Investor sophistication and risk taking

Jan de Dreua,b and Jacob A. Bikkerb,c,*

a BBVA, Vía de los Poblados s/n, 28033, Madrid, Spain
b Utrecht University, Utrecht School of Economics, Kriekenpitplein 21-22, NL-3584 EC Utrecht, the Netherlands
c De Nederlandsche Bank, P.O. Box 98, NL-1000 AB Amsterdam, the Netherlands

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Abstract

Using investment policy data of 857 Dutch pension funds during 1999–2006, we develop three indicators of investor sophistication. The indicators show that pension funds’ strategic portfolio choices are often based on coarse and less sophisticated approaches. First, most pension funds round strategic asset allocations to the nearest multiple of 5%, similar to age heaping in demographic and historical studies. Second, many pension funds invest little or nothing in alternative, more complex asset classes, resulting in limited asset diversification. Third, many pension funds favor regional investments and as such do not fully employ the opportunities of international risk diversification. Our indicators are correlated with pension fund size, in line with the expectation that smaller pension funds are generally less sophisticated than large

* Corresponding author. Tel.: +31 20 524 2352; fax: +31 20 524 1885.
E-mail addresses: jan.dreu@bbva.com, j.a.bikker@dnb.nl.
pension funds. Using the indicators for investor sophistication, we show that less sophisticated pension funds tend to opt for investment strategies with less risk.

*JEL classification:* G11; G23

*Keywords:* Pension funds; Investment policy; Portfolio choice; Gross rounding; Heaping; Diversification; Home bias; Behavioral finance

1. Introduction

During the recent financial banking and sovereign debt crises pension funds sustained huge investment losses. The crash in equity prices, coupled with a dramatic decline of long-term interest rates used to discount liabilities, slashed pension funds’ funding ratios (defined as total assets divided by discounted pension liabilities), with only limited relief from increased bond prices. In 2008 alone the market value of total pension assets in the Netherlands dropped by more than 17%. Together with the impact of lower discount rates, the crisis caused the funding ratio to fall in that year by no less than 49 percentage points. Strikingly, however, sustained losses varied considerably across pension funds, illustrating considerable differences among pension fund’s investment policies. These losses have severe consequences since in many countries pension funds play a central role in investing pension savings and providing old age benefits. This is particularly evident in The Netherlands where the assets of pension funds exceed GDP. Most Dutch pension funds now face significant funding gaps and are forced to increase premiums, cut wage or price indexation and, in a number of cases, even to cut pension rights. Evidently, these investment losses have profound
implications and have raised questions as to risk taking by pension funds and the quality and sophistication of their investment policies.

For pension funds, determining the asset allocation strategy is the most important decision in the investment process. Setting the optimal asset allocation strategy involves two decisions. First, the level of risk preference must be determined in line with the funding ratio and preferences of pension scheme participants and sponsor companies. Second, the allocation of investments to different asset classes should be chosen to maximize expected returns, given a pension fund’s liabilities and its risk preference. Both tasks are highly complex and it is to be expected that the expertise and abilities of different investors in performing them will vary. We examine pension fund investors’ sophistication in setting an optimal asset allocation (task 2) and how this relates to their risk preferences, expressed in terms of risky investments (task 1).

A major contribution in the finance literature on optimal asset allocation is the two-fund separation theorem, which prescribes investors to hold an optimal portfolio of risky assets in combination with the risk-free asset (Tobin, 1958). This optimal portfolio should be mean-variance efficient, implying that for a given expected return, no additional diversification can lower the portfolio's overall risk (Markowitz, 1952). These theorems are building blocks of CAPM, which states that there is only one optimal risk portfolio, that is, the market portfolio (Sharpe, 1964). If this is the correct model, asset allocations for investors with different risk preferences should be simply different linear combinations of the riskless asset and the market portfolio. This implies that investors, including pension funds, should keep the ratio of bonds to equities and other asset classes unchanged across all portfolios and vary allocations to the risk free asset, reflecting varying risk preferences. The finding that investors hold different
proportions of risky assets – including the ratio of bonds to equities – conflicts with the two-fund separation theorem and is called the Asset Allocation Puzzle (see also Canner et al., 1997).

While we concern ourself with institutional investors, the literature on the sophistication of asset allocation decisions has mostly focused on private investors (individuals or households). Empirical research has shown that private investors invest in ways that are hard to reconcile with standard theory and that have been labeled investment mistakes (Campbell 2006, Calvet, Campbell and Sodini, 2007, 2009a,b). Private investors often use simple rules of thumb in allocating their wealth across asset classes, resulting in suboptimal investment portfolios. The behavioral finance literature classifies such suboptimal investment decisions as behavioral biases or cognitive errors. Individuals use heuristics, or rules of thumb, because they have limited attention, memory, education, and processing capabilities. A number of papers have shown that individual investors often rely on simple asset allocation rules. Examples of such rules are asset allocations that tend to be either zero or 100 percent in equities (Agnew, Balduzzi, and Sundén, 2003) and investor’s use of the $1/n$ rule to allocate their money among the $n$ funds they invest in (Huberman and Jiang, 2006). Benartzi and Thaler (2001) show that some private investors use the $1/n$ rule to allocate investments equally among eligible investment funds offered in pension plans and, consequently, that the equity allocation of investors is influenced by the proportion of stock funds offered. The natural conclusion is that the use of heuristics can lead to suboptimal asset allocation by private investors.\footnote{Whilst the use of the $1/n$ rule points to lower sophistication, it is disputed whether this ‘naive’ strategy also leads to lower returns. DeMiguel, Garlappi and Uppal (2007) show that investment strategies following 14 different models derived from modern portfolio theory generate inferior out-of-}

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(Calvet et al., 2007; Goetzmann and Kumar, 2008), (ii) inertia (Agnew et al. 2003; Campbell, 2006; Calvet et al., 2009a) and (iii) holding of losing stocks and selling winning stocks (Dhar and Zhu, 2006; Calvet et al., 2009a).

The tendency to round figures coarsely or to choose attractive numbers is also documented in a number of demographic and historical studies. For instance, self-reported age data in countries or periods characterized by low average levels of education often show high frequencies at attractive, ‘round’ numbers. This phenomenon is called age heaping. Individuals with limited knowledge about their age are found to have a higher propensity to choose a ‘plausible’ number. These individuals do not choose random numbers, but instead have a systematic tendency to choose attractive numbers, particularly those ending in 5 or 0. Age heaping is reported for a number of data sources, including census returns, tombstones, and tax data. Demographic studies have shown that age heaping is correlated to education (e.g. Bachi, 1951), income (e.g. Myers, 1976), illiteracy (Budd and Guinnane, 1991) and, more generally, human capital (A’Hearn, Baten, and Crayen, 2009).

While there is a growing literature documenting behavioral biases of private investors, much less is known about professional parties. Institutional investors are generally considered to be more sophisticated than private investors and are therefore assumed to invest more optimally. A number of theoretical papers argue that more sophisticated investors suffer less from cognitive biases or irrational behavior (e.g. Banerjee, 1992, DeLong et al., 1990, Hirshleifer et al., 1994, and Shleifer and Summers, 1990). However, there is little empirical evidence documenting (i) the

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sample results relative to the use of the 1/n strategy. They conclude that the gain from optimal diversification for mean-variance models is more than offset by estimation error.
investment behavior of institutional investors or (ii) how this behavior is influenced by their level of sophistication.

To fill this gap in the literature, we study the investment behavior of institutional investors with varying degrees of sophistication. Scale advantages should enable large pension funds to hire competent experts and consultants and spend more time and resources on optimizing their investment policies. Consequently, large pension funds should have a lower propensity to use heuristics in determining their asset allocation, but should instead use more advanced rules to guide investment policy. The more sophisticated investors are also expected to be more knowledgeable about the range of investment options available to them, and consequently to have a larger proportion of investments in other assets than bonds and equities. These factors should enable more sophisticated pension fund investors to apply better asset class allocation strategies than those of less sophisticated pension funds.

The influence of sophistication on risk taking is not self-evident. Less sophisticated investors may underestimate risks and consequently take more risk by investing in high risk-high (expected) return assets. Alternatively, less sophisticated investors may be more risk shy, thus compensating for weaker risk management skills, e.g. the ability to measure and control risk and implement diversification strategies. The latter conjecture is confirmed by previous research, showing that risk tolerance in individuals is negatively correlated with financial knowledge and education (Grable, 2000). We hypothesize that, by analogy, the sophistication of institutional investors correlates also positively to risk taking.

We investigate the investment policies of 857 Dutch pension funds during the 1999–2006 period. At the end of 2010, total pension fund assets in the Netherlands amounted
to some € 775 billion, or 132% of GDP, ranking the Dutch pension system in terms of the asset-to-GDP ratio as the largest in the industrial world.\(^2\) We find that pension funds’ asset allocation policies often seem to be relatively simple and that they vary widely, in line with the asset allocation puzzle. This raises the question whether all pension funds implement optimal asset allocation strategies, given their specific profiles and preferences.

To investigate this, we develop three measures of sophistication. The first measure assumes that less sophisticated pension funds are less knowledgeable about their (unpublished) optimal asset allocation, or use human judgment more, and are therefore more likely to choose plausible figures rather than the outcomes of detailed calculations. For example, they may use multiples of 5\% to set their strategic asset allocation. The strategic investment allocation reflects pension funds’ (unpublished) investment objectives, which they report to their prudential supervisor, De Nederlandsche Bank. The strategic asset allocation must meet supervisory requirements. The actual asset allocation may depart from the objective as a result of asset price shocks, since pension funds do not continuously rebalance their portfolios (Bikker, Broeders and De Dreu, 2009). We find that most pension funds do, in fact, apply such a coarse approach in allocating wealth to investment classes. This finding is similar to age heaping found in sociological and historical studies, where it is considered an indication of limited education.

Our second measure records how much pension funds invest in alternative, more complex asset classes such as commodities and real estate (versus more simple classes

\(^2\) Figure 5 in OECD (2011; see page 7) shows for 2010 that the asset-to-GDP ratio of the pension sector is higher in the Netherlands than in all other OECD countries.
such as money market and mixed asset funds), thereby improving asset diversification.³ We find that pension funds that apply rounding to multiples of 5% tend to diversify less to such more complex asset classes. Third, we examine ‘home bias’ and find that many pension funds favor regional investments, thereby limiting international diversification. We also find that all three indicators are correlated to pension fund ‘size’, indicating that smaller pension funds are generally less sophisticated than large funds, which is in line with our expectation.

In accordance with the asset allocation puzzle, we observe for Dutch pension funds that there are large differences in asset allocation strategies across pension funds. Specifically, relative holdings of bonds and equities, investments in more complex asset classes and international diversification all vary significantly. Whereas specific conditions such as size (reflecting scale economies with respect to e.g. asset management and risk management), funding ratio, age distribution of participants, type of pension plans or type of pension fund contribute to this spread (Bikker, Broeders, Hollanders and Ponds, 2012), the variation remains largely unexplained. An important question is whether pension fund investors’ sophistication influences risk taking. It would be a rational risk-management strategy for pension fund investors with less financial expertise to reduce exposure to risks that are not well understood. We investigate the impact of sophistication on risk taking by estimating a model for the strategic bond allocation, where our measures of sophistication are added as explanatory variables. The empirical results indicate that less sophisticated pension funds have a significantly lower risk profile, investing more in bonds and less in equities.

³ Alternative refers to all assets except bonds and equities.
There are at least two reasons why the pension sector in the Netherlands provides an ideal setting to study the impact of investor sophistication on risk taking. First, total assets under administration, our measure of the size of pension funds, which may be related to sophistication, varies widely. Pension funds range in size from small institutions – with assets below one hundred million euro (almost two-thirds of the funds) – to very large institutions with assets of more than one hundred billion euro. The variation in terms of participants is also wide, from less than 100 participants (5% of institutions) to more than a million participants. Large institutions include industry-wide pension funds such as ABP and PFZW, which are among the biggest in the world. Small institutions are mostly company funds that provide pensions for the employees of a single company. Second, De Nederlandsche Bank collects comprehensive data on the investment policies of all these institutions, which allows us to study their asset allocation strategies.

This article is organized as follows. Section 2 describes our dataset, while Section 3 develops three measures of sophistication in pension funds’ investment behavior and examines their mutual connection and relationship to size and other characteristics of pension funds. Section 4 investigates the influence of investment sophistication on risk taking. Section 5 provides an update of our approach for 2007-2010 as a robustness test, while the last section concludes.

2. Data on pension funds

We use a detailed dataset on the investments of 857 Dutch pension funds, consisting of quarterly figures for 1999:Q1 – 2006:Q4. The data is from De Nederlandsche Bank, responsible for the prudential supervision of pension funds and their regulatory
compliance. For each pension fund, data is or should be available on its strategic asset allocation, asset sales and purchases and on the market value of investments in various asset classes. Pension funds generally do not fully and continuously rebalance their actual asset allocation to match their strategic allocation policies (Bikker, Broeders and De Dreu, 2010). As a result, actual asset allocations reflect both active policy decisions by pension funds and (recent) returns on the portfolio holdings. We investigate strategic asset allocations, since these fully reflect active choices of pension funds, in contrast to actual asset allocations, which are also determined by market price shocks. The sample is an unbalanced panel, as not all pension funds are included throughout the sample period, due to new entrants, mergers, dissolutions, and reporting failures.⁴ Pension funds with evident reporting errors have been excluded.⁵ Over 2001-2006, the sample represents around 95% to 99% of pension funds’ participants in the Netherlands. Our sample includes 664 company pension funds, 97 industry-wide pension funds, and 11 professional group pension funds; the status of 85 funds is unknown.⁶

<table>
<thead>
<tr>
<th></th>
<th>Mean value</th>
<th>Standard deviation</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Number of observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of pension funds</td>
<td>614</td>
<td>38</td>
<td>657</td>
<td>510</td>
<td>19,174</td>
</tr>
<tr>
<td>Small funds</td>
<td>388</td>
<td>49</td>
<td>438</td>
<td>252</td>
<td>12,165</td>
</tr>
<tr>
<td>Medium-sized funds</td>
<td>171</td>
<td>13</td>
<td>188</td>
<td>135</td>
<td>5,429</td>
</tr>
<tr>
<td>Large funds</td>
<td>50</td>
<td>6</td>
<td>61</td>
<td>38</td>
<td>1,580</td>
</tr>
</tbody>
</table>

⁴ We also compare the results for a balanced sample comprising 381 pension funds that report at least seven years of data. The results are similar to the tables that are presented, suggesting that survivorship bias is not a significant issue.

⁵ 2082 (10.2%) of the observations have been deleted: zero or negative number of participants (37 observations), strategic allocation not adding up to 100% (10), observations of pension funds with total investments below € 100,000 which are assumed to be not representative (332), too large fluctuation in values of bonds or equity (73), too large difference between actual and strategic allocation (803), and lacking strategic bond or equity allocation (827).

⁶ Company funds provide pension plans to the employees of their sponsor company. They are separate legal entities, but are run jointly by the sponsor company and employee representatives. Industry funds provide pension plans for employees working in an industry. Such pension plans are based on a collective labor agreement between an industry’s companies and the labor unions, representing the employees in that industry. Finally, professional group funds offer pension schemes to groups such as general practitioners and public notaries.
Table 1 presents summary statistics after cleaning up the data. The size of pension funds in the sample ranges from small pension funds with total investments worth less than € 1 million, to large pension funds such as ABP, the public servants pension fund, with total investments of over € 200 billion. The average size of pension fund assets is € 785 million. The number of pension funds varies over the quarters between 510 and 657. Given the total number of pension funds, 857 (after data selection), this implies that each quarter a substantial number of pension funds are – in that quarter – not present in our dataset, due in part to the data clean up. To compare pension funds with different levels of sophistication we define three size classes: small (investments of up to € 100 million), medium (€ 100 – 1000 million) and large (> € 1 billion). Although large in number (63% of the institutions), the small pension funds administer only 2% of total pension fund assets. Conversely, whilst large pension funds represent only 8% of institutions, they administer 86% of total pension fund assets.

All investment figures are split into the respective currencies. We define home bias as more than proportional investments in the euro area. Other characteristics of pension funds, such as number of participants, funding ratio and percentage of pensioners, are available on an annual basis. Where desirable, we interpolate and extrapolate these variables to obtain quarterly values.
3. Investor sophistication

In order to assess the sophistication of pension funds’ investment policies, we develop three measures of sophistication, based on the data discussed above: (i) the use of gross rounding, (ii) investments in alternative, more complex asset classes minus investment in alternative simple assets, and (iii) home bias.

3.1. Gross rounding of asset allocations

We first examine the use of rounded numbers in pension funds’ strategic asset allocation. The histograms in Fig. 1 show the strategic equity and bond allocations of Dutch pension funds. Two patterns stand out. First, and most remarkably, strategic allocations cluster around multiples of 5%. Table 2 shows that the frequencies of 5% multiples used for strategic allocations to both equities and bonds far outstrip those of other numbers. Apparently, pension funds strongly favour round percentages for strategic equity and bond allocations to the nearest 5%. The graphs further suggest that coarse rounding to the nearest 10% is more frequent than rounding to 5%. Apparently, sets of ten are even more attractive than sets of five. Just as Agnew et al. (2003) observes for private investors, we also notice that some pension funds take extreme positions of 0% and 100% in equities or bonds. Second, the dispersion of strategic equity and bond allocation across pension funds is large. The graphs show little or no

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7 Here, we disregard other asset categories, which represent relative small shares in total assets. For a number of (smaller) pension funds these shares are even zero, see Table 3. Section 3.2 investigates this further.
convergence around a certain strategic asset allocation indicating that (beliefs about) optimal asset allocation levels vary widely across pension funds, perhaps (partly) due to diverging conditions such as risk aversion and ageing.

![Fig. 1: Frequency distribution of strategic equity and bond allocations of 857 pension funds (1999:Q1–2006:Q4)](image)

Attractive numbers for rounding should be simple to remember and easy to use for calculations. Multiples of 10%, 5% and also 2% fit the bill. We classify pension funds that use these multiples for their strategic equity and bond allocations as ‘using attractive numbers’. Coarse rounding may point to less sophistication in line with findings for demographic studies. Alternatively, the preference of pension funds to use attractive numbers for their strategic asset allocation may be due to the absence of compelling arguments for more ‘precise’ allocation figures. The latter explanation would be in line with DeMiguel, Garlappi and Uppal (2007), who find that simple heuristics such as the $1/n$ rule generate returns similar to those of more complicated portfolio choice models in the presence of estimation errors. If this alternative

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8 This is also clear from the histograms of actual equity and bond ratios, not shown here. These figures show smooth distributions (actual allocations are influenced by market movement and hence not
explanation were true, we would expect no significant impact of coarse rounding on risk taking. However, our empirical results presented later in this article point elsewhere.

<table>
<thead>
<tr>
<th>Attractive numbers</th>
<th>Small funds*</th>
<th>Medium-sized funds</th>
<th>Large funds</th>
<th>All funds</th>
<th>Uniform distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiples of 10%</td>
<td>37</td>
<td>28</td>
<td>11</td>
<td>33</td>
<td>1</td>
</tr>
<tr>
<td>Multiples of 5%</td>
<td>66</td>
<td>57</td>
<td>29</td>
<td>61</td>
<td>4</td>
</tr>
<tr>
<td>Multiples of 2%</td>
<td>41</td>
<td>33</td>
<td>19</td>
<td>37</td>
<td>25</td>
</tr>
</tbody>
</table>

* Size classes are defined in Table 1.

**Table 2: Attractive numbers used for strategic allocation to both equities and bonds (in %; 1999:Q1–2006:Q4)**

Table 2 shows the percentages of pension funds that use attractive numbers for their strategic allocation to both equities and bonds. The number 66% for multiples of 5% by small pension funds (first column, second row) indicates that two-thirds of these pension funds use 5% multiples for their strategic allocation to both equities and bonds, leaving only 34% of funds allocating other percentages, which may include 5% multiples to either bonds or equity. We compare this to the incidence of attractive numbers for both equity and bond allocations under a uniform distribution. As already suggested by Fig. 1, multiples of 5% (including tens) occur most frequently. On average, 61% of pension funds use multiples of 5% for their strategic allocation to both equities and bonds, far above the 4% expected in a uniform distribution of integers between 0% and 100%. Multiples of 10% are reported at slightly more than half the frequency for multiples of 5% indicating that, on average, pension funds slightly prefer even over odd multiples of 5%. The difference between multiples of 10% and multiples of 2% is only marginal indicating low preference for percentages ending in 2, 4, 6 and 8. We only consider integers to calculate the uniform distribution, while in the dataset rounded), but with the same wide dispersion.
we only consider multiples of 10.0%, 5.0% and/or 2.0% to be attractive numbers. In fact, however, almost one fifth of the pension funds report their asset allocations in decimals. So in reality, the expected use of attractive numbers under the uniform distribution would be even lower than assumed here.

We test whether multiples of, respectively, 10%, 5%, and 2% for investments in equities and bonds occur more frequently \((H_1)\) than under a uniform distribution of integers between 0% and 100% \((H_0)\), using Pearson’s chi-squared test on observed versus expected percentages under a uniform distribution (A’Hearn, Baten, and Crayen, 2009). The uniform distribution is rejected at the 1% significance level for all three multiples, across all three size classes of pension funds,\(^9\) except the use of even numbers for large pension funds.

Table 2 also shows that small pension funds use attractive numbers significantly more frequently than medium-sized pension funds, while large pension funds use attractive numbers least frequently. We test whether the frequencies of certain multiples are equal \((H_0)\) or different \((H_1)\), using the \(t\)-test on the equality of means, respectively, between small and medium-sized funds, and between medium-sized and large funds.\(^10\) We find that the different frequencies between small, medium and large pension funds, across all types of multiples, are significant at the 1% level.\(^11\)

Table 3 shows the frequency distribution of combinations of strategic equity and bond allocations when they are both rounded to 5%. Each non-zero cell presents the

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\(^9\) As well as the combination of both 2% and 5%, not shown in Table 2. The test is based on the assumption that pension funds round their asset allocation to integers.

\(^10\) Note that if the equality of means between (i) small and medium-sized funds, and (ii) medium-sized and large funds has been rejected, the rejection of the equality of means between small and large funds follows automatically. An alternative is the binomial probability test. This test gives virtually the same results.

\(^11\) These test results may have been influenced by the fact that large pension funds tend to invest more in alternative assets. Though rounding plays an important role for other assets too, investment allocations
frequency of a combination linked to (i) a bond allocation with a percentage as in the upper row, and (ii) an equity allocation with a percentage as in the left-hand column. The bottom row gives aggregations for the frequencies corresponding to the respective bond allocations, and the right-hand column gives summations for the frequencies related to the respective equity allocations.

Note: Cells in the upper triangular with values below 0.05% are shown as blanks.

Table 3: Frequency distribution of 5% multiples in strategic equity and bond allocations (in % of observations; 1999:Q1–2006:Q4)

In line with Figure 1, the table confirms that there is a wide variety of investment policies with little convergence to a certain average or median strategy. The most
common strategic allocations are between 20% and 50% for equities and between 50% and 80% for bonds (see shaded cells). The diagonal reflects the frequencies of pension funds where the allocations to equities and bonds add up to 100%, hence without investments in other assets (see e.g. shaded cells). These diagonal cells add up to 36.8%.

The hypothetical optimal asset allocation of pension funds depends on risk preferences of participants and sponsors (determined by e.g. the age structure of participants), expected risks and returns of the different asset classes, the funding ratios and macroeconomic variables such as wage growth, inflation and real interest rates. Typically, Asset-Liability Management (ALM) studies take these factors into account. Such studies could be used to obtain supposed optimal asset allocation estimates, using Monte Carlo simulations based on preferences (such as the risk-return trade off) and on market return and volatility assumptions. However, in practice, ALM studies are not used directly to optimize portfolio investments across asset classes. Rather, they are used as input for a human appraisal process. The widespread use of multiples of 5% indicates that the determination of strategic asset allocations is often based on rough estimates rather than precise measures.

<table>
<thead>
<tr>
<th>Year</th>
<th>Small</th>
<th>Medium-sized</th>
<th>Large</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>60</td>
<td>48</td>
<td>22</td>
<td>54</td>
</tr>
<tr>
<td>2000</td>
<td>64</td>
<td>51</td>
<td>25</td>
<td>57</td>
</tr>
<tr>
<td>2001</td>
<td>66</td>
<td>57</td>
<td>26</td>
<td>61</td>
</tr>
<tr>
<td>2002</td>
<td>70</td>
<td>64</td>
<td>29</td>
<td>65</td>
</tr>
<tr>
<td>2003</td>
<td>70</td>
<td>60</td>
<td>32</td>
<td>64</td>
</tr>
<tr>
<td>2004</td>
<td>70</td>
<td>61</td>
<td>30</td>
<td>64</td>
</tr>
<tr>
<td>2005</td>
<td>66</td>
<td>57</td>
<td>31</td>
<td>59</td>
</tr>
<tr>
<td>2006</td>
<td>65</td>
<td>52</td>
<td>32</td>
<td>56</td>
</tr>
<tr>
<td>Unweighted average</td>
<td>66</td>
<td>56</td>
<td>29</td>
<td>60</td>
</tr>
</tbody>
</table>

* Size classes are defined in Table 1.

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bond allocations. This would affect the last test, but not the rest of the analysis.
Table 4: Multiples of 5% used for strategic asset allocation over time and across sizeclasses (1999–2006; in %)

Table 4 presents the use of attractive strategic asset allocation numbers by small, medium-sized and large pension funds over time. The statistics confirm that small funds are more likely than large funds to choose multiples of 5% for their investment strategies. On average, 66% of small pension funds choose a multiple of 5% for their strategic equity and bond allocations compared to only 56% of medium-sized funds and 29% of large funds. There is some variation over time: the use of 5% multiples increases until 2002 (for large funds: 2003) and decreases afterwards. This may be an indication that the use of ALM models in determining the strategic allocation has increased since 2002/2003. However, the finding that the use of 5% multiples is inversely related to size is consistent over the years. Based on a $t$-test, we find that differences in the use of 5% multiples between small, medium-sized and large pension funds are significant at the 1% level for each year. These findings suggest that small pension funds use less sophisticated asset allocation rules more often than large funds.

3.2. Allocation to alternative asset classes

We investigate how pension funds allocate investments across different asset classes. Our dataset distinguishes the following asset classes: equities, bonds, real estate, mortgages and loans, commodities, mixed mutual funds, and money market instruments. More than 50% of pension funds base their strategic asset allocation on

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12 Mixed mutual funds are investment funds that combine investments in both debt and equity instruments. Money market instruments are short-term debt investments such as certificates of deposits and commercial paper. Our data do not include information regarding underlying investments in these funds. Note that investment assets do not include liquidity for e.g. ongoing payments.
bonds and equities only and do not consider alternative asset classes such as real estate or commodities. This suggests that these pension funds limit their scope for higher expected returns and/or further risk diversification.

<table>
<thead>
<tr>
<th>Size classes pension funds</th>
<th>Equities</th>
<th>Bonds</th>
<th>Alternative simple investments</th>
<th>Alternative complex investments</th>
<th>Average investments (mln euro)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–100 (small)</td>
<td>27</td>
<td>64</td>
<td>4</td>
<td>5</td>
<td>28</td>
</tr>
<tr>
<td>100–1,000 (medium sized)</td>
<td>36</td>
<td>56</td>
<td>1</td>
<td>7</td>
<td>320</td>
</tr>
<tr>
<td>&gt;1,000 (large)</td>
<td>41</td>
<td>45</td>
<td>1</td>
<td>13</td>
<td>8,211</td>
</tr>
</tbody>
</table>

*Note: All allocation numbers are simple averages in percentages. 
*Based on total investments (in € millions). Simple alternative investments include money market funds and mixed mutual funds. Complex alternative investments include real estate, commodities and loans.

**Table 5: Average strategic asset allocation by size class (1999:Q1–2006:Q4)**

Table 5 presents the allocation of pension funds’ wealth across asset classes for pension funds of various size categories. It shows that larger pension funds allocate higher proportions of their investments to equities and lower proportions to bonds, compared to smaller pension funds. Medium-sized funds take an intermediate position. Larger pension funds, seeking better risk diversification and/or higher returns, also invest more in alternative investments than small and medium-sized funds. We split alternative investments into two categories: relatively simple assets (money market funds and mixed mutual funds) and more complex assets (real estate, commodities and loans).

This split shows that larger pension funds invest significantly more in alternative complex assets, but less in alternative simple assets, compared to small funds. This behavior is probably driven in part by supervisory regulations, which require a more sophisticated risk management for institutions that invest in more complex alternative investments. Differences between small, medium-sized and large pension funds for all asset categories distinguished are significant at the 1% level (based on a *t*-test on the
equality of means as used in Table 2), except for simple alternative investments between medium-sized and large pension funds. Over time, diversification to alternative investments has been quite stable, on average, with a slight downward trend for all size classes.

Table 6 provides further insight in the relationship between investments in complex alternative assets and pension fund sizes. The upper panel of this table shows that 83% of small pension funds invest less than 10% of their assets in alternative, complex assets vs. 69% for medium-sized funds and 34% for large funds. Only 18% of small funds invest more than 10% in sophisticated assets whereas 66% of the large funds do so. The lower panel of Table 6 shows that pension funds that round to 5% multiples invest significantly less in alternative complex assets. The outcomes of this table confirm the finding that large funds diversify their investments more. Furthermore, this behaviour turns out to be inversely correlated with heaping.

<table>
<thead>
<tr>
<th>Size classes pension funds</th>
<th>Investments in alternative complex assets</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0%</td>
</tr>
<tr>
<td>0 – 100 (small)</td>
<td>62</td>
</tr>
<tr>
<td>100 – 1,000 (medium sized)</td>
<td>44</td>
</tr>
<tr>
<td>&gt;1,000 (large)</td>
<td>10</td>
</tr>
</tbody>
</table>

Use of ‘attractive numbers’ for strategic asset allocation

| Pension funds that round to 5% | 67 | 14 | 14 | 5 |
| Funds that do not round to 5%  | 31 | 35 | 20 | 14 |

Note: All statistics are simple averages in %.

* Alternative complex asset classes include real estate, commodities and loans. "Based on total investments (million euro).

Table 6: Pension funds that invest in alternative complex assets in % of all pension funds; 1999:Q1–2006:Q4

For a pension fund whose risk management is not sophisticated, it may make sense to invest more in simple alternative investments, as opposed to complex alternative investments that are not fully understood. However, this approach implies less
diversification: *a priori* lower investment returns (at given risk levels) so that sophistication remains ‘better’. Nonetheless, it may be relatively costly for small funds to invest in complex alternative investments. It is difficult to distinguish between unsophisticated or ‘suboptimal investment policies and the most appropriate (but less rewarding) investments for small funds. Nevertheless, we can do this by controlling for the size effect, which reflects the scale of the risk management unit, so that we observe pension fund investment behavior in deviation from its fund size. This is what happens indirectly when, in Section 4, we use the sophistication measures together with size as explanatory variables in the risk aversion or bond allocation model of Equation (3).

### 3.3. Home bias

We investigate in what degree pension funds diversify their investments geographically. International diversification can provide significant benefits by reducing risk for a given level of expected returns. However, not all investors exploit these diversification benefits to the full, as evidenced by their limited ownership of foreign shares. This phenomenon has been documented using macro-economic data (*e.g.* French and Poterba, 1991), firm-specific data (*e.g.* Kang and Stulz, 1997), as well as investor-specific data (*e.g.* Karlsson and Norden, 2007). The main explanations point to explicit and implicit barriers to international investments. Other explanations include the use of domestic assets to hedge against unexpected changes in inflation and cognitive biases. However, these explanations have not been able to fully account for the lack of international diversification by domestic and foreign investors, despite significant risk-return benefits. Therefore, this phenomenon is known as the home-bias puzzle.
Home bias usually refers to a preference by investors to hold domestic assets. Here we refer to more than proportional investments of Dutch pension funds in the euro area, as the data do not present greater detail. International diversification provides substantial risk-return benefits and hence home bias indicates a certain degree of shortsightedness that suggests less sophistication. Table 7 shows that, on average, large pension funds invest 34% of their assets within the euro area, while investments of small pension funds in the euro zone average 53% of assets. The home preference for assets from the euro area is at 47% stronger in less sophisticated pension funds (which round to 5%) than in sophisticated ones (39%). This finding is consistent with a study by Karlsson and Norden (2007), who report a higher likelihood of home bias for less sophisticated investors with lower education levels and no previous experience with investments in risky assets. Remarkably though, the home bias is stronger for sophisticated small and medium-sized funds compared to unsophisticated funds of these size classes (which is unexpected), whereas it is much smaller for sophisticated large funds compared to unsophisticated large funds, in line with ‘theory’. On average, home bias fell from 50% to 42% during 1999-2001 (a similar fall is observed in all size classes), with a slight upward bound in 2006.

<table>
<thead>
<tr>
<th>Size classes pension funds</th>
<th>Investments within the euro area (in%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Funds using 5% multiples</td>
</tr>
<tr>
<td>0–100 (small)</td>
<td>53</td>
</tr>
<tr>
<td>100–1,000 (medium sized)</td>
<td>42</td>
</tr>
<tr>
<td>&gt;1,000 (large)</td>
<td>34</td>
</tr>
<tr>
<td>All funds</td>
<td>43</td>
</tr>
</tbody>
</table>

Note: All percentages are simple averages.

Table 7: Home bias of equity investments a (1999:Q1–2006:Q4)

13 The current share of EMU assets in the worldwide total is just below 28% (IMF Global Financial
We also observe home bias in total investments of pension funds, where small and medium-sized funds hold around 85% of their investments in assets located in the euro area against 63% for large funds. This total-investment euro-area bias confirms the equity euro-area bias of Table 7. Incidentally, pension funds tend to hedge their currency risk with derivatives, reducing their net non-euro exposure to only 4% for small funds and 8% for large funds. Note that currency risk insurance does not wipe out the euro-area bias above, as the lack of international diversification remains.

3.4. An overall index of sophistication

Following Calvet, Campbell and Sodini (2009b) we investigate the relationship of each of the three sophistication measures with a number of pension fund characteristics in order to explain which features of pension funds determine the developed measures. The relationship we use is:

\[
y_{i,t}^k = \sum_j \beta_{j,i,t}^k x_{i,j,t} + e_{i,t}^k
\]

where \(y\) refers to the three measures of sophistication \((k = 1, 2, 3)\), \(x\) to the \(j\) considered pension fund characteristics listed in Table 8, \(\beta\) to the respective coefficients, \(e\) to the error terms, \(i\) to the pension funds and \(t\) to time. The first three columns of Table 8 present the estimation results.

Each of the three measures correlates significantly with size, expressed as the logarithm of total assets, and the signs of the estimated coefficients are in line with expectations that larger size is associated with higher sophistication. This is what we
also observed earlier and it is in line with the idea that size and risk management go hand in hand. Note that gross rounding and home bias point to less sophistication, whereas diversification into alternative assets indicates more sophistication, see the first row of Table 8. Pension funds with larger investments per participant tend to round less and diversify more in alternative assets. Apparently, funds paying higher individual pension benefits are more sophisticated. Funds offering defined-contribution plans are also more sophisticated, possibly related to the fact that most of these funds in the Netherlands were established more recently and at that time introduced the current state of knowledge. The measures vary across pension fund type: particularly the industry-wide funds have less rounding and more diversification, indicating more sophistication, which is as expected. The low R-squares point to the fact that these pension fund characteristics only explain a minor part of the variation in the measures: sophistication varies widely across pension funds, even within size classes, et cetera.

<table>
<thead>
<tr>
<th>Correlation with sophistication</th>
<th>Gross rounding</th>
<th>Diversification in alternative assets</th>
<th>Home bias</th>
<th>Overall index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (logarithm of total assets)</td>
<td>-0.043 ***</td>
<td>0.013 ***</td>
<td>-0.045 ***</td>
<td>-0.044 ***</td>
</tr>
<tr>
<td>Investments per participant</td>
<td>-0.210 ***</td>
<td>0.002</td>
<td>-0.005</td>
<td>-0.196 ***</td>
</tr>
<tr>
<td>Percentage pensioners</td>
<td>0.014</td>
<td>-0.005</td>
<td>0.084 *</td>
<td>0.024 ***</td>
</tr>
<tr>
<td>Funding ratio</td>
<td>-0.019 *</td>
<td>0.012 ***</td>
<td>0.109 ***</td>
<td>-0.017 **</td>
</tr>
<tr>
<td>Industry funds</td>
<td>-0.243 ***</td>
<td>0.073 ***</td>
<td>0.100 ***</td>
<td>-0.241 ***</td>
</tr>
<tr>
<td>Professional group funds</td>
<td>-0.063 **</td>
<td>0.015 *</td>
<td>-0.091 ***</td>
<td>-0.068 ***</td>
</tr>
<tr>
<td>Defined contribution plan</td>
<td>-0.174 ***</td>
<td>0.012</td>
<td>0.110 ***</td>
<td>-0.154 ***</td>
</tr>
<tr>
<td>Gross rounding intercept</td>
<td>-0.043 ***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asset diversification intercept</td>
<td>0.013 ***</td>
<td></td>
<td></td>
<td>-0.113 ***</td>
</tr>
<tr>
<td>Home bias intercept</td>
<td>0.013 ***</td>
<td></td>
<td></td>
<td>0.697 ***</td>
</tr>
<tr>
<td>Gamma2</td>
<td>-0.281 ***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gamma3</td>
<td>0.437 ***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of observations</td>
<td>16,937</td>
<td>16,937</td>
<td>2,092</td>
<td>35,966</td>
</tr>
<tr>
<td>F-statistics</td>
<td>267</td>
<td>253</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>R-squared, adjusted</td>
<td>8.6</td>
<td>9.8</td>
<td>14.0</td>
<td>62.9</td>
</tr>
</tbody>
</table>

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 8. Measures of sophistication and pension fund characteristics (1999:Q1–2006:Q4)
Further following Calvet, Campbell and Sodini (2009b), we construct an overall index of sophistication by regressing the vector of measures of sophistication on (vectors of) pension fund characteristics:

\[
\begin{bmatrix}
y_{1,t}^1 \\
y_{1,t}^2 \\
y_{1,t}^3 \\
\end{bmatrix} = \begin{bmatrix}
\sum_j \beta_{j}^{1} x_{i,j,t} \\
\gamma_2 \sum_j \beta_{j}^{2} x_{i,j,t} \\
\gamma_3 \sum_j \beta_{j}^{3} x_{i,j,t} \\
\end{bmatrix} + \begin{bmatrix}
e_{1,t}^1 \\
e_{1,t}^2 \\
e_{1,t}^3 \\
\end{bmatrix}
\]

Equation (2) combines the three Equations (1) – for \( k = 1, 2, 3 \) – into one vector, and imposes a set of restrictions \( \beta_{j}^{1} = \gamma_2 \beta_{j}^{2} = \gamma_3 \beta_{j}^{3} \) (= \( \beta_{j} \) by definition) for each \( j \). These restrictions force the impact of the pension funds characteristics on the three measures of sophistication to be identical, apart from scaling factors \( \gamma_2 \) and \( \gamma_3 \). This construction of an overall index is based on the assumption that the three measures have a common component, interpreted as (lack of) sophistication. This common component, \( \sum_j \beta_{j} x_{i,j,t} \), is the overall index. The last column of Table 8 presents the estimates of Equation (2). The values of the two gammas lower than 1 (in absolute terms) reflect that the first measure, ‘gross rounding’, is more strongly correlated with this underlying common factor than the other two measures. The negative sign of \( \gamma_2 \) indicates that ‘diversification into alternative assets’ is correlated positively with sophistication while the other two are correlated with lack of sophistication, hence negatively. Table 9 shows the mutual correlations between the measures.

<table>
<thead>
<tr>
<th></th>
<th>Gross rounding</th>
<th>Diversification</th>
<th>Home bias</th>
<th>Overall index</th>
<th>Total investments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross rounding</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diversification</td>
<td>-0.14</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>0.15</th>
<th>0.24</th>
<th>1.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home bias</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall index</td>
<td>0.29</td>
<td>-0.17</td>
<td>0.22</td>
</tr>
<tr>
<td>Total investments</td>
<td>-0.29</td>
<td>0.08</td>
<td>-0.30</td>
</tr>
</tbody>
</table>

The correlations reflect the fact that gross rounding, home bias, the overall index and total investments are negatively associated with sophistication, while diversification is positively correlated. The correlations are quite low, indicating that the measures reflect various dimensions of sophistication. The overall index reflects gross rounding and home bias more closely than diversification. This index is highly (but inversely) correlated with pension fund size. In part, this is due to the construction of the index: it reflects the model \( \sum_j \beta_j x_{i,j,t} \), including size, which covers the sophistication measures only poorly, and ignores their residuals. The next section will show that the measures explain the risk appetite of pension funds, even when controlling for size.

4. Investor sophistication and risk taking

We investigate a possible relationship between the measures of investor sophistication and risk taking. We hypothesize that pension funds with less investment expertise are generally more risk-averse. Assuming that they are less knowledgeable about how to invest assets optimally, less sophisticated funds may deliberately choose a lower risk profile for their asset allocation. This strategy makes sense intuitively, as small funds with limited sophistication and expertise are likely to feel less comfortable with these risks. Conversely, sophisticated pension funds are more likely to have significant in-house expertise and to use sophisticated modelling techniques, which may make them less averse to risk taking. Sophisticated funds may also suffer from overconfidence.
because they put too much trust in the theories and models they have developed (Griffin and Tversky, 1992). As the recent credit crisis shows, risk taking is not always a rewarding strategy since: over the last decade, investments in bonds have yielded higher rewards than equities in most countries.

Fig. 2 presents the average strategic equity and bond allocations over time for pension funds in different size categories. On average, large pension funds invest a greater share of their assets in equities and less in bonds, as also observed in Table 5. The graphs show that this finding is persistent across the sample period.
Investing more in bonds, as small funds do, reduces the mismatch between the duration of assets and liabilities, and reduces the exposure to volatile equity markets. Hence, the graphs indicate that small and less sophisticated funds tend to choose a lower risk exposure. Fig. 2 further shows that strategic asset allocations vary significantly over time, reflecting the dynamic nature of investment policies. Over time, large pension funds have most volatile strategic asset allocation over time. This suggests that they update their investment policy more frequently but may also reflects the fact that the average of large funds is based on a lower number of pension funds (see Table 1).

---

14 Nominal defined-benefit pension liabilities are best resembled by nominal government bonds. Instead, defined-benefit pension liabilities that are fully indexed to prices are best resembled by inflation linked bonds. In many Dutch defined benefit-pension deals, indexation is contingent on the funding ratio of the pension fund. The market value of this contingent indexation can be derived using option pricing theory. In this case it might be optimal to have considerable equity exposure, see e.g. Broeders (2010).
To examine the impact of investor sophistication, or the lack of it, on risk taking, we estimate the following equation:

\[ Bond_{allocation_{i,t}} = \alpha + \beta \text{Heaping}_{i,t} + \gamma \text{Diversification}_{i,t} + \delta \text{Homebias}_{i,t-1} + \varepsilon \text{Size}_{i,t-1} \]

\[ + \zeta \text{Riskpreferences}_{i,t-1} + \eta \text{Governance}_{i} + \theta \text{Pension plan}_{i} + e_{i,t} \]  

(3)

The dependent variable \( Bond_{allocation_{i,t}} \) is the strategic bond allocation of pension fund \( i \) \((i = 1, \ldots, N)\) at quarter \( t \) \((t = 1, \ldots, T)\). The explanatory variables \( Heaping \) and \( Diversification \) are variables indicating sophistication in asset allocation. \( Heaping \) equals one if the strategic equity and bond allocation are multiples of 5% and zero otherwise. \( Diversification \) stands for sophisticated diversification and is defined as ‘the strategic allocation to alternative complex assets’ minus ‘the strategic investment in alternative simple assets’, each presented as a percentage of total assets. \( Homebias \) is the percentage of investments in the EMU. Positive estimates for \( \beta \) and \( \delta \), and a negative estimate for \( \gamma \) would indicate that pension funds with less developed strategies choose a lower risk profile for their portfolio by investing a higher share of their wealth in bonds.

The other explanatory variables are standard elements in bond (or equity) allocation models for pension funds (Alestalo and Puttonen, 2006; Gerber and Weber, 2007; Lucas and Zeldes, 2006, 2009). The variable \( Size \), measured as the log of total investments, is included to estimate the impact of scale on the risk profile of pension funds. This variable is included with a lag to avoid possible endogeneity problems, even though such problems are unlikely. Bond price shocks may lead to an increase in both the actual bond allocation and total investments during the same period, but equity price shocks would have opposite effects on actual bond allocation and total investments. More importantly, we explain the strategic and not the actual allocation. But the
strategic allocation may gradually over time be influenced by asset price shocks (Bikker, Broeders and De Dreu, 2010).\textsuperscript{15} A negative estimate for $\varepsilon$ would indicate that the investments of larger pension funds tend to be riskier. Scale advantages should enable large pension funds to apply a more highly developed allocation policy and, therefore, this variable may also pick up some of the variation that is not explained by the first two variables (Heaping and Diversification), which are used as indicators for the level of sophistication of asset allocation.

*Risk preferences* is a vector of three variables that control for risk preferences of participants and sponsors. The variable ‘assets per participant’ is included to control for the impact of higher average pension assets on risk preferences. A negative coefficient would indicate that participants with higher pension fund investments are less risk averse. The age variable ‘percentage of pensioners’ is included to control for the duration of liabilities (Lucas and Zeldes, 2009).\textsuperscript{16} A positive coefficient for this variable would indicate that pension funds where relatively many participants have a short investment horizon will choose a lower risk profile (see Bikker, Broeders, Hollanders and Ponds, 2012). The variable ‘funding ratio’, calculated as total investments divided by discounted pension liabilities, is included because, from a risk management perspective, a bigger buffer provides room to invest more in risky assets.\textsuperscript{17} A negative coefficient could also indicate decreasing relative risk aversion in line with *e.g.* Cohn *et* ...

\textsuperscript{15} Nevertheless we also estimate this equation with 2SLS or replace total assets by number of participants, see footnote 20.

\textsuperscript{16} Our dataset for 1999-2006 does not contain the average age of participants, as used in Alestalo and Puttomen (2006) and Gerber and Weber (2007).

\textsuperscript{17} This is also according to the Dutch regulatory regime, which requires that the probability of a funding ratio falling below 100% within one year must be less than 2.5% (Broeders and Pröpper, 2010) and pension funds must always hold a minimum buffer of 5%. For risky portfolios a higher buffer is required. The Netherlands does not have a pension benefit guarantee fund.
al. (1975). This variable is included with a one-quarter time lag because it may take some time for changes in a fund’s funding ratio to affect its strategic bond allocation.

**Governance** is a vector of three dummy variables that control for differences in the governance of pension funds. The variable ‘industry-wide pension funds’ equals one if the pension fund provides pension plans for employees in an industry and zero otherwise, whereas the variable ‘professional group pension funds’ equals one if the pension fund provides a pension scheme to a specific professional group (*e.g.* medical profession, public notaries) and zero otherwise. Note that ‘company pension funds’ is the reference group. Finally, the variable ‘defined-contribution plan’ equals one if a defined-contribution pension scheme is offered, as opposed to a defined-benefit plan (zero).

<table>
<thead>
<tr>
<th></th>
<th>All pension funds</th>
<th>Company pension funds</th>
<th>Industry pension funds</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Column</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Heaping (gross rounding)</td>
<td>0.031***</td>
<td>—</td>
<td>0.021***</td>
</tr>
<tr>
<td>Diversification in alternative assets</td>
<td>-0.212***</td>
<td>—</td>
<td>-0.153***</td>
</tr>
<tr>
<td>Overall index</td>
<td>—</td>
<td>0.465***</td>
<td>—</td>
</tr>
<tr>
<td>Pension fund size (t-1)</td>
<td>-0.025***</td>
<td>—</td>
<td>-0.027***</td>
</tr>
<tr>
<td>Investments per participant (t-1)</td>
<td>-0.039***</td>
<td>—</td>
<td>-0.044***</td>
</tr>
<tr>
<td>Percentage pensioners</td>
<td>-0.044***</td>
<td>—</td>
<td>-0.043***</td>
</tr>
<tr>
<td>Funding ratio (t-1)</td>
<td>-0.048***</td>
<td>—</td>
<td>-0.048***</td>
</tr>
<tr>
<td>Industry pension funds</td>
<td>-0.040***</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Professional group pension funds</td>
<td>0.054***</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Defined contribution plan</td>
<td>-0.064***</td>
<td>—</td>
<td>-0.048***</td>
</tr>
<tr>
<td>Intercept</td>
<td>0.962***</td>
<td>0.871***</td>
<td>-0.080***</td>
</tr>
<tr>
<td>Number of observations</td>
<td>16,260</td>
<td>16,937</td>
<td>13,484</td>
</tr>
<tr>
<td>F-statistics</td>
<td>377</td>
<td>2,499</td>
<td>226</td>
</tr>
<tr>
<td>R-squared, adjusted</td>
<td>19.9</td>
<td>13.8</td>
<td>13.9</td>
</tr>
</tbody>
</table>

**Note:** One and three asterisks denote significance at the 10% and 1% levels, respectively.

**Table 10: The strategic bond ratio and indicators of sophistication for various pension fund types (1999:Q1–2006:Q4)**

Columns 1, 3 and 4 of Table 10 reports estimation results for Equation (3), though excluding the home-bias variable, both for all pension funds and for company and...
industry funds separately.\footnote{18} inclusion of ‘home bias’ would reduce the number of observations from 13,517 to 2,007.\footnote{19} All key variables enter with the expected signs and are significant at the 1\% significance level in all three specifications, except the DC dummy for industry funds, which is significant at the 10\% confidence level only. The results provide strong evidence that small pension funds with less than optimal allocation policies are more likely to choose low risk asset allocation strategies. Specifically, the heaping variable’s coefficient has a significant positive sign, showing that pension funds with less advanced asset allocation policies invest more in bonds. The coefficient indicates that pension funds using multiples of 5\% for their asset allocation invest, on average, 3.2 percentage points more in bonds (first column). The coefficient is even higher for \textit{Diversification}, indicating that pension funds investing 10\% of total assets more in alternative complex assets or less in alternative simple assets, invest 2.9\% of total assets less in bonds. Note that in this multiple-regression model (which includes size as explanatory variable) the coefficients of the two sophistication variables reflect the sophistication effect corrected for the size effect. Finally, the size variable enters with a negative sign, indicating that large pension funds raise their risk profiles by investing relatively less in bonds. An alternative size measure, that is, number of participants instead of total assets, leads to virtually identical estimation results.\footnote{20}

\footnote{18} We estimate with pooled OLS and correct the standard errors for heteroskedasticity, using the Huber-White sandwich estimators.  
\footnote{19} We estimate also Equation (3) including ‘home bias’. This variable enters significantly and with the expected sign (more home bias implies higher investments in bonds). The other two measures of (a lack of) sophistication show up with the expected sign when they are significant, that is, for diversification (all variants) and heaping (industry funds). The results are available upon request from the authors, but have not been not reported, since the number of observations for ‘home bias’ is relatively low.  
\footnote{20} The results are available upon request from the authors. We also estimate Equation (3) with 2SLS where the instrument for total assets is number of participants (all in logs). The results are virtually identical.
Two of the three included risk preference variables carry their expected sign for all three samples: a higher funding ratio and more investments per participant each imply relatively lower allocation to bonds, in line with Bikker, Broeders, Hollanders and Ponds (2012). A higher percentage of pensioners should result in a lower risk profile with relatively more bonds, but this is observed for industry-wide funds only. Studies which use average age (not available in our dataset) instead of percentage of pensioners found a similar negative impact of age (Alestalo and Puttonen, 2006; Gerber and Weber, 2007). Compared to company pension funds, industry funds hold relatively less in bonds, while the reverse is true for professional group funds. The latter is explained in Bikker, Broeders, and De Dreu (2010). Defined contribution plans, which have no nominal pension benefit target, tend to hold lower investments in bonds. The goodness of fit (R$^2$) in Table 10 for ‘all pension funds’ is, at 19.9, rather low, indicating that many other determinants of the bond ratio are not captured by Equation (3). This indicates a heavy impact of non-observed preferences, risk aversion and human judgment on strategic allocation. Note that the model fits much better for the – generally larger – industry pension funds, see adjusted R$^2$ of 42.7 versus 19.9 for all funds.

Column 2 of Table 10 presents the coefficient of the ‘overall index of (lack of) sophistication’, estimated in Section 3.4. This index is defined as $\sum \beta_j x_{i,j,t}$ with $x_{i,j,t}$ the variables already occurring in Equation (3) and $\beta_j$ the corresponding coefficients, estimated under restrictions. Inclusion of both this index and the indicators as explanatory variables would by definition cause (full) multicollinearity, so that we estimate the coefficient of this index only. As expected, the $t$-value of this coefficient is higher than each of the $t$-values of the two separate measures of sophistication, which
are now combined in the index. This outcome confirms that the overall index is a useful proxy for the underlying measures of (lack of) sophistication and that less sophisticated pension funds invest more in bonds.

5. An update for 2007-2010 as a robustness check

In 2007, a new regulatory regime for pension funds in the Netherlands came into force. At the same time, the prudential supervisor updated the reporting system for pension funds and adjusted the definition of asset classes. One essential change was that hedge fund investments must henceforth be reported as a separate category, apart from equity. Another change was that mixed funds were split into their constituting components and merged with bonds, equities, *et cetera*. These changes have a significant impact on our diversification measure ‘alternative assets’ and on the dependent variable ‘bonds’ in our risk-taking model of Equation (3). This is why we cannot append the 2007 and later data to our basic sample period 1999-2006 and apply our approach for the entire period at once.

Our dataset extends from 2007:I to 2010:IV, so that we have another 16 quarters of observations available. We use this second dataset to check whether the financial sophistication characteristics of pension funds that we find over 1999-2006 also hold for the successive years. Note that this period is short, compared to the 32 quarters of our sample period 1999-2006, and that we use different definitions of asset classes in accordance with the new reporting standards. We duplicate all calculations of this article for 2007-2010 and briefly discuss the results (available on request). Typical

21 Full multicollinearity if we had the same lags in Equation (1) and (3). Hence, near multicollinearity, as Equation (1) does not include lags.
trends in the summary statistics of this later period (as in Table 1) are a reduction in the number of smaller pension funds from, on average, 368 to 126, and, consequently, larger (remaining) pension funds. Average total assets increased as a result of both consolidation and overall growth. The updated frequency distribution of strategic equity and bond allocations (as in Fig. 1) looks similar, with the same remarkable spikes at multiples of 5%. The share of bonds is lower now and zero allocations for equity are no longer reported. Rounding to multiples of 5% declined during 2007-2010 from 62% to 43%, the reduction being stronger in both relative and absolute terms for medium-sized and larger funds (compare Tables 2 and 3). The reduction in heaping appears suddenly in early 2007, which is probably related to the new reporting system, adding force to the argument that the two considered periods cannot be analyzed jointly. Therefore, we do not interpret the decrease in heaping as an increase in sophistication. The use of complex investments has increased somewhat in all size classes, but remains the highest by far for larger pension funds. The use of simple assets is now low in all pension fund size classes. Over time, the proportions of equities and bonds for larger pension funds have come to differ less from those for smaller funds, due in part to the lower number of smaller funds (compare Tables 4 and 5). Differences in home bias across size classes remain unchanged (compare Table 7). The general picture is that the difference between large and small pension funds increases for one indicator (diversification) and decreases for the two others (heaping and home bias).

In explaining the strategic allocation to bonds over 2007-2010, the coefficient of the measure ‘diversification in alternative assets’ is larger and more significant than before, due to the improved definition of alternative assets (compare Table 10). While heaping was the most statistically significant measure during 1999-2006, it is less prominent in
later years and, in fact, not significantly different from zero for the industry-wide pension funds, probably due to its lower frequency. The estimated overall index of (lack of) sophistication, defined by Equation (2), is also a highly significant explanatory variable in explaining the strategic allocation to bonds: less sophistication goes hand in hand with lower bond investments.

We conclude that the measures of sophistication continue to work well during 2007-2010, but with less emphasis on heaping and a more prominent role for diversification into alternative assets. Furthermore we find that two out of three measures point to increasing sophistication over time.

6. Conclusions

We examine the impact of investor sophistication on risk taking. We focus on pension funds since their size and other characteristics vary widely and comprehensive data is available. To measure investor sophistication, we construct three measures of the sophistication of pension funds’ investment policies. The first indicator gauges the use of attractive, but imprecise, numbers for the strategic allocation of assets to both equities and bonds. Most pension funds in the Netherlands apply such rule of thumb, using particularly multiples of 5%. This supports the observation that in current practice, asset allocation does not follow directly from optimization of ALM models. Rather, it is determined by human judgment, given results from ALM studies. The second indicator is the use of alternative, complex investments other than equities and bonds, as an instrument to diversify the investment portfolio. We observe that many pension funds invest little in alternative, more complex asset classes, suggesting suboptimal portfolio diversification. The third indicator is home bias in the equity
investment portfolio. We show large differences in terms of relative investments in the euro area, suggesting suboptimal international diversification in many pension funds. We find that these three measures correlate with pension fund size indicating that smaller pension funds tend to be less sophisticated than larger ones. Nevertheless, investment sophistication contributes independently to the explanation of risk aversion, showing that investment expertise also varies among pension funds in the same size class. These results suggest that the asset allocation policies of many pension funds, particularly small ones, are suboptimal.

A notable finding is the huge variation in asset allocation practices across pension funds, in a broader context also referred to as the asset allocation puzzle. Part of this variation can be explained by the pension fund’s size, its type of pension plan, its preference indicators, such as assets per participant, participant age distribution and the funding ratio and, finally, its governance type. In addition, we find that all our indicators of investor sophistication are highly statistically significant.

Even when controlling for size, sophistication and other fund-specific variables, pension funds make significantly diverging portfolio choices. We believe that this reflects widely varying views regarding the optimal investment mix. It seems likely that differences in risk-return assumptions for the various asset classes, in the level of expertise of pension fund investment managers and in personal preferences of pension boards also play an important role. The analysis of this latter phenomenon is outside the scope of this article, but is suggested as an interesting topic for future research.

Our findings suggest that further consolidation of the Dutch pension sector, by mergers or increased cooperation (e.g. in so-called general pension institutions, which can administer pensions plans for several companies or industries) may contribute to
improve the sophistication of pension funds’ investment policies. Such benefits of consolidation are in line with previous studies, in which we find a negative correlation between the size of pension funds and the administrative and investment costs per participant (Bikker and De Dreu, 2009; Bikker, Steenbeek, and Torracchi, 2012).

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References


