely influenced by the discount rate applied to liabilities (Exhibit 16): 63.41% of pension funds who apply a market rate hedge their liabilities, while only 20% of those who employ a fixed rate do so. These results show that pension funds have a rather consistent behaviour: those who use a variable rate recognise that fluctuations in the discount rate are reflected in liability value, which calls for liability hedging. Nevertheless, there remain a large 36.59% of funds who use a market rate but do not hedge their liabilities. Moreover, even if those who use a fixed rate are by definition not exposed to the risk of unexpected

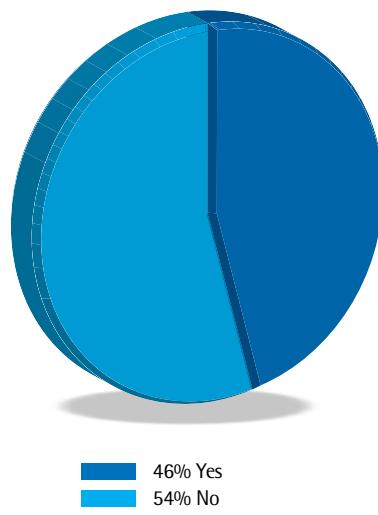
*Exhibit 21: Risk framework used to measure liability risk. The exhibit presents the rate of adoption (in percentage) of quantitative risk frameworks to measure liability risk. Respondents are able to choose more than one response hence why the category percentages add up to more than 100%. The question was put to the 104 participants, and percentages have been normalised by excluding the non-responses (2 out of 104).*



## II. Analysis of the Responses to the Survey

changes in the discount rate, they should still be more concerned with liability hedging, given that the value of liabilities may be impacted by other factors (e.g. by realised inflation if pension payments are indexed on inflation).

*Exhibit 22: Do you hedge your liabilities? (Pension funds only)*  
The exhibit indicates the percentage of responses of pension funds on their hedging practices. The question was put to the 91 pension funds, and percentages have been normalised by excluding the non-responses (4 out of 91).

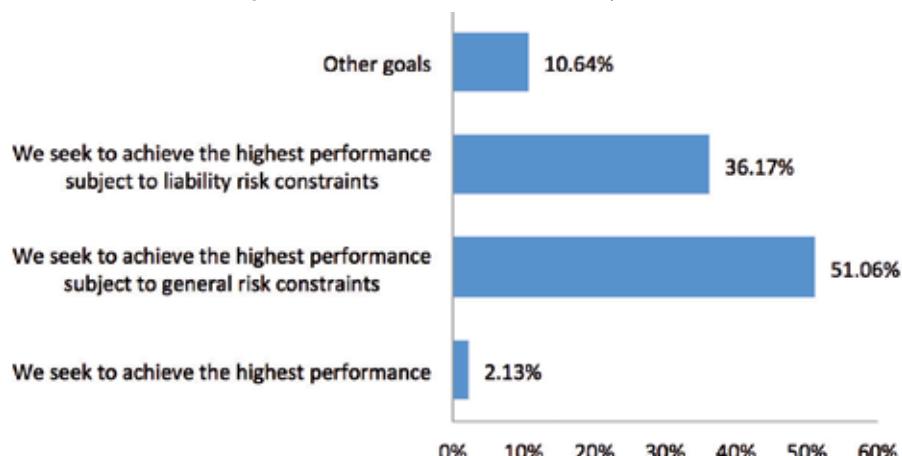


In order to see whether or not they have adopted a pure asset-only perspective, respondents who declare that they do not hedge liabilities are invited in the next question to say what objectives govern their

asset allocation process. A slight majority of them (51.06%) respond that they seek to maximise return subject to risk constraints that do not depend on their liabilities, which implies that they search for the best trade-off between expected return and risk in the absolute sense. Only one respondent says that it seeks the highest performance, regardless of risk, which amounts to having a zero risk aversion. One interesting result is that 36.17% of respondents who answered that they do not hedge their liabilities say here that they seek to maximise the return subject to liability risk constraints. In other words, they perform *surplus optimisation*, that is they try and optimise the portfolio risk-return trade-off in the relative space, where risk is measured relative to liabilities. As recalled in the Background section, surplus optimisation is a somewhat inefficient investment approach which can be regarded as an attempt at *diversifying* away liability risk, while the proper way to manage such risk is to *hedge* it, as is recommended within the LDI paradigm.

Another lesson from Exhibit 23 is that almost all (89.36% of them) respondents who do not hedge their liabilities declare

*Exhibit 23: If you do not hedge your liabilities, how is the asset allocation defined?* The exhibit indicates the distribution of responses of the 47 respondents who answered "No" in Exhibit 22 on their asset allocation framework. The question was put to the 47 pension funds who declare that they do not hedge their liabilities, and there was no non-response.



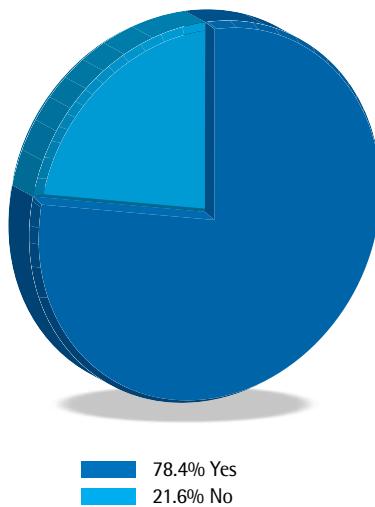
## II. Analysis of the Responses to the Survey

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that they are concerned with performance when they set up their allocation, not to mention the 10.64% who have "Other goals", some of which may also be in that case.

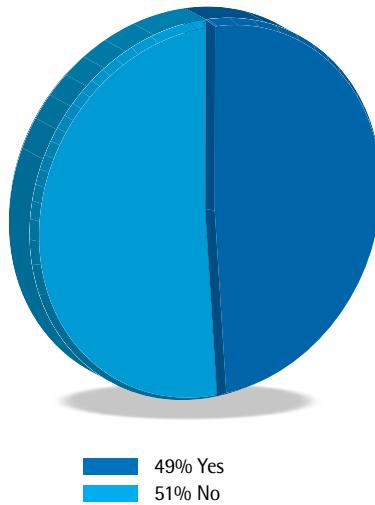
The LDI principle is precisely designed to give the possibility to achieve performance while maintaining a low level of relative risk. The purpose of the next question was to see whether participants are familiar with this investment paradigm. A vast majority of them (78.43% in Exhibit 24) answered positively. This figure suggests that the LDI paradigm has become an accepted norm in ALM for pension funds; it also suggests that the gap between theory and practice is not so large on this particular issue since the LDI principle is deeply rooted in portfolio theory (it is one manifestation of the many "fund separation theorems" - see Section I.1.1.3, Equation (1) and the references cited in the Background section).

*Exhibit 24: Are you familiar with the LDI paradigm? The exhibit indicates the percentage of responses of participants on their familiarity with the LDI paradigm. The question was put to the 104 participants and percentages have been normalised by excluding the non-responses (2 out of 104).*



However, familiarity with the LDI concept does not imply that participants do adopt the fund separation as an investment guideline. As a matter of fact, Exhibit 25 shows that there are virtually as many respondents who do explicitly split their allocation into a PSP and an LHP, as respondents who do not.

*Exhibit 25: Do you split your portfolio in LHP and PSP? The exhibit indicates the percentage of responses of participants on whether they split their portfolio into LHP and PSP. The question was put to the 104 participants and percentages have been normalised by excluding the non-responses (2 out of 104).*



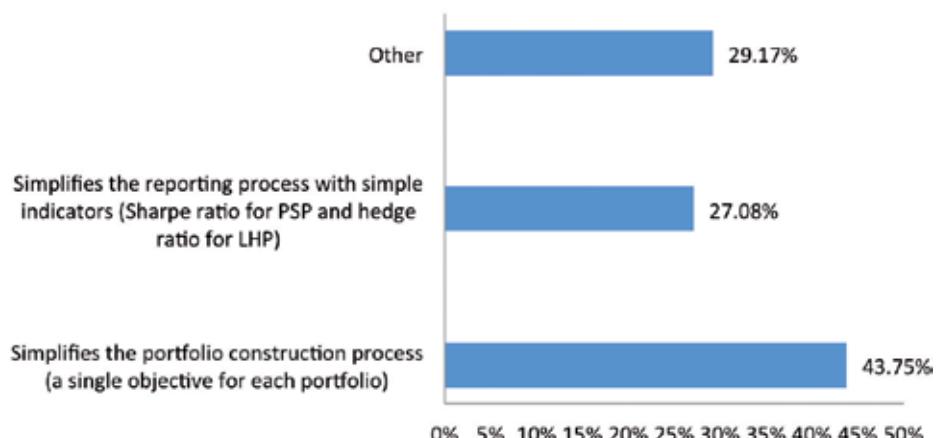
This score is subject to variations across the geographical zones considered in Exhibit 10. The only two countries where a clear majority of respondents adopts a formal fund separation are United Kingdom (16 versus 3 who do not) and Denmark (7 versus 1). The scores in the Netherlands and Germany are the same as those at the global level: in these two countries, the "Yes" and the "No" attracted the exact same number of answers. Finally, in some other regions, fund separation does not seem to be a widespread practice: in Switzerland, two thirds of respondents answered "No", and a similar rate was recorded in North America.

## II. Analysis of the Responses to the Survey

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In view of the mixed results shown in Exhibit 25, it is of equal importance to investigate the reasons that motivate the adoption of fund separation and those that keep some participants from following it. The reason most often quoted by respondents who follow this principle is that it "simplifies the portfolio construction process": this answer was given in 43.75% of cases (see Exhibit 26). This result is not very surprising, since each building block in an LDI strategy has a well-defined role, which is high performance or (absolute) risk-adjusted performance for the PSP, and low risk relative to the liabilities for the LHP. Unlike the old "surplus optimisation approach", which attempts to achieve both objectives within a single portfolio, the LDI paradigm separates the global allocation into two blocks, each of them focusing on a single objective. What further simplifies the process is that the PSP can in principle be designed with no consideration for liabilities. As a result, of the two blocks, the LHP alone depends on the specific liabilities of the fund, while the same PSP can virtually be used by multiple pension funds regardless of the nature of duration of their pension obligations.

*Exhibit 26: If yes, why do you split your portfolio into an LHP and a PSP? The exhibit shows the percentages of the different responses chosen by participants to justify the adoption of the LDI strategy. The question was put to the 50 pension funds that split their portfolio in an LHP and a PSP, and percentages have been normalised by excluding the non-responses (2 out of 50).*

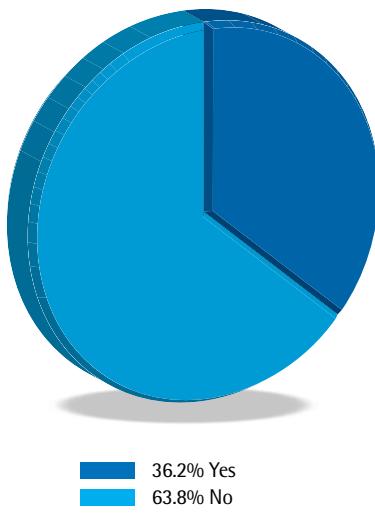


## II. Analysis of the Responses to the Survey

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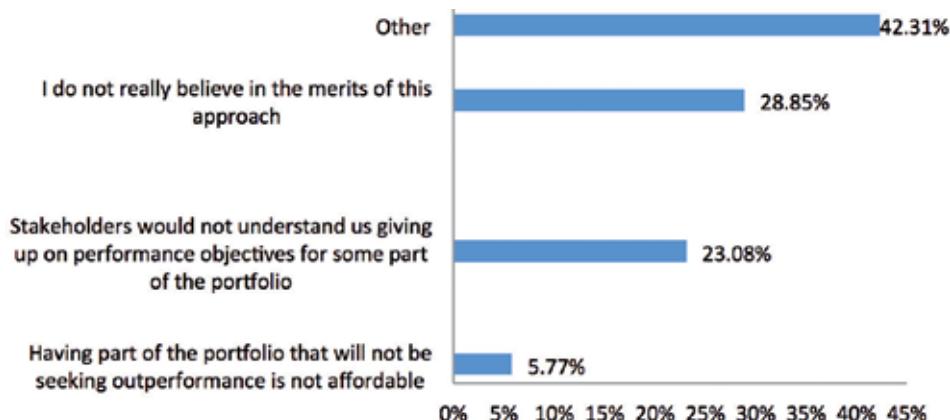
The majority of respondents who separate their allocation into two blocks implement their LDI by themselves: out of the 50, 30 of them say that they do not use external solutions (Exhibit 27).

*Exhibit 27: If you use LDI strategy, do you use external solutions?*  
The exhibit presents the percentage of the responses of those who use or not use external LDI strategies. The question was put to the 50 pension funds that split their portfolio in LHP and PSP, and percentages have been normalised by excluding the non-responses (3 out of 50).



Among those respondents who do not implement the separation between a PSP and an LHP, responses to the question "What are the reasons for non-adoption?" were rather evasive, with 42.31% responding "Other" (Exhibit 28). Those who gave a

*Exhibit 28: If no, why not?* The exhibit shows the percentage of the different responses chosen by participants to justify the non-adoption of the LDI strategy. The question was put to the 52 pension funds that do not split their portfolio in LHP and PSP, and there were no non-responses for this question.



specific answer simply said that they "do not really believe in the merits of this approach" (28.85%) or they invoked the potential loss of performance associated with the use of the LHP (same percentage). Indeed, dedicating a part of the allocation to the pure hedging of liabilities is perceived as a source of a source of poor performance, which would maintain an underfunded pension plan in this status, or which would not be understood by stakeholders. This argument does make sense: if it is severely underfunded, a pension plan has no interest in *fully* investing its assets in a portfolio that by definition tracks the value of liabilities, because this will not help it to address the underfunding challenge. On the other hand, as long as it cares about relative risk, a pension fund should allocate at least *some fraction* of its assets to an LHP, even if it has a cost in terms of performance.

Overall, the results in Exhibit 28 suggest that the opportunity cost (loss of upside potential relative to the liabilities) that follows from the use of an LHP is an important concern that may dissuade pension funds from implementing the fund separation.

## II. Analysis of the Responses to the Survey

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### II.2.2 Liability-Hedging Practices

As recalled above and in the Background section, the theoretical LHP and PSP have clear mathematical definitions, respectively as the maximum Sharpe ratio and the correlation-maximising portfolios. But the portfolios actually held by pension funds are in general different from these abstract constructions. In the next series of questions, we thus investigate in more detail the composition of the LHP and the PSP, and we also study the use of leverage in LDI strategies.

We first focus on the LHP. The theoretical recommendation to maximise the correlation with liabilities implies a qualitative insight, which is that the assets in the LHP should be exposed to the same risk factors as liabilities. Since it is defined as the present value of future promised payments, liability value is highly sensitive to changes in the discount rate, especially when the maturity of pension commitments is long. As a consequence, interest rate risk is one of the main sources of risk in liabilities. The natural approach to hedging it is to invest in fixed-income instruments. In this context, it comes as no surprise to see that 71.23% of respondents indicate that their LHP contains bonds (Exhibit 29). However, when taking a closer look in detail, 12.33% say that they have only bonds, and the remaining 58.90% use fixed-income derivatives together with bonds. The use of derivatives seems to be particularly widespread in Denmark, the United Kingdom and the Netherlands, with respectively 87.50%, 73.68% and 83.33% of respondents from these countries. This strong interest contrasts with the restraint expressed by Swiss respondents, among which the percentage falls to 11.11%.

<sup>19</sup> - There has been also a recent interest among corporations for issuing corporate bonds (e.g. Tesco, Royal Bank of Scotland, Morgan Stanley and Merrill Lynch).

An explanation for the inclusion of derivatives is the existence of frictions and capacity limits within the bond markets. Pension funds are large investors, and the bond market may lack the sufficient capacity to meet their demand, or some bonds may not have the desired level of liquidity. These arguments, which are particularly important for corporate bonds, justify the use of interest rate derivatives such as interest rate swap and futures contracts, which represent a cost-effective way to achieve a target interest rate exposure.

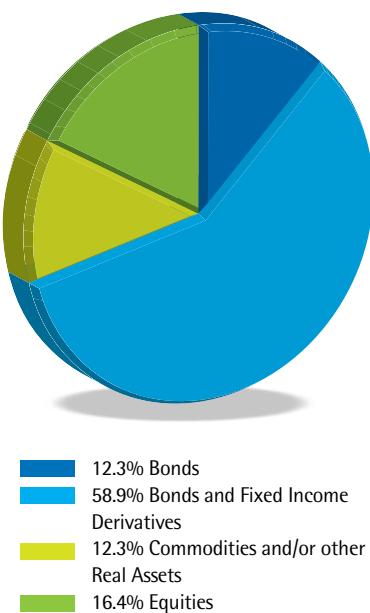
A non-negligible fraction of respondents say that their LHP only contains equities (16.44%) or commodities and/or other real assets (12.33%). Different factors may explain this behaviour. First, many pension funds may be concerned with the performance of their LHP, and bonds may appear expensive in the current economic context. Indeed, interest rates are historically low, which implies low performance on these bonds if they are held until maturity, as well as the risk of severe losses in case interest rates revert back to higher levels, inducing negative bond performance, in case the bonds are sold before maturity date. A second explanation may be related to the perceived inflation-hedging properties of these asset classes. While the most straightforward approach to inflation hedging is to use inflation-linked bonds or inflation-linked derivatives, such inflation-linked bonds, which are mainly issued by sovereign states, are available in limited supply, with real rates that are pushed down by the demand pressure and that tend to be exceedingly low.<sup>19</sup> In this context, pension fund managers may be interested in other asset classes with perceived attractive inflation-hedging

## II. Analysis of the Responses to the Survey

benefits. As recalled in the Background section, the inflation-hedging properties of equities are controversial given that they exhibit a large instability over time (see e.g. Ang *et al.* (2012)). Empirical research has reported evidence that commodities are better inflation hedgers than stocks at short horizons (see e.g. Hoevenaars *et al.* (2008)). Overall, not using bonds within the LHP is a concern because asset classes such as equities and commodities have no easily measurable and stable exposure to interest rate risk, which leaves the main source of risk in liabilities hardly hedged.

*Exhibit 29: How is your liability-hedging portfolio defined?*  
The exhibit presents the percentage composition of the LHP portfolio. The question was put to the 104 participants, and percentages have been normalised by excluding the non-responses (31 out of 104).

20 - They can also use credit derivatives.



Since bonds form the main asset class in the LHP, it is useful to look at the type of bonds included in this portfolio. Exhibit 30 shows that the majority of participants (69.14%) use both corporate and Treasury bonds in their LHP, while only 28.40% have only Treasury bonds and a small 2.47% invest only in corporate bonds.

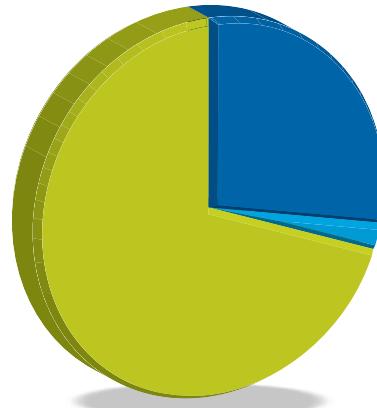
These numbers suggest that the market seeks to take the most of the respective advantages of these two types of bonds. The main advantages of Treasury bonds are that they are by construction hedgers for changes in sovereign interest rates, and that they tend to trade in more liquid markets with long maturities available. Until recently, they were also credited to have zero or negligible default risk, as far as large developed economies were concerned, even though the sovereign debt crisis that started in 2010 has strongly questioned this belief. On the other hand, corporate bonds tend to have a higher expected return due to their embedded default and credit risk premia. Of course, the existence of a default risk premium implies that in some states of the world, default may occur, which is a risk that pension fund managers tend handle by dynamically rebalancing their corporate bond portfolio so as to maintain a focus on high quality issues.<sup>20</sup> Another advantage of investing in corporate bonds within an LHP is that these bonds happen to be better hedges than sovereign bonds for liability risk when liabilities are discounted at a market rate, which includes a spread component (see Section I.1.1.1.2).

Regarding the specific subject of interest rate risk hedging, we next ask participants whether they match the duration of the bonds in their LHP to that of their liabilities. As recalled in the Background section, duration matching is a basic form of liability hedging that aims at immunising the funding ratio against small interest rate changes: if the LHP value and the liability value vary by the same amounts as a response to changes in interest rates, this leaves the funding ratio unchanged.

## II. Analysis of the Responses to the Survey

The result that duration matching is only used by 40% of the respondents (see Exhibit 31) is striking. To better understand the reasons that explain this low penetration of an otherwise standard interest rate risk management technique, we seek to analyse jointly the responses in Exhibit 31 and the responses in Exhibit 16, related to the discount rate used in the valuation of liabilities. Somewhat unsurprisingly, we find that pension funds who discount liabilities using a market rate are much more prone to seek duration matching than those who employ a fixed rate since there were 56.10% of "Yes" in the former category, versus 8% in the latter, a result that suggests the existence of a strong link between the problem of pension liability valuation and pension liability hedging.

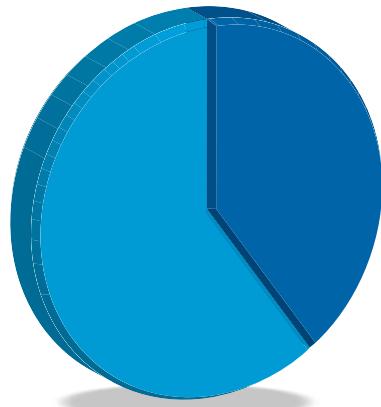
*Exhibit 30: Which types of bonds do you use as part of your LHP? The exhibit presents the percentages of the different types of bonds present in the LHP. The question was put to the 104 participants, and percentages have been normalised by excluding the non-responses (23 out of 104).*



The answers to the question asked in Exhibit 31 are also subject to large fluctuations depending on whether the respondent hedges liabilities: 62.50% of pension funds who hedge their liabilities (see Exhibit 22)

seek duration matching, versus only 10.64% of those who not hedge their liabilities. These differences are not surprising, since duration alignment is a form of liability hedging.

*Exhibit 31: Do you aim to align the duration of bonds in your LHP with the duration of liabilities? The exhibit presents the percentage of responses to this question. The question was put to the 104 participants, and percentages have been normalised by excluding the non-responses (9 out of 104).*



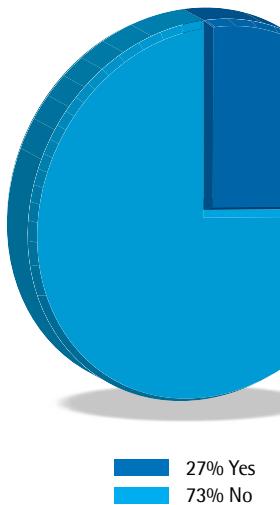
■ 40% Yes  
■ 60% No

An even larger fraction of respondents (72.92%, in Exhibit 32) declare that they do not use duration-matching solutions provided by investment managers. This confirms that duration matching is not seen as a necessity for the construction of an LHP.

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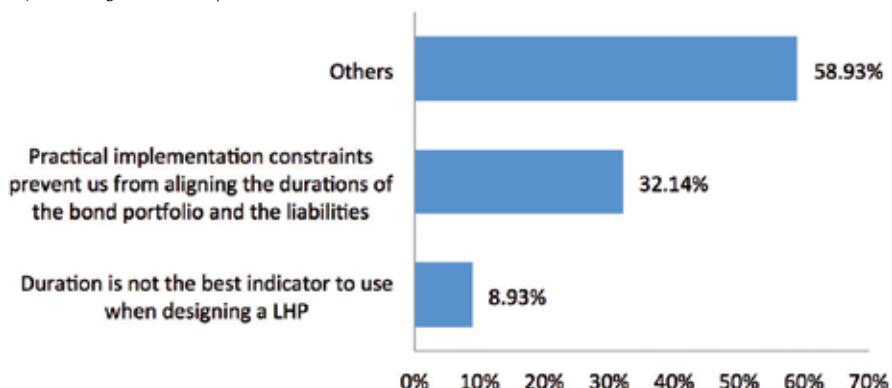
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*Exhibit 32: Do you use duration-matching fixed income solutions provided by investment managers? The exhibit presents the percentages of responses to this question. The question was put to the 104 participants, and percentages have been normalised by excluding the non-responses (8 out of 104).*



Among the reasons for not matching durations, the limitations of duration are invoked in only 8.93% of cases (Exhibit 33). One might have expected a larger proportion of such answers, putting forward the fact that duration matching is effective only for small interest rate changes, and that matching of higher-order sensitivities, such as convexity, is needed to immunise the funding ratio against more substantial changes.

*Exhibit 33: If no, why not? The exhibit indicates the percentages of the different responses chosen by participants to justify their choice. The question was put to the 57 participants who do not do explicit duration matching, and percentages have been normalised by excluding the non-responses (1 out of 57).*

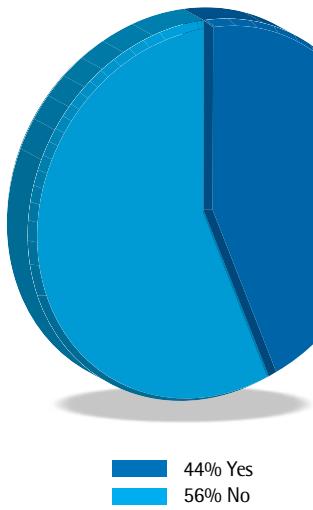


This argument, however, does not seem to be the main concern for respondents. A much larger fraction of them (32.14%) invokes practical implementation constraints that prevent them from aligning the durations. These constraints may be related to the very long duration of typical liabilities: if bonds available for investment have shorter durations, then it is only through the use of leverage, which is not always possible, that the target duration can be reached.

Similarly, duration hedging is only effective to hedge against parallel shifts of the yield curve. In other words, duration matching aims at hedging against changes in the level of interest rates. In case the yield curve changes shape, with changes in slope and/or curvature in particular, more sophisticated interest rate risk management techniques have to be used (see Section I.1.1.1.1). We therefore asked participants whether they seek to align the exposures of assets and liabilities to the slope factor. Unsurprisingly, the responses are not much different from those to the question on duration matching (Exhibit 34): only 43.75% do.

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*Exhibit 34: Do you match asset and liability exposure to changes in the shape of the yield curve (such as steepening and flattening moves)? The exhibit presents the percentage of responses to this question. The question was put to the 104 participants, and percentages have been normalised by excluding the non-responses (8 out of 104).*



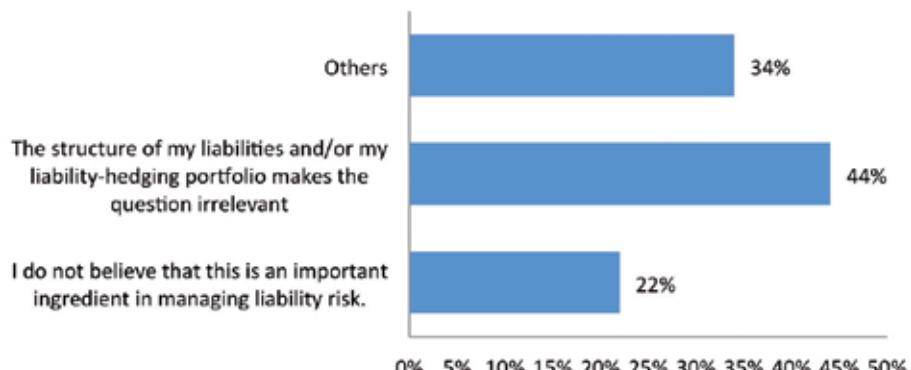
21 - The denomination "locally risky" means that over a short period of time (an infinitesimal period in the mathematical model), the return on the asset is not known in advance. The only asset that is "locally risk-free" is the bank account that earns the continuously compounded short-term interest rate, since the rate earned over a short period is known as of the beginning of the period. On the other hand, because of the uncertainty over future interest rates, the value of the bank account after several periods is not known on the date the investment is set up.

To explain their decision not to match the slope factor exposures, close to half of respondents (44% in Exhibit 35) say that the question is simply not relevant to their specific situation and 22% mention that they do not see this as an important ingredient.

### II.2.3 Use of Leverage

In theory, optimal LDI strategy may involve leverage. Formally, the sum of the weights

*Exhibit 35: If no, why not? The exhibit presents the percentage of responses regarding the non-adoption of the yield curve matching. The question was put to the 54 participants who do not match the asset and liability exposure to changes in the shape of the yield curve, and percentages have been normalised by excluding the non-responses (4 out of 54).*



invested in *locally risky* assets in Equation (1) from Section I.1.1.3 is not necessarily equal to 100%.<sup>21</sup> As a result, cash (the "locally risk-free" asset) is used to make the balance: depending on parameter values, the position in cash can be either sign, positive or negative. A negative weight means that more than 100% of available funds are invested in the risky assets, so the portfolio is leveraged, with for example 100% of the assets dedicated to liability hedging, and a short position in cash being used to finance some non-zero allocation to risk assets such as stocks, bonds, commodities and other alternative classes.

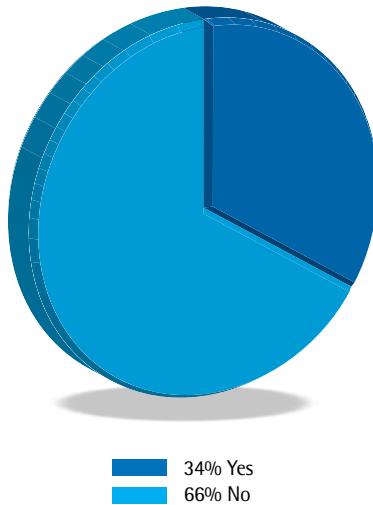
The next series of questions aims at quantifying the usage of leverage by participants, and at understanding their motivations. Exhibit 36 shows that a majority of them (65.91%) does not use leverage. There still remain a significant proportion of respondents (34.09%) who employ it.

When asked why they use leverage, participants answered that they often do so not necessarily by choice, but because some of the instruments that they hold

## II. Analysis of the Responses to the Survey

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*Exhibit 36: Do you use leverage as part of your LDI strategy?* The exhibit presents the percentage of responses to this question. The question was put to the 104 participants, and percentages have been normalised by excluding the non-responses (16 out of 104).



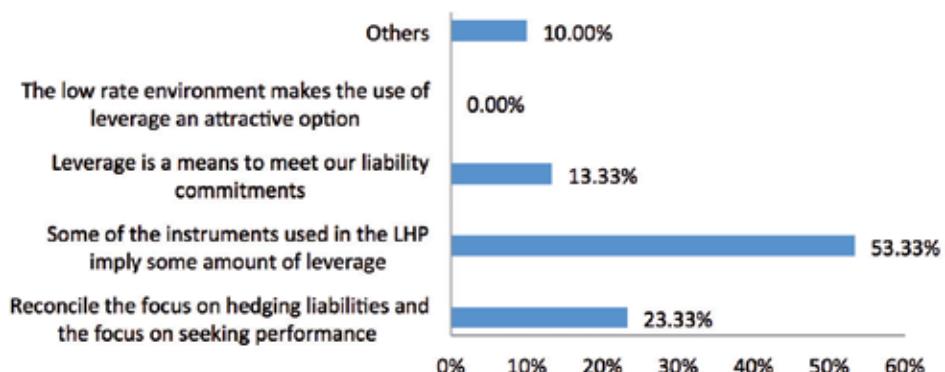
in their LHP automatically imply leverage. This can be the case, for instance, if they use interest rate derivatives such as swaps or futures contracts. Another significant fraction (36.66%) invokes performance considerations. On the one hand, leverage can help to make up for the loss of performance induced by investing in asset classes with good liability-hedging properties but less attractive performance characteristics. In fact, it can be in some cases the only way to achieve the performance targets required to exit an

underfunded status. It is remarkable to note that none of the participants deems the low interest rate environment to be a sufficient reason for using leverage: an explanation may be related to their expectation of future increases in interest rates.

42.11% of participants who shy away from using leverage invoke external constraints, owing to risk limits imposed by the regulator and/or the board of trustees (see Exhibit 38). Indeed, a well-known danger of leverage is that in case the risky assets underperform cash, the portfolio experiences negative returns, and the magnitude of these returns is increasing in the amount of leverage taken. One of the reasons for prohibiting leverage is thus the willingness to protect the interests of beneficiaries by avoiding large losses in pension assets. This concern may also be present in the mind of the 26.32% of respondents who put forward self-imposed constraints.

Finally, Exhibit 39 shows that a large majority of respondents do not implement leverage directly by borrowing, but use derivatives.

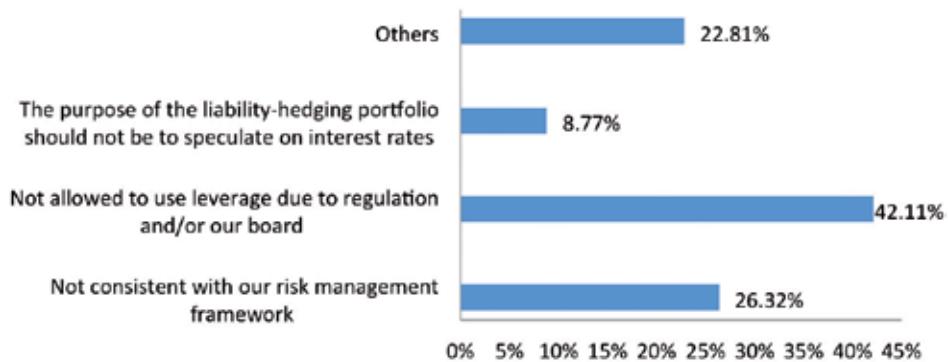
*Exhibit 37: If yes, why do you use leverage?* The exhibit indicates the percentages of the different responses chosen by participants to justify the adoption of the leverage strategy. The question was put to the 30 participants who use leverage, and there was no non-response to this question.



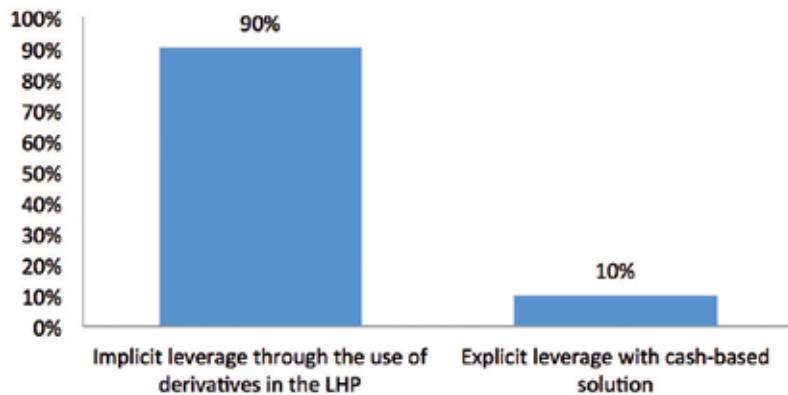
## II. Analysis of the Responses to the Survey

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*Exhibit 38: If no, why not?* The exhibit shows the percentages of the different responses chosen by participants to justify the non-adoption of the leverage strategy. The question was put to the 58 participants who do not use leverage, and percentages have been normalised by excluding the unique non-response.



*Exhibit 39: If you use leverage, which form do you use?* The exhibit presents the responses of participants on the forms of leverage they use. The question was put to the 30 participants who use leverage, and there was no non-response to this question.



### II.2.4 Performance-Seeking Practices

After focusing on liability hedging in Section II.2.2, we turn to two questions on the use of fixed-income products in the PSP.

In Exhibit 40, we report that 78.65% of respondents do not only use fixed-income instruments in their LHP, but also include them in their PSP. This large proportion means that they perceive these instruments as not only attractive for their interest rate hedging properties – which makes them natural candidates for inclusion in the LHP – but also because they are interesting from a risk-adjusted

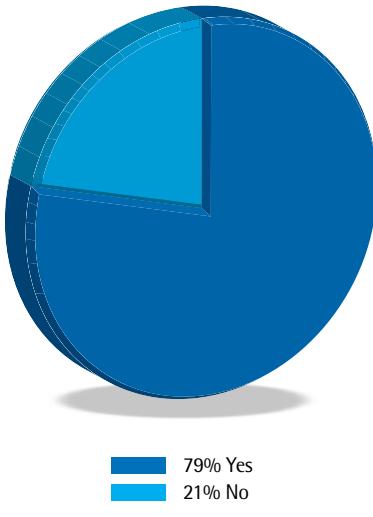
performance perspective. From a purely theoretical standpoint, an asset enters the maximum Sharpe ratio portfolio if it carries a risk premium which is not entirely spanned by other constituents. In practice, an asset is included in the PSP if it has a positive risk premium, or if it brings diversification benefits with respect to the other constituents, or if it enjoys both properties. In other words, the use of fixed-income products in the PSP means that respondents aim at capturing the interest rate risk premium, or at benefitting from their diversification properties with respect to the other classes present in the PSP (e.g. equities).

## II. Analysis of the Responses to the Survey

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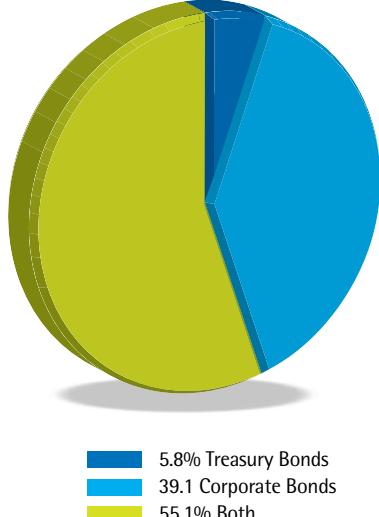
*Exhibit 40: Do you have fixed-income instruments in your performance-seeking portfolio in addition to having them in your liability-hedging portfolio? The exhibit presents the percentage of responses to this question. The question was put to the 104 participants, and percentages have been normalised by excluding the non-responses (15 out of 104).*

Source: EDHEC-Risk Institute



*Exhibit 41: If yes, which type of bonds do you use as part of your PSP? The exhibit presents the percentage of responses to this question. The question was put to the 70 participants who have fixed-income instruments in their PSP, and percentages have been normalised by excluding the non-responses (1 out of 70).*

Source: EDHEC-Risk Institute



More specifically, we invited survey participants to indicate which type(s) of bonds they use in their PSP. Exhibit 41 shows that the majority (55.07%) of respondents who have fixed-income products in their PSP use both Treasury and corporate bonds. This result is similar to the one in Exhibit 20, which shows that the majority of respondents have both types of bonds in their LHP: again, this score can be interpreted as a sign that they seek to take advantage from the properties of both assets. The main difference between the two exhibits is that in the case of PSP, the majority of respondents who use only one type of bond choose corporate bonds (39.13%), and only a small minority (5.80%) goes for Treasuries. This ranking of choices is exactly the opposite of what was observed for the LHP. It is after all not surprising: corporate bonds have higher expected returns than sovereign bonds, and these more attractive performance properties designate them as natural constituents in the PSP.

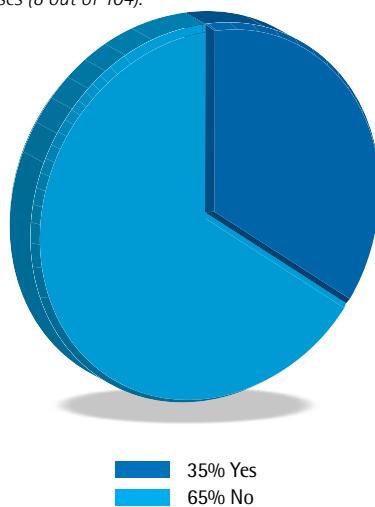
### II.2.5 Allocation to Risk Factors

So far in the survey, we have focused on the use of asset classes within the PSP and the LHP. However, as explained in the Background section (see Section I.1.1.2.3), an approach with growing popularity consists in viewing portfolio construction as a factor allocation exercise. This new paradigm leads investors to frame the allocation decisions in terms of underlying risk factors that drive asset returns, as opposed to allocation to the asset classes themselves. One of the advantages of this approach is that it draws attention on the concentration issues posed by portfolios that contain asset classes with redundant factor exposures. Moreover, recasting asset allocation problem as factor allocation is a natural framework to seek how to best access the premia associated with rewarded factors, such as value and size for example in the equity space.

## II. Analysis of the Responses to the Survey

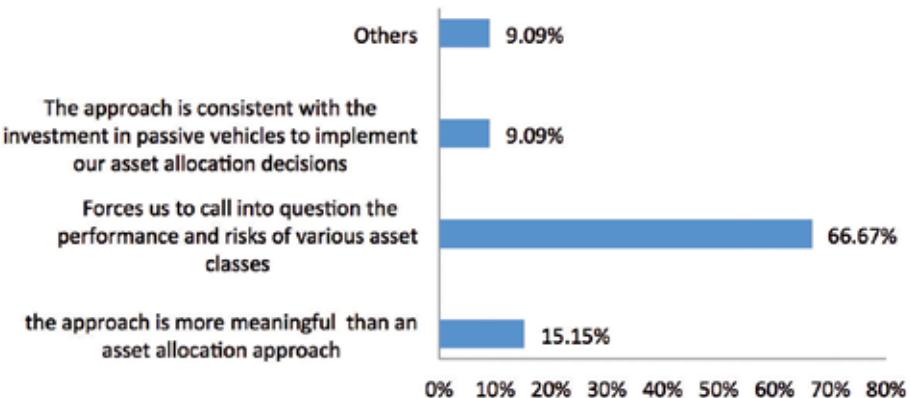
Interestingly, Exhibit 42 shows that 35.42% of respondents adopt this perspective. This percentage represents less than a half, but it is far from negligible, which shows that factor allocation is not only gaining interest, but is also already applied in some form or another by a substantial number of pension funds.

*Exhibit 42: Do you frame your allocation decisions in terms of factors as opposed to, or in addition to, framing it in terms of asset classes? The exhibit presents the percentage of responses on this question. The question was put to the 104 participants, and percentages have been normalised by excluding the non-responses (8 out of 104).*



When asked to motivate their choice to follow this new paradigm, participants most often answer that it "forces [them]

*Exhibit 43: If yes, why do you use a factor allocation framework? The exhibit shows the percentages of the different responses chosen by participants to justify the adoption of the factor allocation strategy. The question was put to the 34 participants who use a factor allocation framework, and percentages have been normalised by excluding the non-responses (1 out of 34).*



to call into question the performance and risks" of asset classes (66.67% of respondents in Exhibit 43). Hence, the main reason for choosing a factor allocation framework is the recognition that splitting the investment universe in asset classes has severe limitations that can be overcome by studying the sources of performance and risks of these assets. On the performance side, measuring the exposures of assets to rewarded factors sheds light on the sources of performance. On the risk side, the knowledge of these exposures helps to avoid over concentration of the portfolio in a limited number of factors that impact several asset classes. The second reason most often cited by participants is the parsimony inherent to the factor framework (15.15%). Indeed, it leads to many different asset classes being "summarised" in terms of a limited number of risk factors. This argument is in fact related to the previous one: by being aware of the exposures of asset classes, pension fund managers are able to assess their effective degree of similarity, thereby going beyond their apparent differences. For example, it is known that equities and corporate bonds, although having very

## II. Analysis of the Responses to the Survey

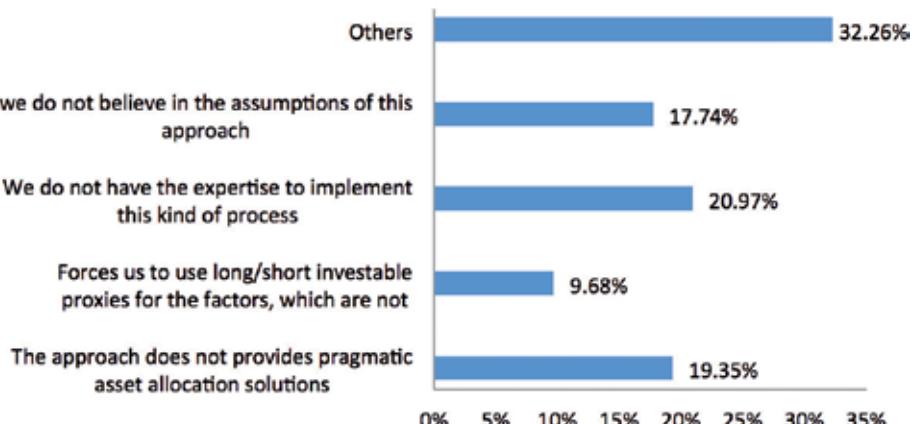
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different institutional characteristics, are both impacted by the presence of credit risk; this common exposure should be taken into account when designing an allocation to these classes. The third reason by decreasing number of responses (9.09%) is that the factor approach is "consistent with [the] desire to invest in passive vehicles". The few respondents who express an interest in passive investment solutions are likely to be interested by the "factor indices" which are being pushed forward by index providers, and which are meant to deliver a stable exposure to selected factors.

It should be recognised, however, that a factor allocation also poses challenges. First, the use of a factor model by definition exposes asset managers to misspecification risk. This risk, however, does not seem to be the main concern of participants who do not implement this approach: in Exhibit 44, it appears that it is a concern to only 17.74% of them. More often invoked are the implementation challenges posed by the factor allocation. The first of these challenges is the measurement of the exposures of assets

to factors, which may raise robustness concerns if these exposures are estimated by regression techniques. This challenge is particularly severe at the asset allocation level: while a relative consensus exists from both the academic and practical perspectives with respect to what can be the meaningful risk factors in the equity space (with the most commonly cited factors being size, book-to-market, momentum, volatility and liquidity), there is no similar consensus regarding what may be a comprehensive factor model that may explain the risks and returns on many different asset classes. Second, once relevant factors have been identified and the allocation to them has been chosen, one has to reframe it in terms of allocation to asset classes: this step is facilitated if the factors are investable, but it is more difficult to implement if they are not, since one has to find investable proxies. An example is given by Fama-French value and size factors: these factors are defined as long-short portfolios, but many pension funds may be required to invest in long-only proxies for these factors. Moreover, even if the factors are investable, the target

*Exhibit 44: If no, why not? The exhibit indicates the percentages of the different responses chosen by participants to justify the non-adoption of the factor allocation strategy. The question was put to the 62 participants who do not use a factor allocation framework, and there was no non-response for this question.*



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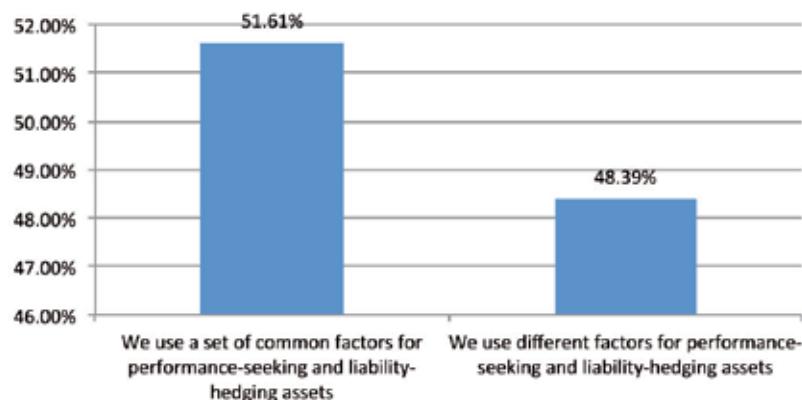
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factor allocation may not be replicable under the weight constraints imposed to the fund: for instance, the presence of long-only constraints on holdings in asset classes may prevent from reaching the desired factor exposures. In view of these difficulties, a large fraction of respondents are sitting on the sidelines: 20.97% of them simply declare that they do not have enough expertise, 9.68% that they cannot use long-short proxies, and 19.35% invoke a lack of pragmatism in the resulting asset allocations. The last two categories of respondents are likely to have in mind the aforementioned difficulties to find investable proxies and to find the asset allocation that exactly matches a given factor allocation.

As one might expect, the choice of factors in a factor allocation approach is a crucial determinant of the quality of the model. With too few factors, one is exposed to a substantial risk of misspecification, given that relevant factors are likely to be omitted. On the other hand, a model with too many factors is likely to raise over-fitting concerns, such as collinearity between regressors, or spuriously high

R-squares and t-statistics, which give the wrong impression that the model is well specified. In the equity universe, standard factors are market, size, value, momentum and volatility. In the fixed-income universe, usual factors are the level of interest rates, the term spread (which proxies for the slope of the term structure), and the credit spread. Because equity is the dominant asset class in the PSP and fixed-income products are dominant in the LHP (see Exhibit 29), one might expect participants to use equity factors for their PSP and bond factors for their LHP. It turns out (Exhibit 45) that this is not the most widespread approach: half participants actually use the same set of factors for both portfolios. This approach has perhaps the merit of internal consistency, but it may lack parsimony. Indeed, Fama and French (1993) study the possibility to explain stock and bond returns with a common set of factors (market, value and size for the equity universe, and term spread and credit spread for the bond class). They find that the equity factors are no longer significant when they are used jointly with term structure factors to explain bond

*Exhibit 45: If you use factor allocation, what approach do you prefer? The exhibit indicates the percentages of the different responses chosen by participants to clarify the type of factor allocation they use. Percentages are based on 44 responses and add up to 100%.*



## II. Analysis of the Responses to the Survey

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returns (except for low-grade bonds), and conversely, term structure factors appear much less significant than equity factors when it comes to explaining stock returns.

### **II.3 Use of Dynamic LDI Techniques**

Dynamic LDI is distinct from static LDI in that it involves periodic revisions of the allocation to PSP and LHP. As explained in the Background section, there are two main, non-exclusive, reasons for engaging in dynamic LDI:

- In the presence of time-varying investment opportunities, the theoretically optimal strategy is neither of the buy-and-hold nor of the fixed-mix type; it is instead a strategy that varies the allocations within and across the PSP and LHP building blocks in response to changes in risk and return parameter values. Moreover, it contains "hedging demands", that is allocations to portfolios whose role is to provide a protection against adverse changes in investment opportunities (see Section I.2.2 for more details);
- Short-term risk constraints, such as minimum funding requirements, cannot be respected in all cases simply by relying on diversification or hedging, unless extremely conservative investment policies are adopted, which severely compromises the access to upside (see Exhibit 8 in Section I.3.3). In that case, an efficient approach to reducing the opportunity costs involved in the respect of the risk constraints is maintaining a substantial allocation to risk asset while pre-committing to reducing this allocation if and when needed. In other words, the goal is to have an allocation to performance assets that depends on a risk budget, defined as the distance

between current wealth and a floor, which represents the minimum acceptable wealth.

These general considerations raise a series of implementation issues among which the following stand out: How can changes in investment opportunities be detected, and how can parameter uncertainty be dealt with? What floor should be chosen for the definition of risk budgets? How can such dynamic strategies be implemented in a cost-efficient manner, especially when the asset mix involves investment in illiquid assets? Addressing these questions is not entirely straightforward, especially those that relate to the changing opportunity set, so that dynamic LDI can unquestionably be regarded as a more advanced form of LDI that can be implemented by a fraction of the most sophisticated pension fund managers. In this part of the survey, we analyse the reasons that lead pension fund managers to use dynamic LDI techniques or not.

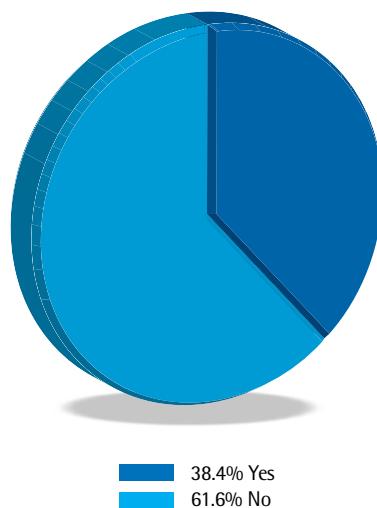
#### **II.3.1 Adhesion to Dynamic LDI**

As a starting point, we ask participants whether they use or consider using dynamic LDI techniques. The majority of the respondents give a negative answer (see Exhibit 46), but the score of 61.46% is not overwhelming, and there remain a comfortable 38.45% of respondents who express an interest in these techniques. As for the question on the separation between a PSP and an LHP (see Exhibit 25), there are geographical disparities: in the Netherlands, Denmark, the United Kingdom, and in North America, half of respondents answer "Yes", a percentage which is higher than the percentage at the global level. In Germany, we even

## II. Analysis of the Responses to the Survey

recorded four "Yes" for two "No". On the other hand, Swiss respondents express less interest than the rest of the population for dynamic LDI (30% of "Yes"). It is worth noting that they were also less likely to split their allocation into a PSP and an LHP (Exhibit 25).

*Exhibit 46: Do you use or consider using dynamic LDI strategies which require periodic revisions of the portfolio policy? The exhibit presents the percentages of responses to this question. The question was put to the 104 participants, and percentages have been normalised by excluding the non-responses (8 out of 104).*



Among the aforementioned two justifications for dynamic LDI, changes in the economic environment are most often invoked by those respondents who choose to set up such an investment process. The questionnaire gave them the choice between two answers: the incorporation of tactical views (selected by 27.78% of respondents in Exhibit 47), and the reaction to changes in market conditions (33.33%). The first reason has to do with active views on what *realised* returns will be for the *future*: for instance, if the manager expects a temporary under-performance of equities with respect to bonds, he/she may be tempted to shift

the allocation towards the latter asset class. The second reason is related to the manager's assessment of the *current level* of risk and *expected return* parameters. This perspective does not involve any predictive power; it involves instead some disciplined process for tracking changes in risk and return parameter values and implementing changes in the allocation as a result. For instance, the existence of an upward shock to equity volatility should rationally involve, everything else equal, a reduction of the allocation to stocks (see the discussion about target volatility strategies in Section I.2.2 for more details).

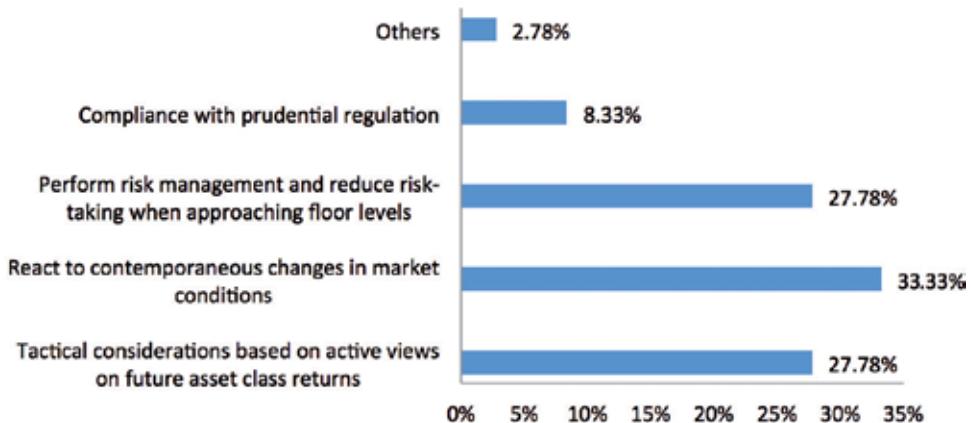
Overall, it appears that the majority of respondents who are engaged or consider engaging in dynamic LDI (61.11%) do so because they are receptive to economic signals, without an explicit focus on generating value through active tactical asset allocation decisions. Perhaps surprisingly, only 36.11% of participants who express an interest for dynamic LDI invoke short-term constraints, whether the respect of a generic floor (27.78%) or compliance with regulation (8.33%). Hence, the second justification for dynamic LDI mentioned in the introduction of Section II.3 is not the main motivation for participants.

One possible motivation for the adoption of a dynamic LDI strategy with risk budgets is the presence of regulatory minimum funding requirements: under such a regulatory regime, the floor is equal to the minimum funding ratio times the value of liabilities (see Section I.3.1).

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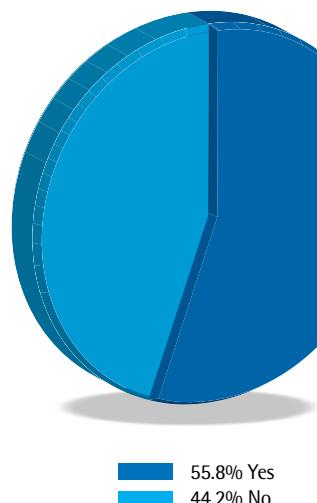
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*Exhibit 47: If yes, what are your motivations? The exhibit indicates the percentages of the different responses chosen by participants to justify the adoption of the dynamic LDI strategy. The question was put to the 37 participants who use or consider using dynamic LDI, and percentages have been normalised by excluding the non-responses (1 out of 37).*



We therefore asked participants whether they do face such a regulatory constraint. While a slight majority of them answers "No" (Exhibit 48), this result masks important regional disparities. For instance, all participants based in the Netherlands who answered this question said "Yes", while the quasi totality of UK respondents (that is, 16 out of 19) answer "No". For Switzerland, the situation is mixed: out of 14 respondents, there were 6 "No" and 8 "Yes".

*Exhibit 48: Do you face minimum funding ratio levels from a regulatory standpoint? The exhibit presents the percentage of responses of participants to this question. The question was put to the 104 participants, and percentages have been normalised by excluding the non-responses (9 out of 104).*



The next question focuses on the implementation of dynamic LDI. Half of the respondents answer that they use derivatives (see Exhibit 49). Broadly speaking, two kinds of derivatives contracts can be used in the context of dynamic LDI strategies. On the one hand one can use dynamic trading in instruments such as futures contracts that have a linear pay-off. On the other hand, one can also use derivatives instruments, such as option contracts, that have a non-linear pay-off. As recalled in Section I.3.2, dynamic asset pricing theory shows that it is actually equivalent to implement a dynamic strategy or to choose a non-linear derivatives pay-off (see Cox and Huang (1989) and Duffie (2001)). From a practical standpoint, however, the choice between the two options is not irrelevant: dynamic strategies involve by nature more frequent rebalancing, which can incur additional transaction costs if the asset classes are little liquid. On the other hand, a static position in an option avoids these costs, and one may think that this argument matters to those participants who use derivatives. Only one fourth of respondents who implement dynamic LDI do it through using cash positions.

## II. Analysis of the Responses to the Survey

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As in the question on the composition of the LHP (Exhibit 29), Denmark and Netherlands are two countries where derivatives are more often adopted than in the rest of the world. On the other hand, none of the three respondents from North America who implement dynamic LDI uses derivatives.

*Exhibit 49: If you use LDI strategies, which mode of implementation do you use? The exhibit presents the percentages of responses to this question. The question was put to the 37 participants who use or consider using dynamic LDI, and percentages have been normalised by excluding the non-responses (1 out of 37).*

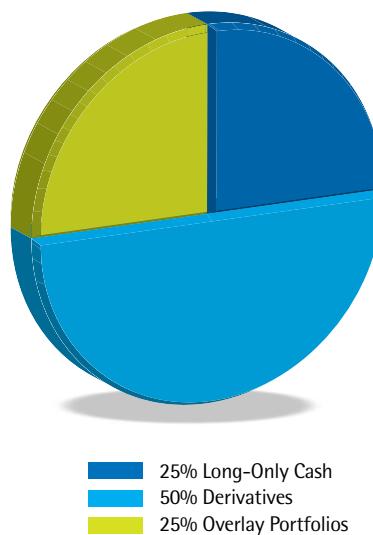


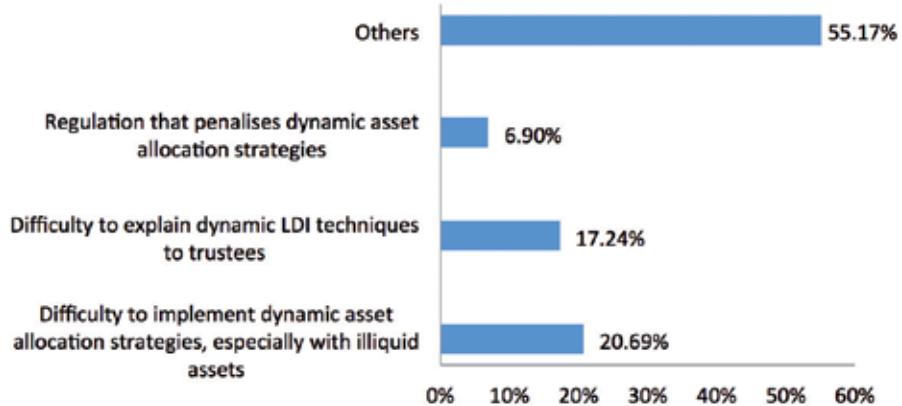
Exhibit 50 gives possible explanations for the non-adhesion of other participants to dynamic LDI. One fifth of them invoke implementation difficulties, an argument that was already behind the reluctance of 64.58% of participants to implement factor allocation policies. This result suggests that more applied research is needed to progress towards implementable solutions that retain the advantages of dynamic policies while complying with real-world constraints (see Martellini and Milhau (2010a) and Amenc *et al.* (2011) for examples of dynamic strategies constructed from

theoretically optimal portfolio rules and being consistent with implementation constraints). Another cited reason is the difficulty to explain dynamic strategies to trustees (17.24%). Indeed, those strategies involve a higher degree of sophistication through the measurement of market conditions and risk budgets, which makes them more difficult to describe to a non-expert audience. One might recognise, however, that while the mathematical treatment of stochastically time-varying investment opportunities and short-term constraints can be sometimes complicated, the strategies that are obtained tend to be simple rule-based strategies that adhere to intuitive and simple principles, such as increasing the allocation to safe assets (the floor-replicating portfolio) when the margin for error is reduced (i.e. approaching the floor - see Section I.3.2), or increase the allocation to stocks when they are inexpensive from a historical perspective (see Section I.2.3). Other participants who keep away from dynamic LDI invoke the unfavourable regulatory treatment of these strategies (6.90%), or other reasons (55.17%).

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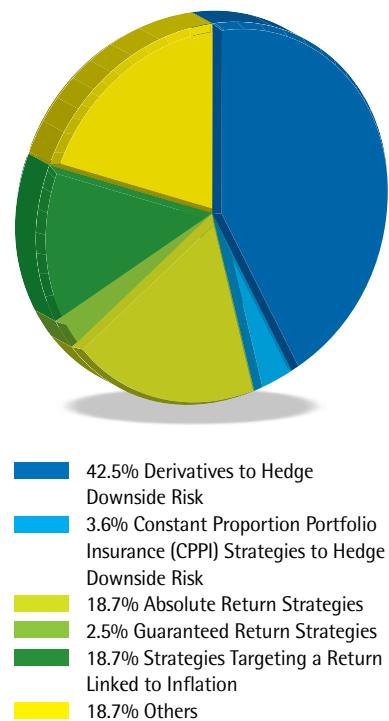
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*Exhibit 50: If no, why not? The exhibit indicates the percentages of the different responses chosen by participants to justify the non-adoption of the dynamic LDI strategy. The question was put to the 59 participants who do not use or consider using dynamic LDI, and percentages have been normalised by excluding the non-responses (1 out of 59).*



If it cannot be expected that pension fund managers implement in practice some theoretically designed dynamic LDI strategy, it is important to recognise that some products and strategies currently exist, which share some of the flavours of the optimal dynamic LDI strategies even though they do not contain all the required ingredients. Among these approaches, we can identify the use of option contracts to hedge equity or fixed-income risks, the use of constant-proportion portfolio insurance strategies (CPPI) or the use of strategies seeking to achieve, or even to guarantee a minimum performance regardless of market conditions. Exhibit 51 discusses whether such proxies for optimal risk-controlled strategies are effectively used by pension fund managers who do not have the willingness or ability to implement a more comprehensive approach to the insurance of short-term risk budgets.

*Exhibit 51: Do you use or consider using any of the following alternatives to LDI strategies? The exhibit presents the percentage of responses to this question. The question was put to the 104 participants, and percentages have been normalised by excluding the non-responses (24 out of 104).*



We find that the use of derivatives in the context of downside risk management is relatively widespread, since 42.5% of the respondents declare that they do use some derivative contract in this context. This

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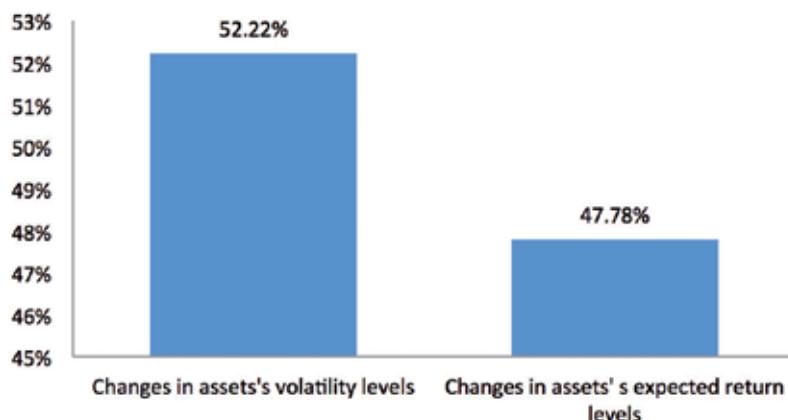
approach, however, is not in equal favour in all regions: Germany and Denmark are the two countries in our sample that show the most pronounced interest, with percentages of respectively 66.67% and 75%. On the other hand, the proportion of Dutch respondents who use derivatives is roughly the same as the proportion in the entire sample, and regions such as Switzerland, the United Kingdom and North America display lower adhesion rates.

From Exhibit 51, small fraction of the respondent also uses CPPI strategies, which perhaps confirms that such strategies are more often used in the design of guaranteed products for private clients, versus in the context of a pension fund money management mandate: as a matter of fact, two of the three respondents who mentioned this technique are based in Switzerland, a country with a largely developed private wealth management industry. Absolute and guaranteed return strategies are also used by a substantial number of respondents in an attempt to reduce the opportunity costs related to managing downside risk with assets that have a linear exposure to underlying risk factors.

### II.3.2 Measurement of Market Conditions

As indicated by Exhibit 47, the desire to react to changes in market conditions is explicitly cited by one third of respondents who express an interest in dynamic LDI, not to mention the 27.78% who use or consider using this approach because it gives them the opportunity to incorporate their views in the allocation, views that may themselves depend on the economic environment. It is therefore of interest to know how participants measure market conditions. In portfolio choice theory, investment opportunities are summarised in those state variables that impact covariances and expected return parameters. We therefore asked participants whether they favour volatilities or expected returns in their assessment of the opportunity set. Exhibit 52 indicates that close to half of them look at expected returns, while the other half consider volatilities. This equal split is perhaps surprising because it is widely admitted that expected returns are much harder to estimate than volatilities, so that it seems more hazardous to rely heavily on them. Only a slight majority (52.22%) adopts a volatility perspective, which suggests

*Exhibit 52: How do you measure market conditions? The exhibit presents the percentage of responses to this question. The question was put to the 104 participants, and percentages have been normalised by excluding the non-responses (14 out of 104).*



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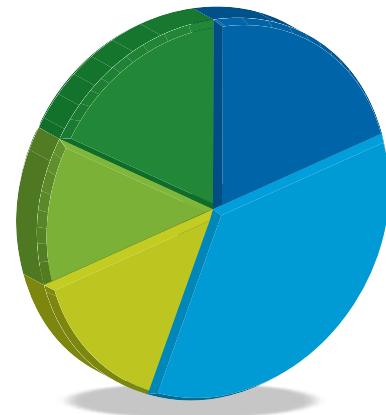
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that target volatility strategies have yet to reach a more global acceptance. Overall, this result suggests that despite the statistical issues associated with the estimation of expected returns, half of participants are sufficiently concerned with the performance of their portfolio to try and generate estimates for these parameters so as to tilt their portfolios towards asset classes that have the highest performance potential given the current market conditions.

### II.3.3 Definition of Risk Budgets

The next series of questions deals with the definition of risk budgets. First, we asked participants which risk measure they use to compute these budgets. Only one fifth of them (see Exhibit 53) rely on volatility. Despite its relative computational simplicity, this indicator has an important limitation, which is that it equally penalises upside and downside risk, and also that it has a pure asset-only focus. Among the dissymmetric measures, which collectively account for the remaining 79.17% of responses, Value-at-Risk stands out as the most commonly used indicator, in spite of its inherent limitation in an asset-liability management context. On the other hand, we find that roughly 50 of the respondents do use risk indicators such as probability of a (large) shortfall or expected shortfall that are consistent with a liability-driven perspective. Overall, the responses to this question indicate that participants have recognised that extreme risks is what they should be most concerned about, with close to half of respondents that use Value-at-Risk (VaR) or the probability of a large shortfall as the definition of their risk budgets.

*Exhibit 53: How do you define your risk budgets? The exhibit presents the percentage of responses of participants on how they define their risk budget. The question was put to the 104 participants, and percentages have been normalised by excluding the non-responses (8 out of 104).*

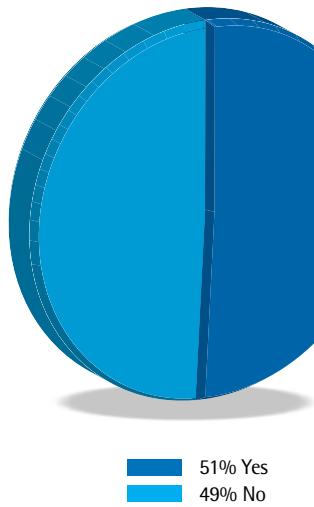


20.8% Volatility of the Assets
35.4% VaR
14.6% Probability of a Shortfall
12.5% Probability of a Large Shortfall
16.7% Expected Shortfall

It should be noted that all of the risk measures mentioned in Exhibit 53 depend on a time horizon. For instance, volatility can be computed at various horizons (e.g. monthly, quarterly or annual), and even when it is annualised, the result may vary across horizons: this effect is known as the "term structure of risk" effect, and it arises for instance in the presence of mean-reversion in stock returns (see e.g. Campbell and Viceira (2005)). Similarly, shortfall indicators obviously depend on the horizon to which returns are measured. Hence, an accurate definition of risk budget should specify a time horizon. However, only a half of respondents declare that they follow this principle (see Exhibit 54).

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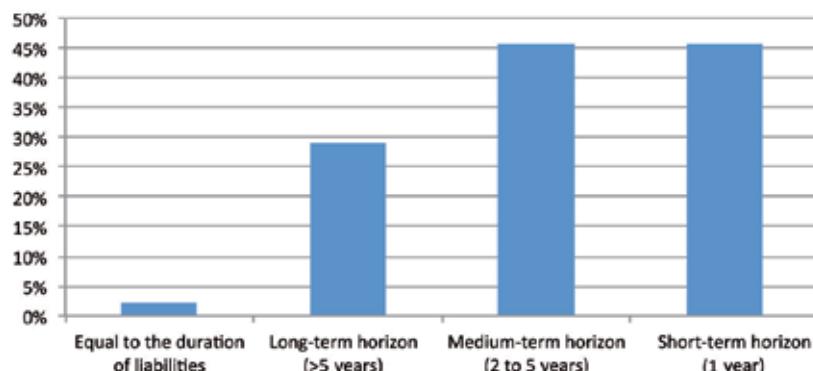
*Exhibit 54: Do you have a formal time horizon for the definition of the risk budget? The exhibit presents the percentage of responses of participants to this question. The question was put to the 104 participants, and percentages have been normalised by excluding the non-responses (6 out of 104).*



22 - No respondent answered both "Long-term horizon" and "Horizon equal to the duration of liabilities", so the fraction of respondents who selected at least one of these answers is  $29.17\% + 2.08\% = 31.25\%$ .

Most of those who define an explicit timeframe have a short to medium horizon in mind, as shown by Exhibit 55. Long horizons, that is, horizons greater than five years or horizons matching liability duration, are only chosen by 31.25% of respondents.<sup>22</sup> This result confirms that while the vast majority of the pension funds have a very long investment horizon, they still have a strong focus on short- to medium-term horizons when it comes to risk assessment.

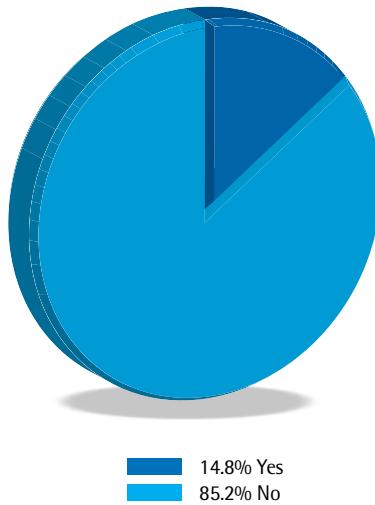
*Exhibit 55: If yes, how do you define your time horizon? The exhibit presents the percentage of responses of participants on the definition of the time horizon. The question was put to the 50 participants who have a formal time horizon, and multiple answers were allowed, so the percentages do not add up to 100%. They have been normalised by excluding the non-responses (2 out of 50).*



Apart from the various statistical risk measures mentioned in Exhibit 53, a risk budget can be defined as the measurable difference between current asset value and a floor defining some minimum acceptable wealth level. We asked participants whether they impose a floor to their assets. Most of them declare that they do not manage their assets with respect to a floor (Exhibit 56); only 14.74% of the respondents try and protect an explicit floor value when managing the pension assets. It can be noted that this percentage is slightly higher within the category of respondents who recognise that they face regulatory funding ratio constraints (Exhibit 48): it grows to 16.98%, while it is only 9.52% among those respondents that are not subject to such constraints. Nevertheless, these percentages are low, and they suggest that minimum funding requirements are not effectively taken into account in the asset management process.

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*Exhibit 56: Do you set floor levels to asset value? The exhibit presents the percentage of responses of participants to this question. The question was put to the 104 participants, and percentages have been normalised by excluding the non-responses (9 out of 104).*



The next question is on the definition of the floor. In an asset management setting, the floor can be set to some fixed value (possibly compounded at the risk-free rate), or equal to some benchmark, either exogenous or endogenous. An example of an endogenous benchmark is given by the maximum drawdown floor (see Exhibits 8 and 9 in Section I.3.3). In an asset-liability management framework, the value of liabilities is a natural benchmark. However,

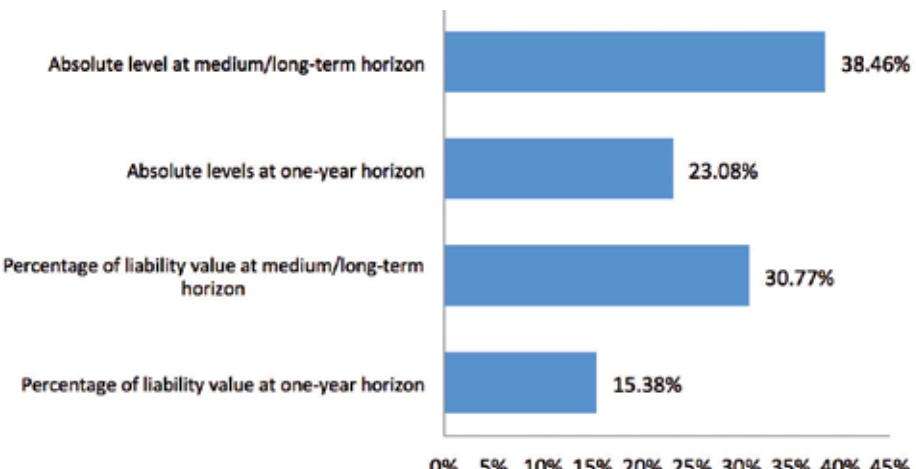
when asked to specify the definition of floors that they adopt, half of respondents say that they take absolute floors: in other words, they do not take into account the presence of liabilities in their choice of a floor. Here again, even though the asset-liability management perspective appears to be the most natural approach in the context of pension fund investing, some pension fund managers still use asset-only benchmarks within the definition of their risk controls.

Only another small half defines their floor as a fraction of liability value. In terms of horizon, the majority of respondents to this question select medium or long-term values. Their answers here are consistent with the answers that they gave in Exhibit 54: all respondents who mention a medium or long-term value in Exhibit 57 and who had a formal horizon in their risk budgets indicated that this horizon was also a medium- or long-term one.

### II.3.4 Mode of Protection against Downside Risk

Downside relative risk arises because the

*Exhibit 57: If yes, how do you define the floor levels? The exhibit presents the percentage of responses of participants on the definition of their floor levels. The question was put to the 14 participants who set floors to asset value, and multiple answers were allowed, so the percentages do not add up to 100%. They have been normalised by excluding a unique non-response.*



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performance assets may perform poorly in case of an increase in liability value. In order to reduce the risk of a large shortfall, most participants use Value-at-Risk minimisation (42.31% in Exhibit 58). This poses two problems. First of all, VaR minimisation has an asset-only focus, while the most natural approach for a pension funds is to approach the risk management problem from an asset-liability perspective. Secondly, VaR minimisation, which is purely based on diversification, typically leads to excessively conservative portfolio strategies, with an exceedingly large associated opportunity cost. As recalled in the Background section, hedging and insurance are more effective approaches to downside risk management in an asset-only or an asset-liability investment management context. The second most popular approach is the use of derivatives. In Section I.3.2, we have argued that the theoretically sound approach to maintain a nonnegative surplus is to purchase, or dynamically replicate, an exchange option that would trade liability value for the value of an otherwise optimal unconstrained strategy. Such an option will be in the money in the event of underfunding, and will then pay the exact difference between assets and liabilities, thereby covering the funding gap. Strictly speaking, this strategy cannot be implemented since the option would have to be written on the underlying LDI/LCI strategies followed by the pension fund, which is not a tradable asset since the pay-off of this strategy depends on the investment decisions made by the pension fund. Nevertheless, it can inspire other derivatives-based insurance strategies that reduce, if not cancel completely,

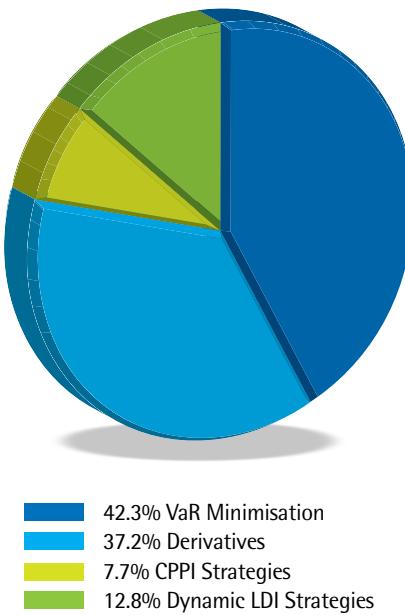
the risk of large losses. An advantage of such strategies over dynamic insurance strategies, such as CPPI or dynamic LDI policies, is that they do not require as much rebalancing, which reduces transaction costs. The costs associated with frequent rebalancing may be reason why only one fifth of participants adopt truly dynamic strategies.

Again (see Exhibit 29 in Section II.2.2), Denmark is one of the countries where the use of derivatives is the most popular, since this solution is cited by 62.50% of Danish respondents. Germany and Netherlands also display higher adhesion rates than the entire sample. Another lesson from these results, which contrasts with the answers to the question on the inclusion of derivatives in the LHP, is that the use of derivatives is as widespread in Switzerland as in the United Kingdom (3 respondents in each of these countries, out of totals of respectively 18 and 19). Finally, only one respondent from North America mentioned the use of derivatives here.

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*Exhibit 58: How do you protect against downside risk in your performance portfolio? The exhibit presents the percentage of responses of participants to this question. The question was put to the 104 participants, and percentages have been normalised by excluding the non-responses (26 out of 104).*



### II.4 Use of Integrated LDI Techniques

For DB corporate pension plans, the analysis of optimal funding and investment decisions involves a proper understanding of the possible conflicts of interest that exist between a number of stakeholders.

- Beneficiaries: they consist of employees, who spend a part of their income as contributions, and retirees, who receive pension payments;
- Pension fund managers and trustees, who are in charge of asset allocation decisions and/or the effective management of pension assets according to these decisions;
- Shareholders of the sponsor company, who may influence the productive investment choices, but not the decisions of the pension fund, and who are ultimately responsible for ensuring that promised liabilities are paid to the pensioners.

Some examples of these conflicts of interest were given in Section I.1.2, e.g. the preference of shareholders for lower funding levels and more risky investment strategies, which conflicts with the preference of beneficiaries for higher funding levels and safer investment strategies, at least unless the latter group is granted some form of access to pension plan surpluses. The last section of the survey, which is open to all types of participants, including representatives of the sponsor company, aims at assessing the perception of these conflicts and at reviewing the existing approaches to sponsor risk hedging.

#### II.4.1 Perception of Conflicts of Interest

Exhibit 59 reviews a list of potential sources of conflicts of interest between groups of stakeholders, and participants were invited to express their views on the existence or absence of such conflicts in practice. Focusing on the items for which more than 20% of "Yes" responses were recorded, we can isolate four domains where respondents have identified the presence of conflicts of interest:

- Shareholders versus beneficiaries (29.07% of the respondents perceive a conflict between these two groups of stakeholders);
- Employees versus retirees (52.33%);
- Pension fund managers versus shareholders (22.09%);
- Trustees versus shareholders (27.91%).

The first conflict is the one which was studied from a theoretical perspective in Section I.1.2, but it is mentioned by less than one third of respondents. In other words, it seems that the asset substitution

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problem, that is the possibility that more risky investment decisions taking place after pension benefits have been promised to beneficiaries may lead to a wealth transfer from these beneficiaries in favour of stakeholders, is not dominant in respondents' perception of the challenges related to an integrated approach to asset-liability management.

The conflict which is most often cited, by more than half of respondents, is between employees and retirees. It is interesting to compare these responses according to the type of funds (see Exhibit 14): among the 38 funds that mention this conflict, 22 are DB funds, eight are hybrid funds, and six are DC funds, a split which reflects the relative risks borne by workers and pensioners. In a DC fund, contributions are either fixed or at least predictable, and cannot be raised to deliver a contractual amount of pension payments: as a consequence, employees are protected against the risk of an unexpected change in their contributions. In a DB fund, on the other hand, this risk is more likely to

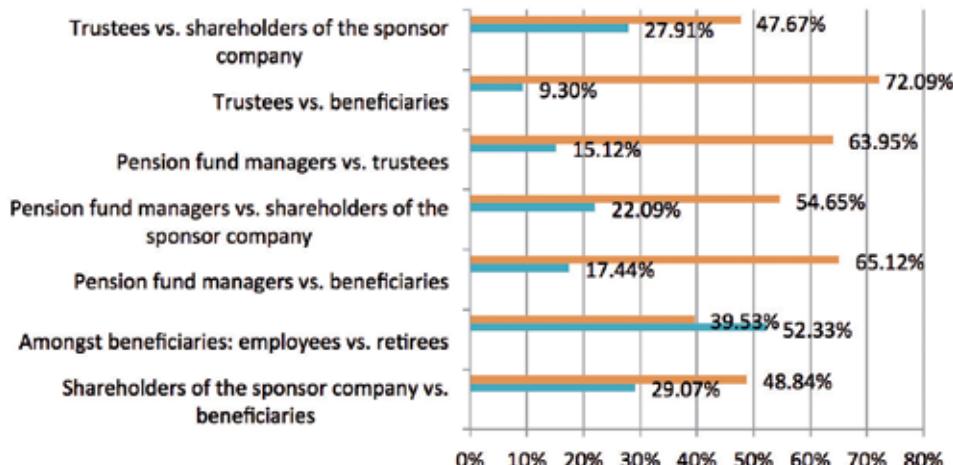
be present: retirees may prefer a higher contribution rate, which guarantees the payment of their pensions, while employees obviously prefer to have higher available income.

We may also note that according to most respondents, the interests of trustees are well aligned with those of pension fund managers (63.95%) and with those of beneficiaries (72.09%). Opinions are more mixed regarding the alignment with shareholders' interests, since only a small half of respondents declare that they do not perceive a conflict here.

### II.4.2 Preferred Discount Rate for Liabilities

In the next question, participants were asked for their opinion on the best discount rate for pension liabilities: as explained above (see Section II.1.3.1), the choice of the discount rate has a large impact on the value of liabilities when they have a long maturity. We saw in Exhibit 16 above that close to half of pension funds use a market rate, while

*Exhibit 59: Do you perceive any evidence of conflict of interests between various stakeholders? The exhibit presents the percentage of responses of participants to this question. The question was put to the 104 participants, and multiple choices were allowed, so the percentages do not add up to 100%. They have been normalised by excluding the non-responses (18 out of 104). The orange (respectively blue) bars represent the answer "No" (respectively "Yes").*

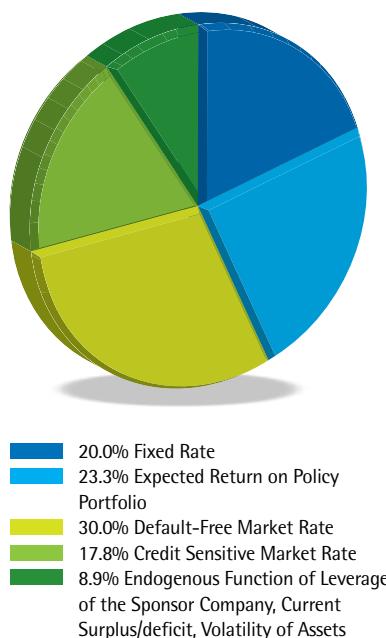


## II. Analysis of the Responses to the Survey

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only 28.74% of them employ a fixed rate. The preference for time-varying rates also appears in Exhibit 60, where only one fifth of respondents are in favour of a fixed rate, while a total of 47.78% uses a market rate. These proportions are remarkably close to those shown in Exhibit 16, so that pension fund practices are in line with the preferences of the whole pool of respondents (pension funds, consultants and sponsor companies). Overall, only 8.89% of respondents think that the discount rate should reflect the financial situation of the sponsor company and the pension plan.

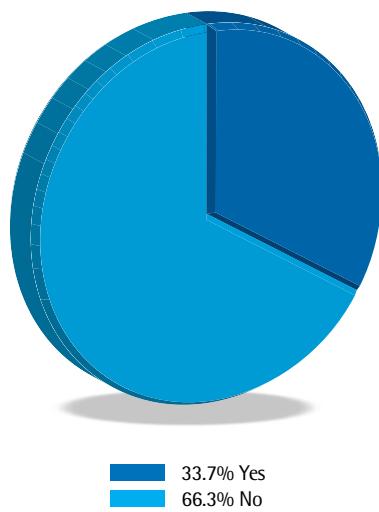
*Exhibit 60: Which discount rate do you think is the most appropriate for pension liabilities? The exhibit presents the percentage of responses of participants to this question. The question was put to the 104 participants, and percentages have been normalised by excluding the non-responses (14 out of 104).*



This result stands in sharp contrast with the prescriptions of asset pricing theory which suggests that pension liabilities should be handled by regarding them as privately held, collateralised, defaultable claims issued by the sponsor company,

municipality or state to workers and pensioners, and as such should be valued using option pricing methodologies similar to the one introduced by Merton (1974) for the valuation of corporate bonds. This approach, which would imply that valuation principles for liabilities streams should account for differences in financial health and capital structure decisions at the sponsor company level, as well as differences in asset allocation policy at the pension fund level, is yet to resonate within the pension fund community, perhaps because of the challenges involved in estimating some of the parameters needed as inputs in such a valuation procedure. However, it should be noted that one third of the respondents do attempt to assess the probability of default risk on pension payments (Exhibit 61), which is a first step towards adopting an integrated approach to asset-liability management for pension funds.

*Exhibit 61: Do you assess the probability of default risk on pension payments? The exhibit presents the percentage of responses of participants to this question. The question was put to the 104 participants, and percentages have been normalised by excluding the non-responses (6 out of 104).*



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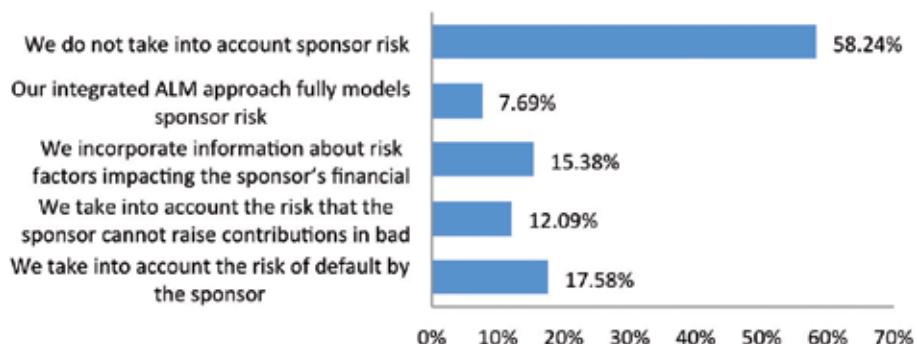
### II.4.3 Sponsor Risk Hedging

As argued in Section I.1.2, the correct valuation of liabilities should take into account sponsor risk, especially in the context of DB pension funds, where the sponsor must make up for the funding gap in the event of a deficit. But as shown by Exhibit 62, and consistent with the aforementioned findings, some progress remains to be made towards the incorporation of sponsor risk into the ALM of the pension fund: if one third of the respondents show some interest in analysing the risk of the sponsor defaulting on pension obligations, more than half of them (58.24%) simply do not hedge against such a risk. Interestingly, this percentage is lower among the DB funds who declared that the sponsor is called to contribute in the case of an underfunding (Exhibit 18): it falls to 46.67% within this category, but this figure still appears large, and shows that sponsor risk is not yet as much taken into consideration as it should be.

As argued in Martellini, Milhau and Tarelli (2012), the likelihood of unfavourable scenarios under which the pension plan ends up in a deficit at a time when the sponsor cannot afford the extra

contributions needed to make up for the gap, can be reduced by dynamic portfolio strategies that would involve short selling a "firm-hedging security", that is an asset positively correlated with firm's asset value. Such an instrument can be in principle the stock of the sponsor company, but in practice it may be difficult for pension funds to engage in shorting the stock of their sponsor company. A possible approach is then to use a proxy for the firm-hedging security, that is, an asset or portfolio with imperfect but hopefully high correlation with the sponsor's asset value, or to use derivatives in order to reduce the exposure to sponsor risk. For instance, the pension fund may purchase put options written on the stocks of the sponsor or on a broad stock index as a proxy. However, a large majority of respondents answer that they do not see derivatives as the best option to deal with sponsor risk (81.71% in Exhibit 63). This opinion is shared in almost all geographical regions covered by the survey, with only small fluctuations from one area to the other. Only one country stands out, namely Denmark, where nearly half of the respondents (three out of eight) express an interest for derivatives for the purpose of hedging that risk.

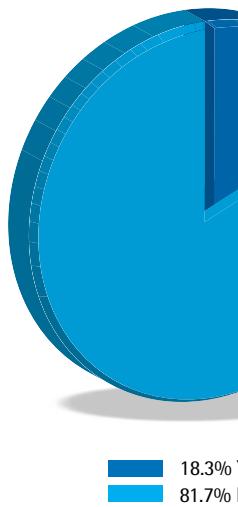
*Exhibit 62: Do you hedge against sponsor risk? The exhibit presents the percentages of responses of participants to this question. The question was put to the 104 participants, and multiple responses were allowed, so the percentages do not add up to 100%. They have been normalised by excluding the non-responses (13 out of 104).*



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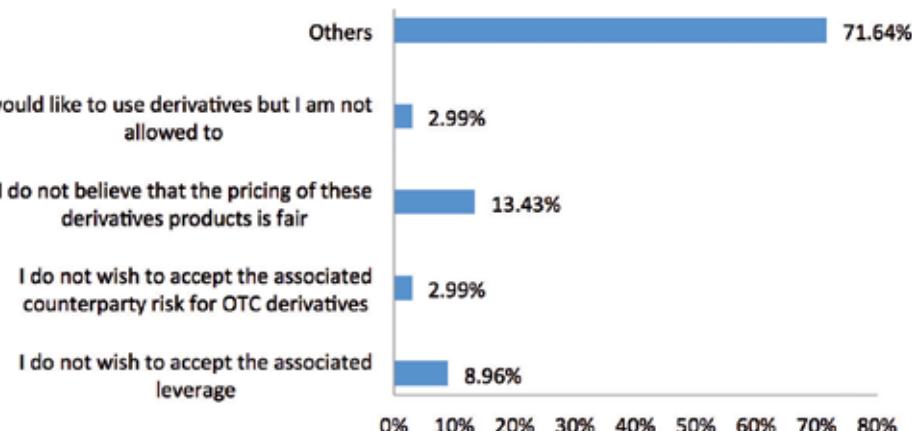
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*Exhibit 63: Do you see derivatives as the best way to implement sponsor risk management? The exhibit presents the percentage of responses of participants to this question. The question was put to the 104 participants, and percentages have been normalised by excluding the non-responses (22 out of 104).*



These respondents are not very specific about the reasons that keep them away from derivatives (see Exhibit 64), but most of those who consider derivatives as a valuable choice put forward the arguments of low costs (85.72% of them in Exhibit 65).

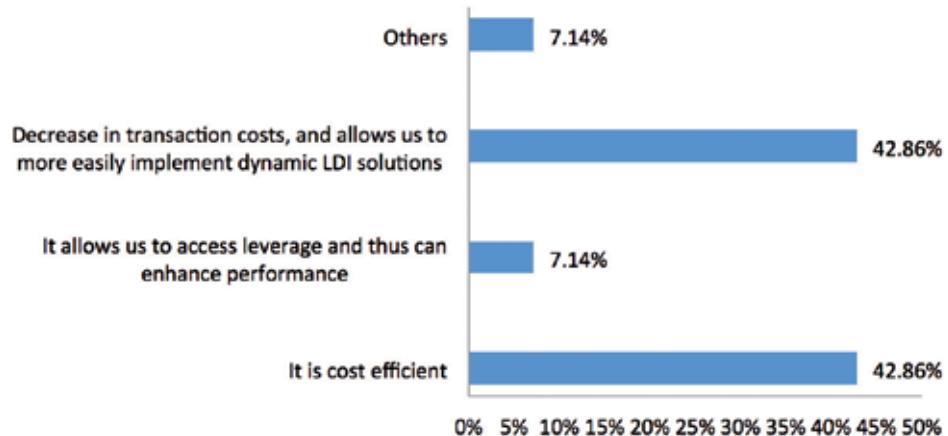
*Exhibit 64: If no, why not? The exhibit presents the percentage of responses of participants regarding the non-adoption of derivatives in sponsor risk management. The question was put to the 67 participants who do not see derivatives as the best option to deal with sponsor risk, and there was no non-response to this question.*



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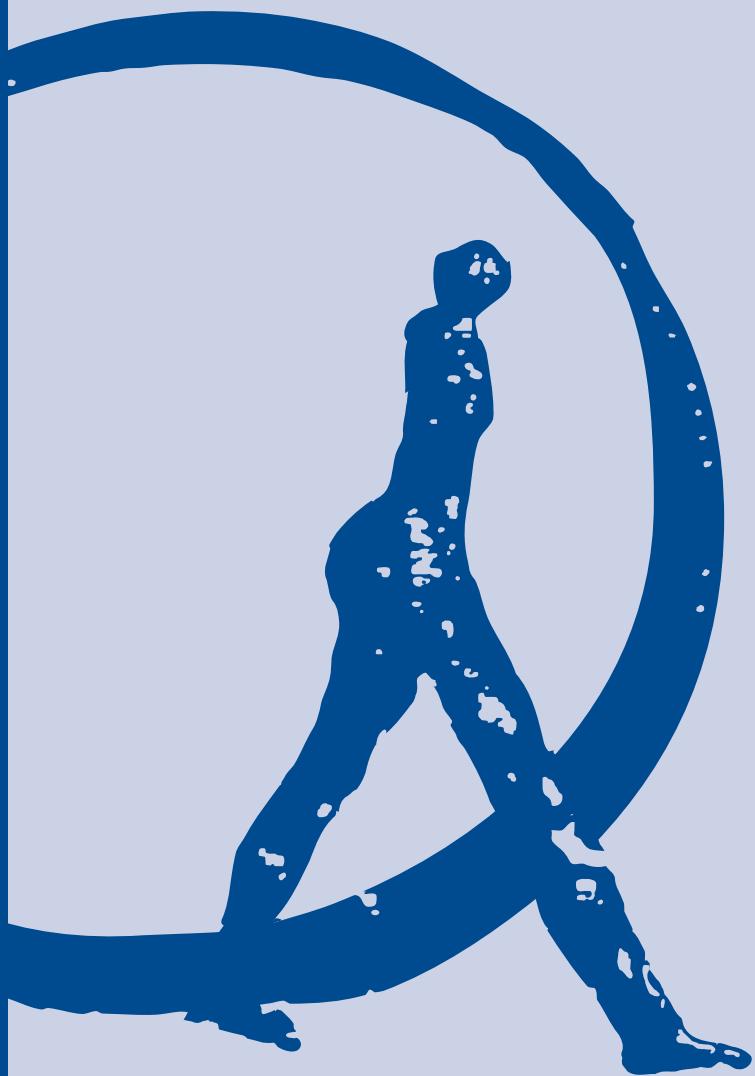
*Exhibit 65: If yes, what are your motivations? The exhibit presents the percentages of responses of participants regarding the use of derivatives in sponsor risk management. The question was put to the 15 participants who see derivatives as the best option to deal with sponsor risk, and percentages have been normalised by excluding the unique non-response to this question.*



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# Conclusion



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A number of profound changes have taken place, which have collectively led to the emergence of a new investment paradigm for pension funds. The standard paradigm for pension fund investments, which used to be firmly grounded around one overarching foundational concept of the *policy portfolio*, is slowly but surely being replaced by a new, more modern, investment paradigm known as the dynamic liability-driven investing (DLDI) paradigm. This new paradigm has two main defining characteristics: on the one hand, a focus on the management of portfolio risk relative to the liabilities, as opposed to absolute risk; and on the other hand, a focus on dynamically time-varying allocation within and across the risky and the safe building blocks.

The purpose of this survey is to assess the views of pension funds and sponsor companies with respect to this new investing paradigm and their desire to integrate this approach into their processes. Overall, there are a few key insights which we obtain from this survey.

First, an overwhelmingly large fraction of the respondents, in fact almost 80% of them, are now fully aware of the LDI paradigm. Secondly, slightly more than 50% of the respondents explicitly measure liability risk through a probability of a shortfall or the magnitude of this shortfall. Thirdly, roughly 50% of them are not only aware of the importance of measuring and managing liability risk, but have effectively adopted the LDI approach, which encompasses an explicit focus on liability hedging that is achieved through a dedicated liability-hedging portfolio, as opposed to seeking to diversify away liability risk within some well-balanced

policy portfolio. In a large majority of the cases, such a liability-hedging portfolio is dominated by fixed-income instruments, sovereign bonds, corporate bonds and interest rate derivatives, which reflects the recognition by pension fund managers that liability risk is strongly dominated by interest rate risks, even for inflation-linked liabilities. The fourth key insight we learn from this survey is that risk allocation, a novel approach to diversification within the performance-seeking portfolio, has already been adopted by more than 35% of the respondents to the survey.

While these results suggest a strong degree of adoption of modern risk management and ALM techniques by pension funds, a number of sources of concern also exist. First of all, we find that about 50% of the pension fund respondents are hedging their liabilities while the rest of the respondents are still sitting on the sidelines. Moreover, duration matching is only perceived as a desirable or a feasible target by about 60% of the respondents who express a focus on liability hedging, which implies that effective liability hedging is not always achieved, not even by those who express an interest in this objective.

Another key insight from the survey is that only about 40% implement a DLDI process, which requires periodic revisions of the portfolio policy. We also learn that half of the respondents who do use DLDI strategies use derivatives in implementation. In this context, we find the presence of a strong geographical factor, with Northern-European countries such as Denmark, Germany and the Netherlands showing a substantially higher adoption rate compared to other countries represented

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in the survey. The desire to adapt the portfolio composition to changes in market conditions (revisions of strategic asset allocation) is perceived as the main motivation for the largest percentage of respondents (33.33%), with the desire to add value through active forecasts (tactical asset allocation decisions) and the desire to reduce risk-taking when approaching floor asset levels (risk-controlled investing) also being major motivations (each with slightly more than 25% of the respondents).

Another source of concern is that most respondents do not translate the minimum funding requirements imposed by the regulation into floors on asset value: more than half of participants recognise that they operate under such constraints, but hardly a fifth of them impose bounds.

The last insight from this survey is that a majority of the respondents are aware of the presence of conflicts of interest between various stakeholders, while slightly less than half of the respondents have already made some steps towards an integrated approach to pension fund asset-liability management if only through attempts to adopt some form of hedging mechanism against sponsor risk.

Overall, the findings in this survey highlight an ever increasing awareness by market participants that pension fund investment management is very much related to liability risk management. While a number of implementation constraints exist that do not facilitate the adoption by pension fund managers of a modern investment framework relying upon an effective use of the three forms of risk management (diversification, hedging and insurance),

and which explain why a number of pension funds are still sitting on the sidelines, the understanding of the potential benefits to be expected from DLDI strategies is clearly on the rise. In particular, risk management is increasingly perceived as being the approach allowing investors to maximise the probability of achieving their long-term objectives while respecting the short-term constraints they face. This is somewhat reminiscent of another prophecy from the late Peter Bernstein who, beyond the (premature) announcement of the death of the policy portfolio, made the following illuminating comments about the central role of dynamic risk management in investment management decisions (Bernstein (1996)): "The word risk derives from the Latin *risicare*, which means to dare. In this sense, risk is a choice rather than a fate. (...) The actions we dare to take, which depends on how free we are to make choices, are what the story of risk is all about."

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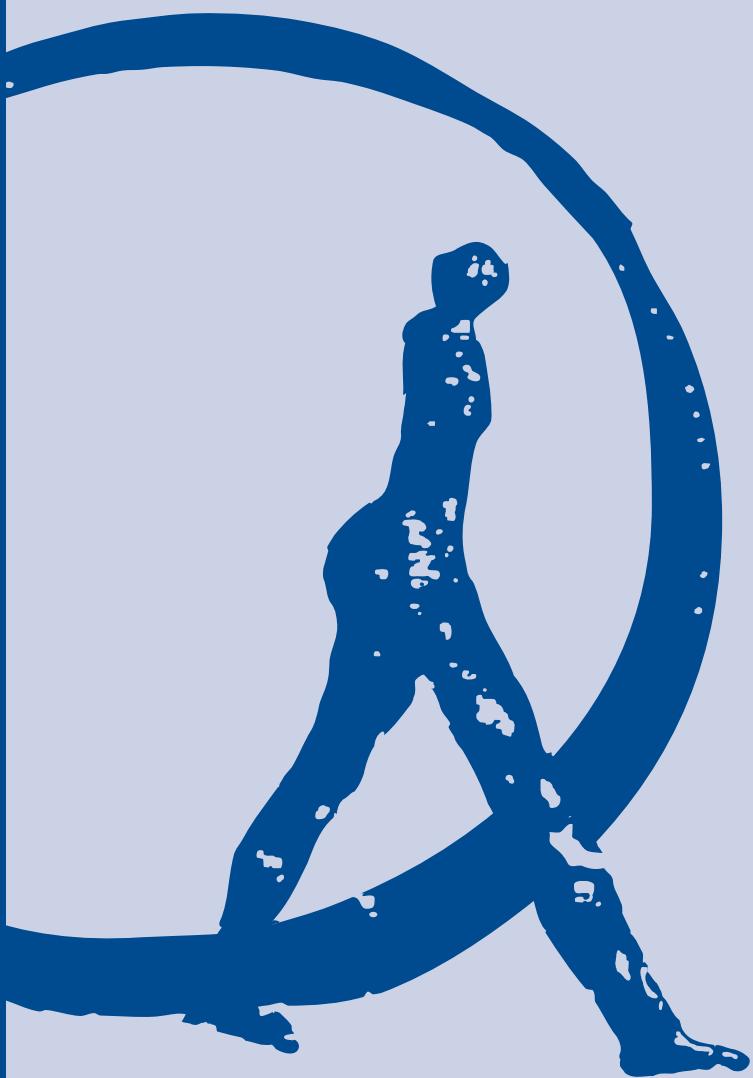
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# About BNP Paribas Investment Partners



# About BNP Paribas Investment Partners

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BNP Paribas Investment Partners is the asset management business of BNP Paribas Group and offers institutional and retail clients around the world a full range of asset management services.

A client-centric organisation, BNP Paribas Investment Partners is structured around three major business lines: Institutional, Distribution and Asia Pacific & Emerging Markets. Institutional is dedicated to European and international institutions (pension funds, insurers, companies, official institutions) and global consultants. The global and European asset management and investment solutions offered include global fixed income (FFTW), multi-asset solutions, European, US and global equities. Distribution (including THEAM) is dedicated to distributors and private banks – both internal and external to the BNP Paribas Group – offering them a wide range of products and investment solutions focused on their needs and the requirements of their individual clients.

Asia-Pacific & Emerging Markets combines local asset management and regional expertise, dedicated to distributions partners and institutional investors, in emerging countries and beyond. It builds on deep local roots dating back more than 10 years in 18 countries.

BNP Paribas Investment Partners' solutions are rooted in the extensive breadth of its range of investment capabilities worldwide. It has some 700 investment professionals (1), each specialising in a particular asset class or product type.

With total assets under management of EUR 479 billion (1), BNP Paribas Investment

Partners is the 6th largest asset manager in Europe (1). It is set up as a multicultural organisation in 38 countries (1).

As a signatory of the United Nation's Principles for Responsible Investment, BNP Paribas Investment Partners has reaffirmed its commitment as a responsible investor.

Main investment capabilities:

- Developed equities
  - Global, United States, Europe, Australia
  - Listed real estate
  - Nordics (Alfred Berg)
- Developed fixed income
  - Global, United States, Europe
- Emerging markets
  - Global emerging markets equity & debt
  - Russia (TKB BNP Paribas Investment Partners)
  - Turkey (TEB Asset Management)
  - China - domestic market (HFT Investment Management Co. Ltd)
  - India (BNP Paribas Mutual Fund India)
  - Indonesia (PT. BNP Paribas Investment Partners Indonesia)
  - South Korea (Shinhan BNP Paribas Asset Management)
  - Australia (Arnhem Investment Management)
  - Brazil (BNP Paribas Asset Management Brasil)
  - Chile (Banco Estado Administradora General de Fondos)
  - Morocco (BMCI Gestion)
- SRI equities & fixed income
  - SRI equities & fixed income
  - Environmental strategies (Impax Asset Management)

# About BNP Paribas Investment Partners

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- Multi-asset solutions
  - Risk & systems, TAA and research
  - Customised and fiduciary solutions
  - Retirement solutions and Innovation
  - Core portfolios and funds
- Alternative and structured products
  - Quantitative, Indexed, alternative and structured management (THEAM)
  - Private equity (BNP Paribas Private Equity)
- Speciality management
  - Employee savings schemes and company retirement investment products (BNPP Epargne &
  - Retraite Entreprises)
  - Wealth management (CamGestion)
- Advisory
  - Multi-management advisory (FundQuest Advisor)

(1) Source: BNP Paribas Investment Partners, as at 31 December 2013. Assets under management and advisory



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## About BNP Paribas Investment Partners

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# About EDHEC-Risk Institute



# About EDHEC-Risk Institute

Founded in 1906, EDHEC is one of the foremost international business schools. Accredited by the three main international academic organisations, EQUIS, AACSB, and Association of MBAs, EDHEC has for a number of years been pursuing a strategy of international excellence that led it to set up EDHEC-Risk Institute in 2001.

This institute now boasts a team of 90 permanent professors, engineers and support staff, as well as 48 research associates from the financial industry and affiliate professors.

## The Choice of Asset Allocation and Risk Management

EDHEC-Risk structures all of its research work around asset allocation and risk management. This strategic choice is applied to all of the Institute's research programmes, whether they involve proposing new methods of strategic allocation, which integrate the alternative class; taking extreme risks into account in portfolio construction; studying the usefulness of derivatives in implementing asset-liability management approaches; or orienting the concept of dynamic "core-satellite" investment management in the framework of absolute return or target-date funds.

## Academic Excellence and Industry Relevance

In an attempt to ensure that the research it carries out is truly applicable, EDHEC has implemented a dual validation system for the work of EDHEC-Risk. All research work must be part of a research programme, the relevance and goals of which have been validated from both an academic and a business viewpoint by the Institute's advisory board. This board is made up of internationally recognised researchers, the Institute's business partners, and representatives of major international institutional investors. Management of the research programmes respects a rigorous validation process, which guarantees the scientific quality and the operational usefulness of the programmes.

Six research programmes have been conducted by the centre to date:

- Asset allocation and alternative diversification
- Style and performance analysis
- Indices and benchmarking
- Operational risks and performance
- Asset allocation and derivative instruments
- ALM and asset management

These programmes receive the support of a large number of financial companies. The results of the research programmes are disseminated through the EDHEC-Risk locations in Singapore, which was established at the invitation of the Monetary Authority of Singapore (MAS); the City of London in the United Kingdom; Nice and Paris in France; and New York in the United States.

EDHEC-Risk has developed a close partnership with a small number of sponsors within the framework of research chairs or major research projects:

- Core-Satellite and ETF Investment, *in partnership with Amundi ETF*
- Regulation and Institutional Investment, *in partnership with AXA Investment Managers*
- Asset-Liability Management and Institutional Investment Management, *in partnership with BNP Paribas Investment Partners*
- Risk and Regulation in the European Fund Management Industry, *in partnership with CACEIS*
- Exploring the Commodity Futures Risk Premium: Implications for Asset Allocation and Regulation, *in partnership with CME Group*

# About EDHEC-Risk Institute

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- Asset-Liability Management in Private Wealth Management, *in partnership with Coutts & Co.*
- Asset-Liability Management Techniques for Sovereign Wealth Fund Management, *in partnership with Deutsche Bank*
- The Benefits of Volatility Derivatives in Equity Portfolio Management, *in partnership with Eurex*
- Structured Products and Derivative Instruments, *sponsored by the French Banking Federation (FBF)*
- Optimising Bond Portfolios, *in partnership with the French Central Bank (BDF Gestion)*
- Asset Allocation Solutions, *in partnership with Lyxor Asset Management*
- Infrastructure Equity Investment Management and Benchmarking, *in partnership with Meridiam and Campbell Lutyens*
- Investment and Governance Characteristics of Infrastructure Debt Investments, *in partnership with Natixis*
- Advanced Modelling for Alternative Investments, *in partnership with Newedge Prime Brokerage*
- Advanced Investment Solutions for Liability Hedging for Inflation Risk, *in partnership with Ontario Teachers' Pension Plan*
- The Case for Inflation-Linked Corporate Bonds: Issuers' and Investors' Perspectives, *in partnership with Rothschild & Cie*
- Solvency II, *in partnership with Russell Investments*
- Structured Equity Investment Strategies for Long-Term Asian Investors, *in partnership with Société Générale Corporate & Investment Banking*

The philosophy of the Institute is to validate its work by publication in international academic journals, as well as to make it available to the sector through its position papers, published studies, and conferences.

Each year, EDHEC-Risk organises three conferences for professionals in order to present the results of its research, one in London (EDHEC-Risk Days Europe), one in Singapore (EDHEC-Risk Days Asia), and one in New York (EDHEC-Risk Days North America) attracting more than 2,500 professional delegates.

EDHEC also provides professionals with access to its website, [www.edhec-risk.com](http://www.edhec-risk.com), which is entirely devoted to international asset management research. The website, which has more than 58,000 regular visitors, is aimed at professionals who wish to benefit from EDHEC's analysis and expertise in the area of applied portfolio management research. Its monthly newsletter is distributed to more than 1.5 million readers.

## EDHEC-Risk Institute: Key Figures, 2011-2012

Nbr of permanent staff	90
Nbr of research associates	20
Nbr of affiliate professors	28
Overall budget	€13,000,000
External financing	€5,250,000
Nbr of conference delegates	1,860
Nbr of participants at research seminars	640
Nbr of participants at EDHEC-Risk Institute Executive Education seminars	182

# About EDHEC-Risk Institute

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## The EDHEC-Risk Institute PhD in Finance

The EDHEC-Risk Institute PhD in Finance is designed for professionals who aspire to higher intellectual levels and aim to redefine the investment banking and asset management industries. It is offered in two tracks: a residential track for high-potential graduate students, who hold part-time positions at EDHEC, and an executive track for practitioners who keep their full-time jobs. Drawing its faculty from the world's best universities, such as Princeton, Wharton, Oxford, Chicago and CalTech, and enjoying the support of the research centre with the greatest impact on the financial industry, the EDHEC-Risk Institute PhD in Finance creates an extraordinary platform for professional development and industry innovation.

## Research for Business

The Institute's activities have also given rise to executive education and research service offshoots. EDHEC-Risk's executive education programmes help investment professionals to upgrade their skills with advanced risk and asset management training across traditional and alternative classes. In partnership with CFA Institute, it has developed advanced seminars based on its research which are available to CFA charterholders and have been taking place since 2008 in New York, Singapore and London.

In 2012, EDHEC-Risk Institute signed two strategic partnership agreements with the Operations Research and Financial Engineering department of Princeton University to set up a joint research programme in the area of risk and investment management, and with Yale

School of Management to set up joint certified executive training courses in North America and Europe in the area of investment management.

As part of its policy of transferring know-how to the industry, EDHEC-Risk Institute has also set up ERI Scientific Beta. ERI Scientific Beta is an original initiative which aims to favour the adoption of the latest advances in smart beta design and implementation by the whole investment industry. Its academic origin provides the foundation for its strategy: offer, in the best economic conditions possible, the smart beta solutions that are most proven scientifically with full transparency in both the methods and the associated risks.

# **EDHEC-Risk Institute Publications and Position Papers (2011-2014)**



# EDHEC-Risk Institute Publications (2011-2014)

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## 2014

- Deguest, R., and L. Martellini. Improved Risk Reporting with Factor-Based Diversification Measures (February).
- Ducoulombier, F., F. Goltz, V. Le Sourd, and A. Lodh. The EDHEC European ETF Survey 2013 (February).

## 2013

- Lixia, L., and S. Stoyanov. Tail Risk of Asian Markets: An Extreme Value Theory Approach (August).
- Goltz, F., L. Martellini, and S. Stoyanov. Analysing statistical robustness of cross-sectional volatility. (August).
- Lixia, L., L. Martellini, and S. Stoyanov. The local volatility factor for asian stock markets. (August).
- Martellini, L., and V. Milhau. Analyzing and decomposing the sources of added-value of corporate bonds within institutional investors' portfolios (August).
- Deguest, R., L. Martellini, and A. Meucci. Risk parity and beyond - From asset allocation to risk allocation decisions (June).
- Blanc-Brude, F., Cocquemas, F., Georgieva, A. Investment Solutions for East Asia's Pension Savings - Financing lifecycle deficits today and tomorrow (May)
- Blanc-Brude, F. and O.R.H. Ismail. Who is afraid of construction risk? (March)
- Lixia, L., L. Martellini, and S. Stoyanov. The relevance of country- and sector-specific model-free volatility indicators (March).
- Calamia, A., L. Deville, and F. Riva. Liquidity in european equity ETFs: What really matters? (March).
- Deguest, R., L. Martellini, and V. Milhau. The benefits of sovereign, municipal and corporate inflation-linked bonds in long-term investment decisions (February).
- Deguest, R., L. Martellini, and V. Milhau. Hedging versus insurance: Long-horizon investing with short-term constraints (February).
- Amenc, N., F. Goltz, N. Gonzalez, N. Shah, E. Shirbini and N. Tessaromatis. The EDHEC european ETF survey 2012 (February).
- Padmanaban, N., M. Mukai, L . Tang, and V. Le Sourd. Assessing the quality of asian stock market indices (February).
- Goltz, F., V. Le Sourd, M. Mukai, and F. Rachidy. Reactions to "A review of corporate bond indices: Construction principles, return heterogeneity, and fluctuations in risk exposures" (January).
- Joenväärä, J., and R. Kosowski. An analysis of the convergence between mainstream and alternative asset management (January).
- Cocquemas, F. Toward better consideration of pension liabilities in european union countries (January).

# EDHEC-Risk Institute Publications (2011–2014)

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- Blanc-Brude, F. Towards efficient benchmarks for infrastructure equity investments (January).

## 2012

- Arias, L., P. Foulquier and A. Le Maistre. Les impacts de Solvabilité II sur la gestion obligataire (December).
- Arias, L., P. Foulquier and A. Le Maistre. The Impact of Solvency II on Bond Management (December).
- Amenc, N., and F. Ducoulombier. Proposals for better management of non-financial risks within the european fund management industry (December).
- Cocquemas, F. Improving Risk Management in DC and Hybrid Pension Plans (November).
- Amenc, N., F. Cocquemas, L. Martellini, and S. Sender. Response to the european commission white paper "An agenda for adequate, safe and sustainable pensions" (October).
- La gestion indicielle dans l'immobilier et l'indice EDHEC IEIF Immobilier d'Entreprise France (September).
- Real estate indexing and the EDHEC IEIF commercial property (France) index (September).
- Goltz, F., S. Stoyanov. The risks of volatility ETNs: A recent incident and underlying issues (September).
- Almeida, C., and R. Garcia. Robust assessment of hedge fund performance through nonparametric discounting (June).
- Amenc, N., F. Goltz, V. Milhau, and M. Mukai. Reactions to the EDHEC study "Optimal design of corporate market debt programmes in the presence of interest-rate and inflation risks" (May).
- Goltz, F., L. Martellini, and S. Stoyanov. EDHEC-Risk equity volatility index: Methodology (May).
- Amenc, N., F. Goltz, M. Masayoshi, P. Narasimhan and L. Tang. EDHEC-Risk Asian index survey 2011 (May).
- Guobuzaité, R., and L. Martellini. The benefits of volatility derivatives in equity portfolio management (April).
- Amenc, N., F. Goltz, L. Tang, and V. Vaidyanathan. EDHEC-Risk North American index survey 2011 (March).
- Amenc, N., F. Cocquemas, R. Deguest, P. Foulquier, L. Martellini, and S. Sender. Introducing the EDHEC-Risk Solvency II Benchmarks – maximising the benefits of equity investments for insurance companies facing Solvency II constraints - Summary - (March).
- Schoeffler, P. Optimal market estimates of French office property performance (March).
- Le Sourd, V. Performance of socially responsible investment funds against an efficient SRI Index: The impact of benchmark choice when evaluating active managers – an update (March).

# EDHEC-Risk Institute Publications (2011–2014)

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- Martellini, L., V. Milhau, and A.Tarelli. Dynamic investment strategies for corporate pension funds in the presence of sponsor risk (March).
- Goltz, F., and L. Tang. The EDHEC European ETF survey 2011 (March).
- Sender, S. Shifting towards hybrid pension systems: A European perspective (March).
- Blanc-Brude, F. Pension fund investment in social infrastructure (February).
- Ducoulombier, F., Lixia, L., and S. Stoyanov. What asset-liability management strategy for sovereign wealth funds? (February).
- Amenc, N., Cocquemas, F., and S. Sender. Shedding light on non-financial risks – a European survey (January).
- Amenc, N., F. Cocquemas, R. Deguest, P. Foulquier, Martellini, L., and S. Sender. Ground Rules for the EDHEC-Risk Solvency II Benchmarks. (January).
- Amenc, N., F. Cocquemas, R. Deguest, P. Foulquier, Martellini, L., and S. Sender. Introducing the EDHEC-Risk Solvency Benchmarks – Maximising the Benefits of Equity Investments for Insurance Companies facing Solvency II Constraints - Synthesis -. (January).
- Amenc, N., F. Cocquemas, R. Deguest, P. Foulquier, Martellini, L., and S. Sender. Introducing the EDHEC-Risk Solvency Benchmarks – Maximising the Benefits of Equity Investments for Insurance Companies facing Solvency II Constraints (January).
- Schoeffler.P. Les estimateurs de marché optimaux de la performance de l'immobilier de bureaux en France (January).

## 2011

- Amenc, N., F. Goltz, Martellini, L., and D. Sahoo. A long horizon perspective on the cross-sectional risk-return relationship in equity markets (December 2011).
- Amenc, N., F. Goltz, and L. Tang. EDHEC-Risk European index survey 2011 (October).
- Deguest,R., Martellini, L., and V. Milhau. Life-cycle investing in private wealth management (October).
- Amenc, N., F. Goltz, Martellini, L., and L. Tang. Improved beta? A comparison of index-weighting schemes (September).
- Le Sourd, V. Performance of socially responsible investment funds against an Efficient SRI Index: The Impact of Benchmark Choice when Evaluating Active Managers (September).
- Charbit, E., Giraud J. R., F. Goltz, and L. Tang Capturing the market, value, or momentum premium with downside Risk Control: Dynamic Allocation strategies with exchange-traded funds (July).
- Scherer, B. An integrated approach to sovereign wealth risk management (June).
- Campani, C. H., and F. Goltz. A review of corporate bond indices: Construction principles, return heterogeneity, and fluctuations in risk exposures (June).
- Martellini, L., and V. Milhau. Capital structure choices, pension fund allocation decisions, and the rational pricing of liability streams (June).

## EDHEC-Risk Institute Publications (2011–2014)

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- Amenc, N., F. Goltz, and S. Stoyanov. A post-crisis perspective on diversification for risk management (May).
- Amenc, N., F. Goltz, Martellini, L., and L. Tang. Improved beta? A comparison of index-weighting schemes (April).
- Amenc, N., F. Goltz, Martellini, L., and D. Sahoo. Is there a risk/return tradeoff across stocks? An answer from a long-horizon perspective (April).
- Sender, S. The elephant in the room: Accounting and sponsor risks in corporate pension plans (March).
- Martellini, L., and V. Milhau. Optimal design of corporate market debt programmes in the presence of interest-rate and inflation risks (February).

# EDHEC-Risk Institute Position Papers (2011-2014)

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## 2012

- Till, H. Who sank the boat? (June).
- Uppal, R. Financial Regulation (April).
- Amenc, N., F. Ducoulombier, F. Goltz, and L. Tang. What are the risks of European ETFs? (January).

## 2011

- Amenc, N., and S. Sender. Response to ESMA consultation paper to implementing measures for the AIFMD (September).
- Uppal, R. A Short note on the Tobin Tax: The costs and benefits of a tax on financial transactions (July).
- Till, H. A review of the G20 meeting on agriculture: Addressing price volatility in the food markets (July).



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